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ICAO

W.R. Fromme	Director, Air Navigation Bureau
O. Fritsch	Chief, Accident Investigation and Prevention Section
Y. Kravchenko	Technical Officer, Accident Investigation and Prevention Section
P. Lamy	Chief, Personnel Licensing and Training Section
D. Maurino	Technical Officer, Personnel Licensing and Training Section
D. Lane	Secretary, Accident Investigation and Prevention Section
R. Ezrati	Chief Interpreter

USSR

A.M. Goryashko	Deputy Minister of USSR Civil Aviation
B.A. Ryzhenkov	Executive Secretary, USSR Commission for ICAO
G.A. Kryzhanovskiy	Director of Civil Aviation Academy
Y.A. Balakin	Director of Leningrad Civil Aviation Department
V.Z. Artemyev	Chief of International Branch, Civil Aviation Academy

The working languages of the seminar were English, French, Russian and Spanish.

OBJECTIVES OF THE SEMINAR

The great importance that ICAO places on the application of Human Factors knowledge is reflected in Assembly Resolution A26-9: "Human Factors programmes ... should be put to practical use, with a view to raising the safety level of air transport." Given this importance, it was considered essential that as many as possible attend the seminar in Leningrad, so they could benefit from the papers and discussions presented by the world's foremost experts in Human Factors. The seminar was not limited only to State officials; the attendance also included representatives from airlines, manufacturers and academic institutions.

The theme of the seminar was "the application of Human Factors knowledge to aviation management, training and operations", with the following objective: "to improve safety in aviation by making the States more aware and responsive to the importance of Human Factors in civil aviation operations through the provision of practical Human Factors materials and measures, developed on the basis of the experience in States".

EVALUATION OF THE SEMINAR

The keynote speakers and panel chairman were asked to assess the seminar. The following evaluation reflects their assessment as presented to the seminar on the final day.

This first international seminar on Human Factors, held jointly by the USSR and ICAO, constituted an important step in the ICAO Human Factors programme. There were over 230 participants from 30 States. As well, a number of international organizations and associations participated.

The seminar underlined the importance of consolidating the experience and knowledge gained by States in the area of Human Factors. The excellent attendance attests to the need for further seminars, both to update the knowledge level and to share that knowledge and commitment to Human Factors among States.

The USSR initiative, which led to the holding of this seminar, confirms a deep commitment to solving the Human Factors problems which confront aviation. Delegates to the seminar expressed their appreciation to the USSR for its generosity and hospitality.

The purpose of this assessment is to present ideas and to make recommendations for future seminars. The time frame of five days for the seminar was perhaps too long. The combination of lengthy sessions, a large number of papers and coincident professional tours of the highest calibre imposed a demanding schedule on the participants. Future events should preferably be less demanding. In view of the success of the seminar and the quality of material presented, there is general agreement that the proceedings should be circulated widely to States as soon as possible.

With regard to future seminars, both regional and global seminars are recommended. Regional seminars would allow the participation of a greater number of countries, particularly those of the developing world, while global seminars would ensure that the momentum generated by this Leningrad seminar is not lost. As well, a global seminar every three or four years would allow a focus on broader issues while regional seminars could target specific concerns.

The theme of this seminar was intentionally broad to ensure sufficient speakers and adequate attendance. This resulted in a wide range of topics being presented. The seminar was, therefore, not as focused as it would have been with a more specific theme. As well, speakers had some difficulty in preparing their papers without knowing the exact target audience. Future seminars, particularly regional ones, could be more focused in content and the target audience more accurately identified.

In the future, ICAO will consider inviting specific speakers to assist in selecting a theme, thus ensuring that the correct message is delivered and identifying the appropriate target audience. While a combination of theoretical and practical papers are appropriate when the goal is to update knowledge, it may be less successful for those seminars designed to encourage the participation of developing States.

Now that the lines of communication between States have been opened, attempts should again be made to establish nationally mixed panels. Such panels generate discussion and debate, while nationally aligned panels tend to present one point of view.

The seminar objective was:

> "To improve safety in aviation by making States more aware and responsive to the importance of Human Factors in civil aviation operations through the provision of practical Human Factors materials and measures, developed on the basis of experience in States."

Within the context of the statements made above, the objective was achieved. However, many countries who would have benefited most from exposure to Human Factors issues were unable to attend. This substantiates the need for regional seminars on a yearly basis.

In conclusion, the seminar was classified as a success. Future efforts, supported by a full-time co-ordinator and published seminar guidelines, should be even more successful. ICAO has made an excellent start in promoting the study of Human Factors and encouraging the development of Human Factors programmes.

PRESENTATION OF ABSTRACTS

The number shown in brackets after the title of a paper indicates the page in Appendix A on which the full text (in its original language) may be found.

Perspectives in Human Factors (A-1)

J. Lederer

In aviation, human error accounts for over 65 per cent of the accidents. Air traffic is expected to double within the next 15 years. If the accident rate remains constant, the accidents will double and public confidence in air travel will be threatened. Application of Human Factors knowledge is our best counter.

The objectives of Human Factors were obvious long before a distinct discipline emerged. For instance, eighty years ago the Wright Brothers used a simulator to train their students. Sixty-five years ago, pilots in the U.S. Army Air Service knew that flight by the seat-of-the-pants, without a horizon for reference could cause vertigo and developed the needle-ball-airspeed technique. This was replaced by the artificial horizon indicator by Sperry for Jimmy Doolittle in 1929. The book Blind Flight in Theory and Practice by Ocker and Crane, was translated into Russian and accepted by the USSR years before its importance was recognized in the USA.

These and other milestones will be discussed as well as the contributions of our pilot psychologists and notable Human Factor practitioners. Items for ongoing research will be suggested.

Jerry Lederer, President Emeritus, Flight Safety Foundation, began his career in the pre-Lindbergh era as Aero Engineer for the US Air Mail Service, the first system of scheduled air transportation. After serving as head of loss prevention for aviation insurance interests, he was appointed in 1940. Director, Safety Bureau CAB. Upon completing several war assignments, he activated the Flight Safety Foundation in 1947. Retiring in 1967, he was appointed NASA Director, Office of Manned Space Flight Safety. In 1970, he became NASA Director of Safety, retiring in 1972. Among many awards are two gold medals from the Soviet Federation of Cosmonauts.

The relationship between Human Factors and flight safety (n/a)

A.M. Goryashko

The paper considers the factors which influence the development of crew errors. It analyzes the reasons obstructing an effective solution to human performance problems. These reasons include the lack of a common approach towards understanding the problem and criteria for the causes of crew errors. Ways of solving the problems are developed. The paper presents an integrated solution to questions related to Human Factors considerations when organizing flight-related activities, aircraft control and training of flight crews and controllers. The paper demonstrates the need for preventative measures with respect to all components influencing human performance.

Mr. Goryashko graduated from the Pilot's Training School. He flies six types of aircraft and has accumulated a total flight time of 12,000 hours. He is highly qualified and experienced in organizing air transport systems and ATC systems in the USSR. He graduated from the Civil Aviation Academy. He has served as Deputy Chief of the USSR Flight Safety Supervision Board. He is currently a Deputy Minister of Civil Aviation in the USSR.

The march of cockpit automation: will humans ever replace computers? (A-9)

E.L. Wiener

The practice of Human Factors in aviation is largely a race to keep up with rapidly advancing technology, and always to some extent losing the race. By the decade of the 1960s the profession had closed the gap. Tangible benefits to both transport and military aircraft could be demonstrated.

Our challenge today is to develop a "philosophy of automation" which will allow us to integrate the new technologies and devices as they become available. We must also develop operational doctrine and training methods which will allow us to exploit the positive features of automation, and control the negative aspects.

Earl L. Wiener is a professor of Management Science and Industrial Engineering at the University of Miami. He received his BA in psychology from Duke University, and his PhD in psychology and industrial engineering from Ohio State University. He served as a pilot in the U.S. Air Force and U.S. Army, and is rated in fixed wing and rotary wing aircraft.

Since 1979 he has been active in the cockpit automation research of NASA's Ames Research Center. Dr. Wiener is immediate past-president of the Human Factors Society. He is co-editor of Human Factors in Aviation, published by Academic Press in 1988.

Human Factors: the operational challenge (A-19)

F.H. Hawkins

The effectiveness of Human Factors research and regulatory effort must be assessed on the flight deck. Several aspects call for attention. For example, a prime need is to clarify the scope and purpose of the technology of Human Factors. This will help to improve pilot credibility and encourage management support, both of which are far less universally evident. As well, basic pilot education in human performance and behaviour before entering airline service needs to be defined.

Airlines have adequate tools for measuring pilot flying capability but inadequate means of estimating pilot unsupervised performance and behaviour in line operations and this is another challenge to the practitioners of Human Factors.

Captain Frank Hawkins has flown for over 30 years as a KLM captain and R&D pilot. For some 20 years he was responsible for flight deck design. During that time, and since retiring from flying, he has specialized in aviation Human Factors, written numerous papers and authored the widely used textbook Human Factors in Flight. He holds a Master of Philosophy degree in Applied Psychology and in the United Kingdom is a Fellow of the Royal Aeronautical Society, Liveryman of the Guild of Air Pilots and a Member of the British Association for Autogenic Training and Therapy. In the United States, he is a Member of the Human Factors Society, the Society of Automotive Engineers and the SAE S-7 Committee on flight deck design.

PANEL 1: HUMAN FACTORS CONSIDERATIONS IN AIRCRAFT DESIGN

1. Human Factors considerations in the design of the TU-204 aeroplane (A-520)

A.A. Tupolev

Some aspects of Human Factors considerations applied in the development of the TU-204; design of the cockpit, electronic remote control system, control levers, flight management and monitoring systems.

Mr. Tupolev graduated from the Moscow Aviation Institute in 1949. He is a general designer of a well-known aircraft design bureau where his career went from designer to head of the establishment. He is a member of the USSR Academy of Sciences, author of 47 scientific works and has won the Lenin Prize and USSR State Prizes.

2. Human Factors considerations in the research on future control systems (A-25)

V.V. Biryukov, S.Y. Boris, V.V. Rogozin and V.A. Zhiltsov

Considerations in Human Factors research using simulators and airborne laboratories for development of new cockpit display concepts, the evaluation of different types of control levers, the selection of control laws for the stability and controllability enhancement system and the determination of the pilot's functions in automated flight modes.

Mr. Biryukov is a university graduate and test pilot. Until 1977, he was a flight instructor. Since 1979, he has been a test-pilot at the Flight Research Institute. He has flown approximately 40 types of aeroplanes and approximately 20 versions thereof (including approximately 15 aerobatic aeroplanes). He has a total flight time of approximately 6,000 hours.

He specializes in the testing of future control systems and in aircraft certification.

Mr. Boris graduated from the Moscow Aviation Institute in 1973 and holds a Masters degree. He currently works in the Flight Research Institute as the head of the aeroplane control systems section.

His expertise is the modelling and flight testing of experimental control systems.

Mr. Rogozin is a graduate of the Moscow Physico-Technical Institute. He currently works at the Flight Research Institute where he is a leading Engineer in aircraft ***testing and heads the flight testing of future control and display systems in*** *airborne laboratories.*

Mr. Zhiltsov is a graduate of the Kirovograd Military Aviation School. He began his career as an airline pilot and since 1971, he has been a test-pilot at the Flight Research Institute. He has flown approximately 25 types of aeroplanes and has accumulated some 18,000 hours. He is qualified as a test-pilot and specializes in display and navigation systems.

3. Criteria for evaluating ergonomic factors in civil aviation aeroplane cockpits (A-36)

N.A. Stolyarov

This paper relates to the analysis and synthesis of the man-machine system, on the basis of flight safety requisites. Analytical dependencies of visual attention distribution characteristics on the dynamic parameters of the aeroplane displayed on instruments are developed. An analysis of the necessary quantity and quality of information, on the basis of maximum human capabilities, is provided.

Mr. Stolyarov is a graduate from the S. Ordzhonikidze Moscow Aviation Institute. He began his career at the A.N. Tupolev Design Bureau and was involved in aeroplane development from 1963 to 1975. He worked in the State Scientific Research Institute of Civil Aviation from 1975 to 1986. He has been working at the Scientific Experimental Centre for ATC Automation since 1986.

He is a prominent expert in aviation man-machine systems and holds a Doctor of Technical Sciences degree.

PANEL 2: THE ROLE OF ADMINISTRATIONS, OPERATOR AND MANUFACTURER MANAGEMENT IN FOSTERING SAFETY

4. Communicating human error causes through accident investigation: promises and limitations (A-52)

P. Kayten

Accident reports are a major source of information on human errors in real-world situations. But the very nature of most accidents hampers our search for the causes of the errors. At the National Transportation Safety Board (NTSB), we have been faced with several questions, such as: (a) Who should conduct human performance investigations? (b) What facts should be collected and what should be ignored? (c) Is a systems analysis appropriate or possible? (d) What is the role of Human Factors research in accident investigation?

This paper discusses these questions and addresses some special problems for human performance investigators: (a) Data are difficult to document. (b) Data are difficult to analyze in causal terms. (c) We are ambivalent about their worth for determining accident causation. (d) We are convinced of their worth, but are uncomfortable about their use for purposes other than accident investigation.

Phyllis Kayten received a Bachelor of Arts degree in Psychology in 1971, and a Doctor of Philosophy degree in 1978. As a program manager at Ship Analytics, Inc. from 1980-83, she developed training curricula for merchant marine operational personnel, and designed and managed research to validate the equivalence of simulator training. From 1983-1985 she was a Human Performance Investigator at the National Transportation Safety Board. From 1986 - January 1990, she served as Special Assistant to John K. Lauber, Member of the National Transportation Safety Board. Since January 1990, she has served as Deputy Scientific and Technical Advisor for Human Factors for the U.S. Federal Aviation Administration.

5. Safety awareness training in Canada: one government's approach (A-65)

J.P. Stewart

The paper covers the safety awareness training offered by the Department of Transport with emphasis on Human Factors training. It is based on the realization that Human Factors is, perhaps, the only remaining area in which major gains may be made in accident rate reduction. The theme of the programme is "risk management".

Two major aspects of the programme are the Pilot Decision Making Course and the Company Aviation Safety Management Programme. The paper discusses the reasons for the development of these programmes, their effectiveness in preventing accidents and our intentions to develop follow-on programmes.

Jim Stewart has been involved with aviation for almost 30 years as a pilot, accident investigator and safety specialist. After 21 years with the Canadian Air Force, Jim was employed as an accident investigator with the Department of Transport.

Jim is now Director of the Aviation Safety Programs Branch in Transport Canada, where he is responsible for the development of safety educational programs.

Jim holds an airline transport pilot's licence, is President of the Canadian Society of Air Safety Investigators and is on the Advisory Committee of the Aviation Safety Institute of Canada.

6. Human Factors in air traffic control (A-75)

P.G. Harle

In 1989 the Canadian Aviation Safety Board conducted a special investigation into air traffic services in Canada. It showed that human performance factors caused or contributed to approximately 90 per cent of the occurrences. In Canada, the high frequency of such errors is probably related to current shortages in the number of qualified controllers. There is evidence that many controllers are demonstrating the effects of chronic fatigue and personal stress. Inattention or vigilance errors appear to be present in at least half of the ATS occurrences studied. Not surprisingly, there were also frequent errors in controller planning and judgement, and errors in the information transfer process -- particularly concerning inter-controller co-ordination. Improvements in methods of investigation, data collection and analysis following loss of separation will be required. Additional research and safety promotion is also needed to ensure effective human performance in ATC.

Peter Harle joined the Royal Canadian Air Force in 1959. He completed several assignments in pilot training, and served as Commandant of the No. 3 Flying Training School. Following four years of staff duties at NATO Headquarters in Brussels, Belgium, he served as the Commanding Officer of the air defense and low level fighter training base at Goose Bay, Labrador. Colonel Harle retired from the Canadian Forces in 1985 and joined the Canadian Aviation Safety Board. As the Chief, Evaluation in the Safety Programs Branch, he is responsible for the analysis of Safety deficiencies in the National Civil Air Transportation System and for the proposals for corrective actions. He holds a BSc in Mechanical Engineering.

7. Human Factors in aviation, a senior airline captain's viewpoint (A-82)

R. Macdonald

This discussion paper is on the concept of Human Factors as an integral part of current pilot training scenarios and the possibility that inadequacies of such training programs result in being unprepared for highly complex, advanced technology flight operations demands. It suggests that the pilot graduate must develop a level of knowledge at least equal to, if not better than, that of the ground school instructor providing the training.

A case in point is the rejected take-off, where a rapid sequence of events very rarely develops as in pre-planned instructional models. Specific aspects and their Human Factors implications are reviewed. The paper seeks to answer some serious questions about pilot training and accident investigation as these relate to Human Factors analysis.

Born in Aberdeen, Scotland, Captain Ron Macdonald soloed in May, 1947. He recently retired from Air Canada as a senior L1011 pilot with over 24,000 flying hours. He has been involved in flight safety since 1951 and has held many positions within CALPA, IFALPA and ICAO. He has also served as an accident investigator and has participated in six major aircraft accident investigations. He has received many awards from pilot associations including the prestigious CALPA Flight Safety Award. He has been honoured by many of the world pilot associations for his unselfish devotion to the advancement of flight safety.

8. An operator's Human Factors considerations (A-86)

A.H. Roscoe

Both the manufacturer and the operator have a clear responsibility for maintaining high standards of flight safety.

Related issues are addressed in this paper using examples from real-world studies.

Pilot workload is one such issue that is of particular importance and is discussed in some detail. For example, the influence of automation and operating procedures on levels of workload will be examined. In addition, the relationship between manufacturer and operator, the policies of airline management and the importance of "within airline" communications are considered.

Dr. Alan Roscoe, a graduate of the Victoria University of Manchester, is currently Chief Medical Officer of Britannia Airways where, in addition to his clinical and aviation medicine responsibilities, he is involved in research into new flight deck technology and pilot workload.

Before joining the airline six years ago Dr. Roscoe spent fifteen years in clinical practice followed by fourteen years as the Established Medical Officer at the Royal Aircraft Establishment at Bedford, and as a consultant in aviation medicine and Human Factors to several organisations, including Britannia Airways.

PANEL 3: THE ERGONOMICS OF AIRCRAFT AND OTHER EQUIPMENT

9. Human Factors of the high technology cockpit (A-98)

E.L. Wiener

The rapid advances of cockpit automation in the last decade outstripped the ability of the Human Factors profession to understand the changes in human functions required. High technology cockpits require less physical (observable) workload, but are highly demanding of cognitive functions such as planning, alternative selection, and monitoring. Furthermore, automation creates opportunity for new and more serious forms of human error, and many pilots are concerned about the possibility of complacency affecting their performance. On the positive side, the equipment works "as advertised" with high reliability, offering highly efficient, computer-based flight. The challenge to the Human Factors profession is to aid designers, operators, and training departments in exploiting the positive side of automation, while seeking solutions to the negative side.

Earl L. Wiener is a professor of Management Science and Industrial Engineering at the University of Miami. He received his BA in psychology from Duke University, and his PhD in psychology and industrial engineering from Ohio State University. He served as a pilot in the U.S. Air Force and U.S. Army, and is rated in fixed wing and rotary wing aircraft.

Since 1979 he has been active in the cockpit automation research of NASA's Ames Research Center. Dr. Wiener is immediate past President of the Human Factors Society. He is co-editor of Human Factors in Aviation, published by Academic Press in 1988.

10. Human impacts of advanced air traffic control systems (A-107)

R.E. Morgan

An overview is presented of U.S. Federal Aviation Administration activities which are aimed at ensuring that advanced air traffic control systems, under development according to the National Airspace System Plan, will effectively support the controllers who use them. This paper briefly describes: the systems that are setting the pace, assessment of controller impacts, projection of personnel requirements for system installation and operation, and controller training to augment system benefits.

Since 1970, Ronald E. Morgan has worked as an air traffic control specialist, supervisor and manager, and has gained operational experience at both en route and terminal air traffic facilities. Also, he received a commercial pilot certificate and is certificated to provide basic and advanced ground instruction, as well as flight instruction. Mr. Morgan is now the Acting Manger of the Federal Aviation Administration's Advanced Systems and Facilities Division. This division is responsible for specification of requirements for, and operational evaluation of advanced air traffic control systems.

11. Controller and pilot decision making in transmitting and receiving microburst wind shear alerts from an advanced terminal wind shear detection system (A-116)

J. McCarthy and W. Sand

Approximately 650 air carrier passenger fatalities caused by low-altitude wind shear have occurred in the United States over the past 15 years. The most common form of lethal wind shear is the microburst, a strong downdraft and horizontal outflow that occurs near the earth's surface. A microburst detection and warning system has been developed using Doppler radar and an array of surface wind sensors either together or independently. The system is intended to induce an early avoidance decision on the part of the flight crew, thus avoiding a potentially catastrophic wind shear accident.

This paper presents air traffic controller and pilot experience with this new system. Human Factors related to the ergonomics of microburst situations are explored, as well as air traffic and flight standards policy issues.

Dr. John McCarthy is the Director of the Research Applications Program at the National Center for Atmospheric Research. He directs the research associated with weather hazards, such as the FAA Terminal Doppler Weather Radar Project and the Low-Level Wind Shear Alert System Project, which addresses the technical development of sensing systems to detect and warn of low-altitude wind shear. He also participates on the Federal Aviation Administration (FAA) Research, Engineering and Development Advisory Committee and the National Airspace System (NAS) II Design Review Committee, developing an integrated terminal weather information system for the future. He received his BA in Physics from Grinnell College (1964), his MS in Meteorology from the University of Oklahoma (1967), and his PhD in Geophysical Sciences from the University of Chicago (1973).

12. Human Factors considerations for Loran-C receivers (A-126)

M.S. Huntley, Jr.

Loran-C is an inexpensive, compact and functionally powerful area navigation system which is popular with general aviation pilots. The system is simple and precise and provides real-time information on distance, bearing and ground speed to pilot selected NAVAIDS, airports and air route intersections. Currently few receivers are certified for IFR flight. Used only in VMC or as a back-up system the design of the displays, controls and logic of these receivers is not critical. When used in IMC, good Human Factors design is critical. Current potential Human Factors issues when Loran-C is used in IMC are identified, including display and control formatting, prompting for programming and function selection, error detection and correction, selection of emergency functions, warnings and alerts, cockpit location and air traffic control compatibility.

Dr. Huntley is an engineering Research Psychologist with the US Department of Transportation's TSC (Transportation System Center) in Cambridge, Massachusetts since 1973. He received his Doctorate in experimental psychology from the University of Vermont in 1970. His research interests have been concerned primarily with the influence of alcohol and task induced stress on operator performance in highway, railroad and aviation environments. For the past six years, Dr. Huntley has been the manager of TSC's programs on cockpit Human Factors.

13. The national aviation Human Factors plan (A-143)

H.C. Foushee

Human error has been identified as a causal factor in 66 per cent of air carrier fatal accidents, 79 per cent of commuter fatal accidents and 88 per cent of general aviation fatal accidents. These and non-aviation accidents have stimulated new discussions of the human performance problem and in the United States has led to the Aviation Safety Research Act of 1988, that specifically directs the FAA to substantially augment its research programme dealing with the relationships between various Human Factors and aviation safety.

All of the major categories specified in the Aviation Safety Research Act have extensive Human Factors implications, such as controller performance research, civil aeromedical research, and aircraft maintenance inspection, etc.

The FAA is developing a national plan for Human Factors research. This will include research aimed at the alleviation of human performance problems in all types of aircraft, in the air traffic control environment, and in the interaction of the two environments.

H. Clayton Foushee recently joined the Federal Aviation Administration as Chief Scientific and Technical Advisor for Human Factors. He is a graduate of Duke University and completed his PhD in social psychology at the University of Texas in 1979. Prior to joining FAA, Dr. Foushee was Principal Scientist of the Crew Research and Space Human Factors Branch at the NASA-Ames Research Center, where he headed a research program concerned with group performance factors in both aviation and space flights. He has worked extensively with high fidelity simulation approaches to research and training, and has participated in the development of training approaches that seek to facilitate crew performance such as cockpit resource management training. At FAA, Dr. Foushee is co-ordinating an effort to develop a comprehensive aviation Human Factors research plan.

14. Ergonomics and human error (A-152)

R.G. Green

Ergonomic issues are not presently as fashionable, when aviation Human Factors are discussed, as the social psychology of the flight deck and its management. Nevertheless, ergonomic problems continue to prevail in all types of cockpits and continue to cause accidents. This paper examines a number of relatively recent accidents that appear to have been caused by poor equipment design and also examines similar problems that have been identified by incident reporting systems. It is concluded that in order to obviate this form of problem it is necessary both to change attitudes within the aviation system so that the criteria for acceptance of known ergonomic problems are improved, and to develop more sophisticated and standardized techniques for the evaluation and certification of the cockpit work space.

Roger Green is a graduate in experimental psychology from the University of Sussex. He has spent his entire career at the RAF Institute of Aviation Medicine where he is now Head of the Psychology Division. His work has involved some laboratory research, but has largely centred on the problems of Human Factors and flight safety. Among his present responsibilities is the operation of the UK Confidential Human Factors Incident Reporting Programme (CHIRP).

15. Human Factors requirements as the basis for aviation occupational selection and training systems (A-162)

W.E. Collins

Optimal safe performance requires the thorough application of known Human Factors data to the rapidly evolving aircraft and air traffic systems. Those applications are necessary (a) to optimize the fit of the operator to system requirements and (b) to optimize the selection of operators and the training regimens used. Selection of air traffic control specialists, for example, must be based on the Human Factors requirements identified by job/task analyses. These requirements also provide the basis for the development of performance measures needed to assess the impact of system changes. Of special importance is the way in which these and other specialists in the aviation occupations are trained for the transition/overlap periods between present and future systems.

Williams E. Collins, PhD is Director Civil Aeromedical Institute (CAMI) in Oklahoma City, since August 18, 1989. He was acting director of CAMI since Dec. 1987. Dr. Collins began his career at CAMI in 1961 as a research psychologist. He was head of the Aviation Psychology Laboratory for over 20 years and later managed the Human Resources Research Branch.

Dr. Collins has served on and chaired numerous professional committees and meetings at the national level. He is a fellow of the Aerospace Medical Association, the American Psychologist Association, the American Psychological Society, the American Association for the Advancement of Science, and the N.Y. Academy of Sciences. He is also an adjunct professor at two Oklahoma universities: the Department of Psychiatry and Behaviourial Sciences at the Oklahoma University Health Sciences Center and at the Department of Psychology at the University of Oklahoma. Dr. Collins earned his advanced degrees in psychology at Fordham University.

PANEL 4: HUMAN PERFORMANCE CONSIDERATIONS IN AIRCREW TRAINING, AIR TRAFFIC CONTROL AND ACCIDENT INVESTIGATION

16. Simulator use and reducing the negative influence of Human Factors (A-172)

L.M. Berestov and G.S. Meerovich

Training methods aimed at reducing the number of crew errors are described, including the application of the artificial intelligence concept to the design of the instructor's work station. Correlations of the crew simulator training programme with equipment failures predicted from aircraft certification tests are presented.

Mr. Meerovich is a graduate of the Moscow Aviation Institute. He is the head of a laboratory in the Flight Testing Institute, a Doctor of Technical Sciences and a professor. He is a leading specialist in aviation simulator engineering.

Mr. Berestov graduated from the Moscow Aviation Institute. Since 1957 he has worked in the Flight Testing Institute of the Aviation Industry. At present, he is the first deputy head of that institute. He is a Doctor of Technical Sciences, Professor, Honoured Worker of Science and Technology, author of five monographs and more than 40 publications and the winner of the N.E. Zhukovsky Prize for research in the field of aerodynamics.

17. Ensuring the reliability of pilots' performance in flight (A-190)

A. Kalchenko and N.F. Nikulin

A method is presented for quantitative evaluation of pilot workload in transport aircraft in normal and abnormal situations. A criterion for the evaluation of pilot performance reliability is presented. It represents perfect performance and makes it possible to predict safe performance in different operating conditions and critical phases of flight. A predictive method for professional flight training is proposed.

Mr. Nikulin has worked as a professional pilot in Civil Aviation since 1956. He is a flight engineer and a pilot. He holds a Masters degree. He has a total flight time of more than 10,000 hours on seven types of aircraft.

Mr. Kalchenko graduated from the Civil Aviation Academy in 1974. He is a pilot with more than 5,000 hours flight time on piston-engined and jet aircraft. He is a specialist in flight operations and flight safety, candidate of Technical Sciences and author of more than thirty scientific works and publications. At present, he is the first Deputy Head of the Civil Aviation Academy.

18. Principles of modelling flight crew activities during final approach of heavy transport aircraft (A-202)

M.M. Tereshchenko

The longitudinal trim characteristics of an aircraft are of major importance in emergency situations, particularly in the approach and landing phase.

A method is proposed for defining the adequacy of the handling instructions in an aircraft flight manual, with a view to improving these instructions on the basis of statistical modelling applied to the final approach phase.

Mr. Tereshchenko is a graduate of a flying school, the Civil Aviation Academy and the Institute of Management. He has flown Mil helicopters and Antonov, Yakovlev and Tupolev aeroplanes. He has a total flight time of more than 10,000 hours. He has worked as a helicopter pilot, as a flying school instructor, as the head of a simulator training centre, as the head of a civil aviation territorial control service and as the head of civil aviation control.

For his services he was awarded the honourary title of "Honoured Pilot of the USSR".

At present, he is the Head of the Flight Operations Department in the USSR Ministry of Civil Aviation.

19. A study of the Human Factors role in accidents and incidents (A-224)

V.A. Goryachev

An analysis of data from aircraft accidents and identification of the role of Human Factors in these events is presented. The most common Human Factors are identified as are their causation.

Mr. Goryachev graduated from the Moscow Aviation Institute in 1959. Since then he has worked in the State Scientific Research Institute of Civil Aviation in Moscow *specializing in flight safety, aircraft dynamics, flight personnel training, the testing and implementation of aviation simulators and the influence of Human Factors. Since 1988, he has been the Head of the State Scientific Research Institute of Civil Aviation. He is a Doctor of Technical Sciences and the author of more than 100 scientific papers and 40 publications.*

20. Human Factors considerations when ensuring flight safety in air traffic control tasks (A-239)

V.I. Mokshanov

The role of the controller in ATC is defined. The basis of the interaction of the controller with the ATC system is considered. The development of the optimum interaction of the controller with ATC systems is outlined.

Mr. Mokshanov is a graduate of the Moscow Power Institute. From 1967 to 1974 he worked in the State Scientific Research Institute of Civil Aviation. Since 1974, he has worked in the Scientific Experimental Centre for ATC Automation.

He is a leading specialist in air traffic control and has written several scientific papers. He has much experience in the development and implementation of automated ATC systems and in air traffic safety enhancement. He is the winner of a State prize of the USSR and is a Doctor of Technical Sciences.

PANEL 5: HUMAN FACTORS APPLICATIONS TO THE TRAINING OF FLIGHT CREWS, AIR TRAFFIC CONTROLLERS AND MAINTENANCE PERSONNEL

21. New directions in crew-oriented flight training (A-258)

J.R. Hackman

Recent research findings suggest directions for the next generation of CRM training. Three of these are described. First, course designers and instructors should recognize that cockpit crews are teams, and design CRM training accordingly. Second, recognition that the captain is a team leader, and that captains should be as competent in team leadership as most of them are in the technical aspects of flying. Third, acknowledgement that organizational and regulatory contexts bear powerfully on whether the lessons learned in CRM courses will take root and prosper, and the need to begin the never-ending process of "tuning" those contexts so that they actively support teamwork and coordination.

J. Richard Hackman is a Cahners-Rabb Professor of Social and Organizational Psychology at Harvard University. He received his undergraduate degree in mathematics at MacMurray College in 1962, and his Doctorate in social psychology from the University of Illinois in 1966. He taught at Yale University until 1986, when he moved to Harvard. Professor Hackman conducts research on topics in social psychology and organizational behaviour, including the performance of work teams, social influences on individual behaviour, and the design and leadership of self-managing units in organizations. He currently is completing a multi-year NASA-supported study of factors that influence the effectiveness of aircraft flight crews.

22. Determinants of flight crew performance (A-276)

R.L. Helmreich and J.A. Wilhelm

CRM training represents one means of enhancing flight crew performance. The impact of such training can be evaluated using the behaviour of crews in simulator and line flights, changes in attitudes, self-reports of participants and analyses of accidents and incidents. Preliminary findings from a study of CRM effectiveness indicate significant effects on all three types of measures. However, the data also show that not all participants benefit from the training and some show a "boomerang effect" showing less favourable attitudes regarding crew coordination. Personality characteristics have been shown to be a major determinant of reactions to CRM training as well as line performance. Other related issues are also described.

Robert L. Helmreich is professor and chair of the graduate program in social psychology at the University of Texas at Austin. He received a PhD in personality and social psychology from Yale in 1966. He has conducted research sponsored by NASA and the Office of Naval Research on small-group performance under stressful conditions as well as research supported by the National Science Foundation and National Institute of Mental Health on personality factors and motivation. His current research focuses on crew selection, composition, crew co-ordination, and training for both aviation and space environments. He is a fellow of the American Psychological Association and a former editor of the Journal of Personality and Social Psychology.

23. Flight crew qualification (A-287)

J. Kern

The traditional way in which commercial aviation pilot requirements are met is changing. Due to advancing technology and the rapid growth of the industry, the military can no longer be considered as the prime source of aviators in the United States. In order to ensure that a professional and qualified source of pilots remains constant, we have to enhance our training and standardize our qualification procedures. This can be accomplished through the integration of Cockpit Resource Management into flight training, the introduction of regulatory initiatives to keep pace with technology and the establishment of proficiency based qualification programmes. When these challenges are successfully met we can then meet the demands of the industry in the 1990s and beyond.

Mr. Kern is Associate Administrator for Certification and Regulation in the U.S. FAA. He was formerly Director Office of Flight Standards and Deputy Director in the Office of Flight Safety. He has a total of over 7,000 flying hours both fixed and rotary wing aircraft.

24. Human Factors considerations for aircraft maintenance and inspection personnel (A-291)

W.T. Shepherd

Much research is related to the selection, training and performance of pilots and air traffic controllers. However, considerably less research has been devoted to other aviation career fields, particularly for the specialists who inspect and maintain transport aircraft. There is an urgent need to develop information in at least the following areas: 1) methods for selection, training and certification of maintenance and inspection personnel; 2) work environment considerations; 3) job performance aids; 4) human engineering of equipment; and 5) information transfer methods.

The FAA has embarked on a study to improve the knowledge of the work and needs of maintenance and inspection specialists. It was initiated with task analyses in air carrier maintenance facilities. Various aspects of the programme and the expected results are presented.

Dr. William Shepherd is Manager of the Biomedical and Behaviourial Sciences Branch in FAA's Office of Aviation Medicine. He is responsible for Management of the FAA Headquarters Aeromedical Research Program. Dr. Shepherd has BSc and MSc degrees in aerospace engineering and a PhD degree in psychology from the University for Connecticut. He is a rated pilot with multi-engine and flight instructor ratings.

25. An abilities-based approach to pilot competency and decision-making (A-302)

G.J.F. Hunt

The increasing enthusiasm for Cockpit Resource Management in recurrent flight training may be the result of changed modern aircraft technology and an increased awareness that human performance is the single most important predictor of safe and effective aircraft operations. Traditionally, flight training has been seen primarily as the acquisition of aircraft manipulation and navigational skills. More recently, to these *ab initio* requirements attitudinal skills have been added translating into decision-making, leading and communicating strategies. In an on-going programme (HURDA - Human Resource Development in Aviation) concerned with the identification of generic constructs of pilot competency, patterns of processing abilities are being identified as predictors of flight crew performance management (FCPM). Further, these abilities are being postulated as competency requirements for inclusion in licensing and training prescriptions from *ab initio* to airline operations.

26. Human Factors applications to the training of flight crews: the next generation of Cockpit Resource Management (CRM) training (A-310)

A.L. Ueltschi

Airlines, military organizations and regulatory agencies throughout the world have become interested in implementing CRM training for flight crews. Some operators are now using CRM training. Others anticipate doing so.

Three generations of CRM training are discussed. The first generation, which began in the late 1970s and early 1980s, has given way to a second generation CRM, which is rapidly becoming the industry standard.

The direction for a third generation CRM is proposed including a focus on measurable performance standards.

Mr. Ueltschi was born in Frankfurt, Kentucky. A career pilot, from young barn stormer to airline captain, he still maintains flight proficiency. He is chairman, president and chief executive officer of Flight Safety International, Inc., which he founded in 1951. He also serves as chairman and president of Project ORBIS, the non-profit flying eye hospital, which volunteers its teaching services to eye surgeons all over the world. The non-political ORBIS missions have visited 50 countries, including the Soviet Union in 1987.

PANEL 6 - PSYCHOLOGICAL AND PHYSIOLOGICAL ASPECTS

27. Psychology in civil aviation in Cuba: its field of application in the study of Human Factors (A-318)

P. Cabrera Daniel, J. Antoni Espinel, G. Lima Mompó and M. del C. Pico Penabad

The paper addresses the principles of aviation psychology, whose field of study is basically aimed at humans and their interface in the man-machine-environment system.

We shall deal with aspects such as: professional selection of flight crews and ATC personnel; clinical psychology applied to annual physical check-ups and flight crew and ATC personnel prophylaxis; and accident prevention and investigation.

We shall also refer to some research carried out in our country and the results thereof with reference to Human Factors and flight safety.

28. Flicker fusion frequency, a specific experience in the aviation environment (A-328)

P. Cabrera Daniel, G. Lima Mompó, M. del C. Pico Penabad and S. Ruíz de Ugarrio

Knowledge of the operator's psychological capacity for work is highly significant to work efficiency forecasts. This has given rise to the development of different methods of assessment, one of the main ones being an analysis of cortical dynamics.

Our research attempts to evaluate such dynamics, as an integral part of a system designed to assess the functional status of flight crew members on a psychological and psychophysiological basis.

For these reasons, 130 pilots of varied background were assessed with a flicker instrument. This allowed us to establish standard criteria for flicker fusion frequency based on the principle that the pilot perceives the greatest amount of information during flight with his eye. Therefore this organ is the first to show disturbance when the subject is tired or suffers from some impairment in cortical dynamics.

29. Psychological and linguistic variables in flight crew training on Human Factors (A-335)

A. Camps, E. Laphitz, H.O. Leimann-Patt and C.A. Pessolano

Some questions have not yet been resolved in terms of the efficiency of CRM courses: 1) The apparent impossibility of modifying behaviourial attitudes whose origin is entrenched in the pilot's alloplastic personality. 2) The inaccessibility of certain paranoid personalities (omnipotent or overvalued) which, paradoxically, produce a 10 per cent boomerang effect. This may not only distort the purpose of CRM training, but could actually make it counterproductive.

By using a combination of LOFT (Line Oriented Flight Training), video and computerized psychodiagnosis, it was possible to determine which neurolinguistic and psychological variables play a part in pilot error. A video will be shown to present the preliminary results and the methodology used.

Mr. Leimann-Patt is Chief of the Research Department at the National Institute of Aviation Medicine of Argentina. He is the author of two books: Systemic Aeronautical

Psychiatry and Secondary Flight Disadaption Syndromes, and various papers. He is a member of the Aerospace Medical Association and the Western European Association for Aviation Psychology.

Dr. Pessolano is the director of the National Institute of Aerospace Medicine in Buenos Aires.

Adel Camps is a psychologist and Human Factors researcher in Buenos Aires.

Edouardo Laphitz is a pilot instructor specializing in Human Factors.

30. Reduced pilot vigilance during long-haul flights (A-352)

V. Carmigniani and J. Paries

Variations in alertness and performance during monotonous activities are often associated with irregular work cycles and pronounced jet lag. A study of pilot performance during long-haul flights is presented. Its purpose is to identify low vigilance phases and to assess their effect on pilot performance. The methodology is based on an objective evaluation of fluctuations in pilot alertness based on physiological parameters, together with an analysis of the activities performed. Preliminary results show significant variations in electroencephalogram spectra and in the frequency of eye movements. Alternating phases of high pilot vigilance and drowsiness were observed. Reduced vigilance seems to be more pronounced in flights following a sleepless night, even if this flight is performed during the day.

Mr. Carmigniani has been a civil aviation research and operations engineer since 1979 and is now serving in the Aircraft Operation Office of the Aeronautical Training and Technical Inspection Service in France. He is in charge of Human Factors aspects in the context of DGCA-funded studies and in charge of aircraft performance (member of ECAC group (DPAC) and ICAO group (SGTOAA)). He presented a paper on the "Archimedes Study" (errors in mental representation) at the 5th Symposium on Aviation Psychology in Columbus (April 1989).

Mr. Paries is a Civil Aviation Engineer, who works as the Assistant to the Chief of the Regulations Office of the Aeronautical Training and Technical Inspection Service (SFACT) in France. He is a member of the ICAO Human Factors and Flight Safety Study Group and heads the Human Factors Studies at SFACT.

31. Supervision of medical fitness of flight personnel - an irreplaceable method for the prevention of aviation accidents - the methodology used in the National Aviation Medicine Centre of Mexico (A-366)

A. Sanchez Sanchez

In view of the magnitude and the consequences of accidents, the basic objectives pursued by the medical authorities of the Ministry of Communications and Transport are: to preserve the health and the employment of civil air transport personnel and ancillary services, to prevent job-related risks and diseases conducive to such risks and to raise safety levels for personnel, users and goods transported and to contribute to the protection of the corresponding infrastructure.

With this aim in mind, medical fitness is assessed periodically by means of physical check-ups. These check-ups, which assist in the prevention of accidents attributable to Human Factors, are described together with their methodology.

Dr. Sanchez Sanchez graduated from the National Autonomous University of Mexico (UNAM) in 1958 and was awarded scholarships by the Governments of Italy, France, Yugoslavia and Japan to do post-graduate studies in occupational medicine, medical-surgical emergencies and public administration. He has also been working in the medical-surgical Security Institute from 1957 to date. He was later appointed Chief of the Departments of Forensic Occupational Medicine and Occupational Pathology of the Social Welfare Department of the Ministry of Labour; he was Deputy General of Medical Services of the Government of Mexico City and from the previous presidential Administration to date he has been Director General of Preventive Medicine in the Department of Transport of the Ministry of Communications and Transport.

32. A new methodical approach to flight fitness: continuous in-flight EEG, ECG and infrared television recording (A-381)

G. Hardicsay and F. Kóródi

This study compares the diagnostic and prognostic value of thermography with other examination methods. The controlling mechanism of the vegetative nervous system were recorded in hypobaric chamber, infrared thermogram, ECG, blood pressure and psychophysiological parameters. Changes of ECG and psychophysiological parameters were correlated with the hyper activity of the sympathetic nervous system.

Infrared thermographic examinations were also performed. An extreme hypersympathicotomy on the preflight thermogram was demonstrated in a simulated accident. After flight training a disharmonious decrease of infrared radiation was detectable. In addition, results from infrared examinations in a flight simulator (type TU-154) are compared to other psychophysiological examinations. This method could also be useful for verification of flight training.

Ferenc Kóródi received his diploma as mechanical engineer in 1969 at the Technical University of Budapest. He later completed psychological studies in Leningrad. In 1982 he graduated with a PhD in psychological sciences. Since 1982, he headed the Psychological Department of Civil Aviation Medical Service and in 1984 he became the head of the Health Department at the Ferihegy Airport, Budapest. His scientific activity is oriented towards the psychological examinations of crew members and the verbal communication between crew and ATC.

Gabor Hardicsay graduated from the Sommelweis Medical University at Budapest in 1972. He began his medical practice in the same year. He entered the field of aviation medicine in 1975 and now practices both internal medicine and aviation medicine. In 1980 he was appointed chief medical examiner of the Civil Aviation Authority of Hungary. His scientific research is mainly aimed at in-flight incapacitations.

INDIVIDUAL PAPERS

33. The systems approach in Human Factors considerations (A-372)

Y.P. Darymov

The complex influence of Human Factors on flight safety can be successfully determined if a systems approach is used, but this requires scrutiny at both the macro and micro levels. The macro approach implies a review of the problem as a whole and the development of an overall concept for resolution. This approach may involve an integrated programme which includes the selection and training of aviation personnel, the ergonomics of the work stations, work technology, duty time and rest, accident investigation and prevention. At the micro approach level, on a step-by-step basis,. solutions may be sought to take Human Factors into account in the design, development and operation of specific ergonomic systems such as "pilot-aeroplane", "crew-aircraft", "ATC controller-aircraft", etc.

Mr. Darymov has professional training as a pilot, a pilot-in-command, an ATC controller and as a traffic controller engineer. He has experience in flying duties, air traffic control, pedagogical activities and the organization and training of aviation specialists for civil aviation. He has performed scientific research on flight operations, air traffic control, flight safety and Human Factors.

He is a member of the Air Navigation Commission of ICAO.

34. Towards design-induced error tolerance (A-393)

J.J. Speyer

Except for the recommendations of Fitts, Wanner, Wiener and Curry, few fundamental design guidelines appear to be available in the scientific field of Human Factors, illustrating *a posteriori* that this activity is an art in infancy. With new technology emphasis was gradually put on Human Factors by all those concerned: manufacturers, airworthiness authorities, pilots and airlines. Measuring the impact of new technology on the operational interface could help setting up this Human Factors capability which in turn should eventually influence design guidelines and specifications.

The emerging role of pilot is becoming more that of a systems monitor than that of a control handler. Several views suggest that the pilot be brought back into a more active role to avoid automation or design induced errors.

Mr. Speyer is an aeronautical engineer. He is a graduate of the Polytechnic School University of Brussels in electromechanics and the Massachusetts Institute of Technology. He is currently Project Manager, Operations Engineering, in the Flight Division of Airbus Industrie where he has been responsible for certification, performance monitoring, operational liaison and ergonomics. In particular, he has been concerned with experimental evaluation and measurement of the man-machine interface.

35. Beyond pilot error: a pilot's perspective (A-415)

L. Friob, M. Sorsa and R.B. Stone

Pilots are frequently blamed for aircraft accidents by investigation authorities. The causes expressed are generally narrow in scope and fail to address the essential underlying factors such as training, procedures and pressures by the management. Airline pilots believe it is time to look beyond the immediate causes of accidents - beyond the cockpit crew. The accident investigation process should review in depth company operational procedures and practices, the training of the crew and possible stress factors set by commercial pressures.

This paper attempts to portray the human frailties pilots see in themselves as well as those induced by the airline or the design of the aircraft. Management of these problem areas is discussed.

Lucien Friob is a Captain with Air Belgium and currently flies the Boeing 757. He started his career twenty years ago and has logged 15.000 flight hours on worldwide *networks. He has an Industrial Engineer and has a degree in business management from University of Louvain. He is Chairman of the Human Performance Committee of the International Federation of Airline Pilots Association since 1986 and has also been a Member of the ICAO PELT Panel. He did participate in pharmacological research projects on stress, and has authored several papers on Pilot Licensing and Training.*

Captain Sorsa is an active Airline Pilot flying Finnair MD-80 aircraft. He received a Master's degree in applied psychology from Helsinki University and specialized in Aviation Safety and Human Factors. He has been actively developing Human Factors training and the application of Human Factors in accident investigation. Captain Sorsa is a member of the IFALPA Human Performance Committee and IFALPA's representative in the ICAO Human Factors Study Group. He has been an active member in Western European Association for Aviation Psychology and a secretary of WEAAP's 1985 Conference.

Richard B. Stone is a Captain with Delta Airlines, in Atlanta, currently flying the B767/757. He has served as Captain for 22 years on the FH227, DC9, B727, and B757. As a member of the International Federation of Air Lines Pilots' HUBER Committee, he participates in Human Factors, medical, training and licensing matters. He has served as an accident investigator (ALPA/IFALPA) in many major US accident investigations. He has Bachelor of Science and Master of Science degrees.

36. Becoming a captain: personality development by non-technical training and education (A-423)

A. Droog

The RLS Government Civil Aviation Flying School trains pilots for KLM Royal Dutch Airlines. Both KLM and RLS are working towards the full integration of technical and non-technical skill training. The KLM captain's profile and the RLS non-technical training syllabus will be outlined. The aim of the non-technical training within RLS is to develop sensitivity and skills in six fields: communication, teamwork, organization, decision making, leadership and stress. The concepts and methods used or being developed will be presented.

Mr. Droog is an aeronautical engineer who graduated from Delft Technical University in 1972. From 1978 to 1988 he worked with "Psychotechniek Consultants", Utrecht as an advisor involved in the selection of pilot trainees and pilots for RLS (Civil Aviation Flying School) and KLM. During the same period he studied psychology at Utrecht University (fields: personality, organization). Since 1988 he has been at the RLS Flying School, working as a Psychologist for Training and Education.

37. The Human Factors programme in Aerolíneas Argentinas (A-430)

R. Rubio

The paper presents a brief summary of how the Human Factors concept was approached and its implementation from the point of view of the organization and on the basis of a process of re-assessing attitudes. It includes a list of events and an analysis of their development.

Roberto Adolfo Rubio is an aircraft commander with Aerolíneas Argentinas, currently flying B727s and serving and Training Co-ordinator. He has 32 years of flying experience and 16,000 hours of flight time. He has served as an instructor in the Navy (having begun his career in naval aviation) and has been with Aerolineas Argentinas since 1975. From 1987 to the present he has served as Executive Secretary of the Professional Development Commission and has been responsible for conducting the Cockpit Resource Management course.

38. Use of magnetoencephalography (MEG) and electroencephalography (EEG) in processes of selection and training of air traffic controllers (A-435)

R.M. Heron

In Canada, only a small percentage of applicants are found acceptable for air traffic control training. Further, many trainees fail during training, thus, a serious shortage of air traffic controllers is predicted. The explanation for this appears to be that (a) current psychometric techniques for isolating and measuring the special skills required for ATC operation are not sensitive enough and (b) there is currently no means of developing or upgrading these skills. A new technique, combining use of MEG and EEG, might improve the situation.

MEG/EEG technology promises (a) improved predictability, understanding and measurement of ATC skills, and (b) an increase in the success rate of applicants and trainees.

Dr. Heron obtained her PhD at the University of Calgary, Canada in 1975. Subsequently, she carried out applied ergonomics research in the area of road safety, specializing in the perception of traffic signs. After three years as a Professor at Queen's University, teaching ergonomics, she headed up the Department of Research and Statistics at the Worker's Compensation Board in Edmonton. For the last eight years she has been Principal Ergonomist at the Transportation Development Centre in Montreal. She is a member of the Human Factors Association of Canada and has been elected to the Professional Register of the Ergonomics Society in the United Kingdom.

39. Automation of flight data processing and presentation in replacing flight progress strips (A-448)

I. Deuchert

In the beginning of the 1980s the "Ad hoc Group for the Co-ordination of the STT Programme on Colour Displays, Stripless Systems and Speech Compressing in ATC" was established within Eurocontrol. This paper presents the work of this group, and its sub-group "ODID", including the question of how to code information by means of colour to increase capacity.

Two simulations were carried out at the EEC Bretigny, the first for two adjacent control sectors in the UK, the second for the Bruxelles-East sectors adjoining Frankfurt-West airspace. In the third simulation, more emphasis will be put on graphic displays and input devices. As well, research work in the field of optimizing the controller/computer interface in under way.

Ms. Deuchert was an air traffic controller at Frankfurt and Dusseldorf (TWR, APP and ACC) from 1968 to 1983, during which time she studied psychology at Frankfurt University. Since 1981 she has served as a psychologist within Federal Adminstration for Air Navigation Services (BFS).

40. Methods for supervision and checking of air traffic controllers (A-453)

R. Mârşan and V. Soitu

From the psycho-medical point of view, the methods for supervision and checking of the air traffic controllers performance consist of specialized examinations with a high degree of diversity and specificity, depending on when they are carried out. The paper is the result of a study carried out among the Bucharest ACC air traffic controllers. It attempts to determine human weaknesses from the physiological and psychological point of view. Its purpose is to define more accurately the best working hours and to eliminate the fatigue factor, thus reducing the probability of human failure.

Rodica Mârşan graduated from the Faculty of Philosophy, Department of Psychology, at the University of Bucharest in 1989. She then worked as a psychologist in the Sports Medicine Centre until 1985. Since 1985 she has been a psychologist with the Tarom Airline where she deals with the psychological expertise of pilots and air traffic controllers and works with in close co-operation with the psychology laboratory of the Aeronautical Medical Centre.

Vasile Soitu graduated from the Faculty of General Medicine in Bucharest in 1971. Since 1973 he has been directly involved in the medical examination of flight personnel and air traffic controllers as a specialized inspector. Since 1989 he has been the Chief Doctor in the Department of Civil Aviation.

41. Environmental factors influencing flight crew performance (A-462)

M. Simons

Developments in commercial aviation have changed the pilot's task to that of a flight systems manager. In this task optimum vigilance is required. It is anticipated that the performance of the modern pilot might be impaired by the cumulative effects of frequent disturbance of sleep and prolonged exposure to mild hypoxia, low relative humidity, ozone and noise. Therefore, research on the effects of a combination of environmental factors on performance is recommended. Such research should include controlled studies under cockpit-environmental conditions, employing over time assessment of psychological performance and using tasks that are representative for the task of a modern pilot. Simulation of cockpit-environmental factors should include a cabin altitude of 8000 feet, relative humidity of <10%, temperature 20 - 25 C, ozone levels of 0.10 - 0.25 ppm and continuous noise of 75 - 80 dBA. Exposure time to these conditions should exceed 8 hours.

Dr. Simons graduated from the State University of Utrecht, Faculty of Medicine, MD Degree in 1973. From 1973 to 1977 he was a General Practitioner and from 1977 to 1981 served as a Medical Officer in Zambia and Chad. He then completed post graduate degrees in Cardiology and Internal Medicine. He is currently a Research Physician at Netherlands Aerospace Medical Centre.

42. Human resources development and accident prevention, in focus: the human nature (A-472)

C.M. Machado Pernambuco

An analysis of the accidents from the last five years, seems to indicate that education should be the main field of interest as far as safety matters are concerned. Education should be divided in two areas to focus on the ultimate expression of human nature, the relations with which the individual deals. One area is defined by the relation between the individual and environment. It may be treated through management development. The other relates to the individual dealing with himself, which may be accomplished by "self management". This is directly related to human nature, being a determinant in the effectiveness of the first area.

43. Character, personality and flight safety: the myth of the "right stuff" in civil aviation (A-475)

H.O. Leimann-Patt and C.A. Pessolano

90 per cent of Human Factors induced accidents take place in a psychosocial context that promotes unsafe or dangerous attitudes. The mythical "right stuff" becomes a main risk factor. It should therefore be renamed the "wrong stuff". The origin of this term can be traced to Greek mythology, which is why the three most dangerous character flaws are called Bellerophonic, Icarian and Phaethonic.

This paper analyzes the psychological characteristics and the socio-cultural origins of these characteropathies with a view to preventing them. Certain behavioral patterns can be easily detected. The importance of these patterns for recruitment and training will be discussed.

44. The effect of passenger motivation and cabin configuration on aircraft emergency evacuations (A-489)

C. Marrison and H.C. Muir

The need for Human Factors studies in cabin safety is highlighted by the fact that the percentage of people who die in technically "survivable" accidents has not dropped. Research funded by the UK CAA investigates the influence of cabin configurations on the rate at which passengers can evacuate.

A range of configurations were evaluated (a) when passengers were competing to evacuate the aircraft and (b) when passengers were evacuating in an orderly manner. Volunteers in groups of 60 performed a series of emergency evacuations. A total of over 2000 volunteers took part. In the paper, the evacuation rates for the range of configurations tested are included. It was found that the blockages can be significantly reduced by changes to the cabin configuration.

Claire Marrison, BA, MSc, is a Research Officer whose primary research is cabin safety. Following an investigation into the influence of flying on the physical and psychological health of cabin staff, she conducted a literature review for the CAA on the "Behaviour of Passengers in Aircraft Emergencies". Claire is currently working on a CAA sponsored project assessing the influence of certain aspects of cabin layout on passenger evacuation behaviour. She is also the secretary of the Aviation Working Party for the Parliamentary Advisory Committee for Transport Safety.

Helen Muir, MA, PhD is the Director of the Applied Psychology Unit in the College of Aeronautics. She holds a degree in psychology and a Doctorate from the University of London. Helen has been involved in applied research in the field of transportation since 1973. Since establishing MSc Course in Applied Psychology, her objective has been to develop and promote Aviation Psychology research including pilot workload assessment and crew activity analysis. The field of cabin safety and aircraft emergencies is Helen's main area of research interest. This has led to the development of a research facility for cabin evacuation trials and to a major programme of research into passenger behaviour in aircraft emergencies.

45. 30 years of jet losses: conclusions regarding Human Factors research (A-504)

H. Caesar

Lufthansa's Flight Safety Department has developed a database with consistent criteria to categorize and analyze accidents of all western built jet-aircraft above 20,000 kg since 1953. These data of more than 500 total (hull) losses and more than 1000 substantial damages offer research background regarding human, technical and environmental causes, flight phases, aircraft types, world region, size of airline, long- and short-haul comparison, two and three men cockpit and other criteria.

Knowledge gained from this research led to alteration or adaption of selection profile, rules and procedures, training and information of flight crews. Deficiencies could be detected and avoidance strategies developed.

Captain Caesar started his career with Lufthansa as co-pilot on Lockheed Superconstellations L1049G and L1649A, Vickers Viscount 814D, Boeing B707 and B720.

In 1963 he was promoted to captain and flew Convair 440s, Viscount's, Boeing B727s, DC10s and he is currently flying B747s. Captain Caesar is an instructor and check pilot.

Since 1971 he has served as Director, Safety for Lufthansa. In this position he is responsible for the supervision of Lufthansa's Safety Standards in regard to flight operations, including the investigation of all incidents and accidents in Lufthansa and it's subsidiaries.

Captain Caesar is a member of IATA's Safety Advisory Committee, of the International Advisory Committee of the Flight Safety Foundation and of the International Society of Air Safety Investigators.

Note to the reader: Also included in Appendix A (beginning on page A-530) are the texts of eight papers for which no abstracts are available.

APPENDIX A

PRESENTATION OF PAPERS

PERSPECTIVES IN HUMAN FACTORS

J. Lederer

I feel very honoured to be invited to this first ICAO seminar on Human Factors because the first president of ICAO, Dr. Edward Warner, was my mentor on the philosophy of aviation safety over a half a century ago. In 1940, when I was in charge of civil aircraft accident investigation and safety regulations for the civil aeronautics board of which he was vice-chairman, he sent me a memo suggesting that we try to discover not only how pilots commit unsafe acts but more important, "why" they do so. In respect to safety regulations he often stated that the purpose of government is to protect the innocent in circumstances over which they have no control such as being a passenger in unairworthy airplanes.

It is an honour to be invited to discuss safety in the Soviet Union where many distinguished scientists and engineers have contributed so much to aerospace developments. Sputnik has influenced a global perspective of our planet in relation to the universe. Humanity is being well served by this new outlook. I proudly wear these two medals given to me by the Soviet Federation of Cosmonauts for my participation in the USA Apollo Moon Landing Programme.

When I prepared the abstract for this talk, my ambition exceeded my time limitation. The full paper will be available from ICAO. I shall touch on several aspects of it.

This first viewgraph is from page 11 of the fine ICAO Accident Prevention Manual. It depicts "why" we meet here (do not bother to read the text). Mechanical causes of aircraft accidents have diminished over the years while human causes now dominate the accident scene. It is generally agreed by those who should know that at least 65 per cent fatal accidents in airline operations are caused by inappropriate behaviour of the cockpit crew. Experience with industrial accidents tells us that the unsafe act occurs hundreds of times before it results in a loss of an eye or maiming of a hand. This is probably true also in airline operations. If so, the behaviour of flight crews should be monitored to intercept the cause of an accident before it occurs. For example, failure to complete a check list might be discovered in time to avoid a catastrophe. Hence, the need to adopt a system for using flight data recorders to review crew performance. This is now practised by a sizable number of airlines with pilot consent based on no punitive threat for inadvertent departure from good practice. Results have been very rewarding. Cockpit crews are found to be grateful for the warnings they have received.

Captain J.E. Carroll, retired vice-president for flight standards and training of United Airlines defined the problem of inadequate cockpit crew performance as follows:

> "Why does a person who is carefully selected, highly trained, properly checked and licensed, physically fit, mentally well balanced and unusually well paid, sometimes perform in less than the optimum fashion, despite being aware that the penalty of human error could be catastrophic?"

He went on to explain how Cockpit Resource Management (CRM) and Line Operational Flight Training (LOFT) can moderate the introduction of cockpit emergencies.

The next viewgraph indicates the extent of the possibilities for human error; some ten thousand air transports in operations with twelve million departures per year, and growing.

The next viewgraph lists the fatal airline accidents of last year, 1989, with thirty-two fatal accidents. The twenty-four little dots denote accidents that will probably be attributed to human error, about 70 per cent of the total, when the analyses are completed. These involve flying into hills and mountains, overshooting, undershooting, loss of control etc. Accidents due to terrorism are not included in this count. The possibility that some of these accidents resulted form human error in design, maintenance or air traffic control must also be considered and could increase the 70 per cent.

The next viewgraph portrays the flight stages in which the accidents occurred. Almost half, 48.3 per cent, take place in the final approach and landing stage. An excellent Boeing study of airline safety, by Lester Lautman, suggests the need for improved approach path guidance and stabilization of approaches by the time the airplane arrives at a given altitude, say 500 feet. Automatic landing might improve this situation. The report says that "the first accident due to an automatic landing has yet to be recorded."

The next viewgraph reveals a rarely mentioned "why" of pilot error. Psychological pressure to meet schedule performance. Pilot takes off after a heart attack to avoid losing his take off slot. Other pressures arise form airline competition for on time performance, or to meet curfew time constraints, or to economize on fuel consumption. Even a captain's personal commitment to get home or to be at some other place at a definite time may invite an operational hazard. His emotional state may also be a factor.

The adoption of a pilot's code of professional conduct, may provide an antidote to such pressures. Physicians have been guided for centuries by the widely accepted Oath of Hippocrates. The USA Air Transport Command and the Allied Pilots' Association have adopted such a code.

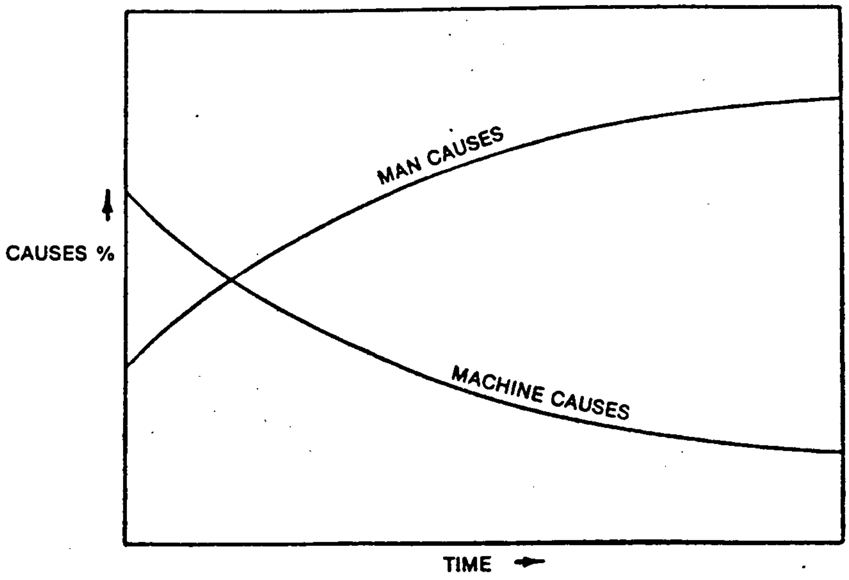
The next viewgraph shows fatal accidents per million flights -- a very fine record but its approach to zero indicates how difficult it will be to improve this good fatal accident rate.

The public perception of safety is based not on this good rate but on numbers of accidents reported by the media. It must be improved if public confidence in airline safety is to be maintained, because if traffic doubles, as expected, in the next twenty years, there will be a fatal airline accident on the average of one per week at this good rate.

The last viewgraph is from the Boeing report and calls attention to significant crew factors that demand your attention.

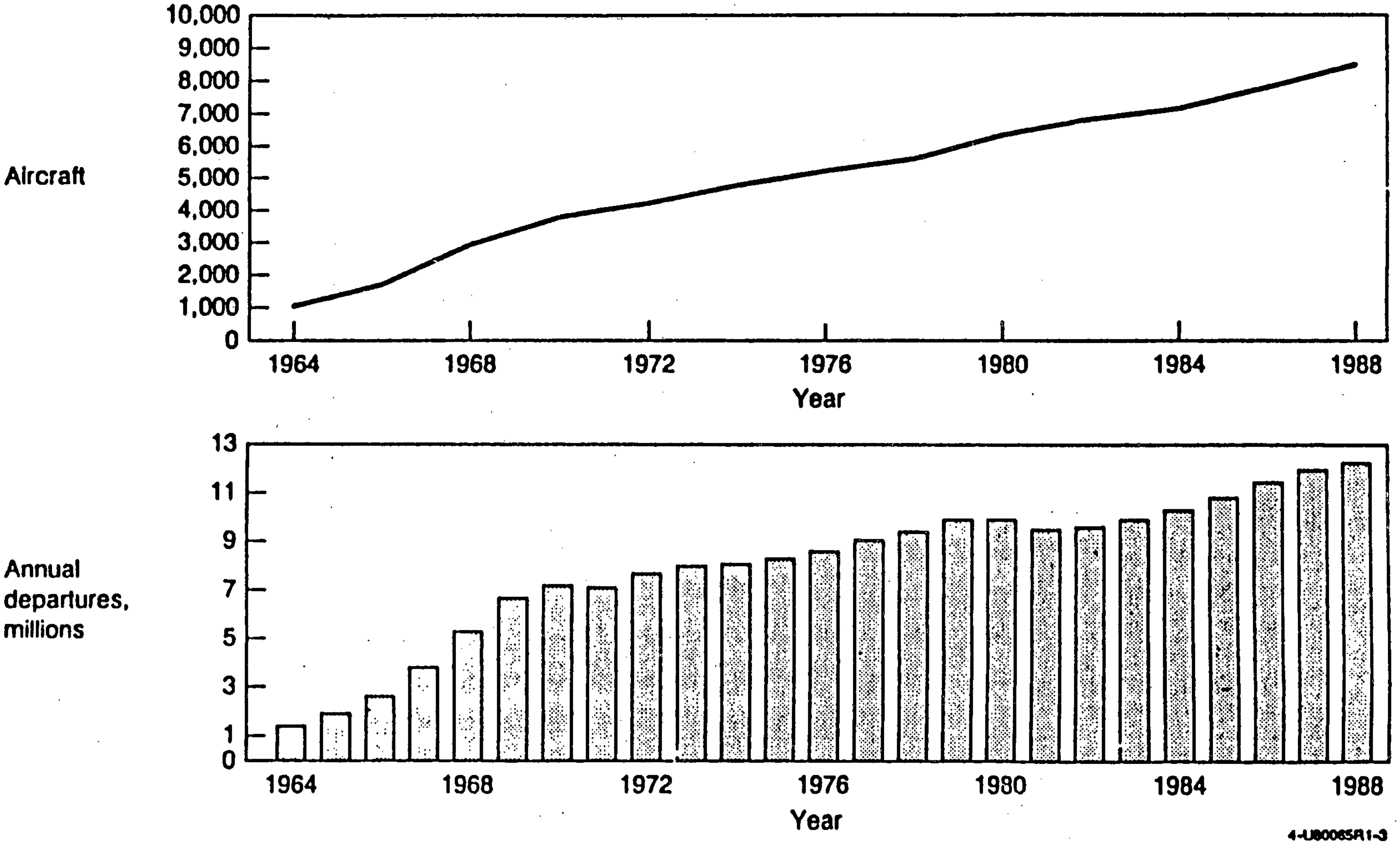
Note also the reference to management concern for safety. The study shows that airlines where safety policy and implementation comes from the CEO are the ones with the best safety performance. Perhaps airline executives should take refresher courses in safety management from training centres such as Al Ueltschi's Flight Safety International. I would also suggest that top airline executives be called to testify about their safety policies when hearings are held on accidents or incidents involving their airlines.

The late Harold R. Harris, when he was vice-president of PAN AM World Airways about forty years ago declared, "anxiety never disappears in a human being in an airplane. It merely remains dormant when there is no cause to arouse it. Our challenge is to keep it forever dormant."



Jet Aircraft in Service and Annual Departures

Worldwide Operations—1964-1988



1989
Worldwide Fatal Accidents in Commercial Jet and Turboprop Operations

Flight Safety Foundation, January 1990

Source: Flight Safety Foundation, based on information from Aviation Information Services Ltd. (AISL) Major Loss Record, U.K. Civil Aviation Authority (CAA) World Airline Accident Summary, Boeing Commercial Airplane Company, and other sources.

Scheduled Commercial Passenger Jet Flights

Date	Aircraft Type	Operator	Location	Flight Phase	Fatalities Pass/Crew	Total Occupants Pass/Crew
Jan 8	B-737-400	British Midland Airways	Near E. Midlands airport Leicestershire, England	Cruise	47 / 0	118 / 8
Left-side engine failed while approaching cruise altitude. Crew shut down right-side engine and could not restart. Aircraft crashed across a motorway about 1/2 mile from runway threshold.						
Feb 24	B-747-122	United Airlines	Honolulu, Hawaii, U.S.	Climb	9 / 0	336 / 18
Portion of fuselage skin separated during climb, creating hole through which nine passengers were sucked out. Aircraft returned safely to Honolulu.						
Mar 10	F-28 Mk.1000	Air Ontario	Dryden, Ontario, Canada	Takeoff	21 / 3	65 / 4
Aircraft crashed and burned following takeoff in a snowstorm.						
Jun 7	DC-8-62	Surinam Airways	Near Zanderij Int'l Airport, Paramaribo, Surinam	Final Approach	166 / 9	177 / 9
Aircraft crashed when it undershot runway during approach in darkness and fog.						
Jun 17	IL-62M	Interflug	Schonefeld Airport Berlin, East Germany	Takeoff	20 / 0	103 / 10
Takeoff was aborted and aircraft overran across a road into fields. Aircraft wing struck a water tank and fire broke out, spread and destroyed the aircraft.						
Jul 19	DC-10-10	United Airlines	Sioux City, Municipal Airport Sioux City, Iowa, U.S.	Cruise & Landing	110 / 1	285 / 11
Number two engine suffered uncontained fan disc failure, fragments of which severed hydraulic lines, resulting in loss of flying controls. During emergency landing, a wing contacted the runway and the aircraft cartwheeled, broke up and caught fire.						
Jul 27	DC-10-30	Korean Air	Tripoli Int'l Airport, Tripoli, Libya	Landing	68 / 4	182 / 18
Undershot on landing in thick fog and collided with two houses and several cars. Six people on the ground were also killed.						
Sep 3	B-737	Varig	Near Sao Jose do Xingu, Brazil	Cruise	12 / 0	48 / 6
Aircraft became lost because of an apparent navigational error and ran low on fuel. Aircraft made a successful emergency belly landing but sustained substantial damage.						
Sep 20	B-737-401	USAir	La Guardia Airport, New York, U.S.	Takeoff	2 / 0	55 / 6
Aircraft overran runway following an aborted takeoff, hitting a pier and finally coming to rest in the river.						
Oct 21	B-727-224	TAN/SAHSA	Near Tegucigalpa, Honduras	Approach	129 / 3	139 / 7
Aircraft flew into a mountain while positioning for an approach during daylight with precipitation, low clouds and strong gusting winds.						
Oct 26	B-737-209	China Airlines	Near Hua-lien, Taiwan	Climb	47 / 7	47 / 7
Aircraft flew into the side of a hill after making an incorrect turn during the initial climb. The accident occurred during rain and darkness.						

Scheduled Commercial Passenger Turboprop Flights

Feb 3	Fokker F-27 Mk 600	Burma Airways	Near Mingaladon Airport Rangoon, Burma	Takeoff	23 / 3	25 / 4
Aircraft took off and entered fog. It veered left and collided with a tree. A fire broke out on impact, destroying the aircraft.						
Mar 8	Shorts 330	Olympic Aviation (Olympic Airways)	Mt. Kerkis, Samos, Greece	Approach	31 / 3	31 / 3
Aircraft flew into a hillside while preparing to land in daylight, with thick fog.						
Apr 10	Fairchild FH227B	Uni-Air	Near Valence, France	Approach	19 / 3	19 / 3
Aircraft flew into the side of a mountain during darkness with rain and light mist.						
May 8	Beech 99	Holmstroem Air	Virkvarns Airport, Oskarshamn, Sweden	Final Approach	14 / 2	14 / 2
Aircraft reportedly stalled, entered a steep bank and crashed.						
Jun 11	Twin Otter 300	Aerotaca	Caribabare, Columbia	Approach	6 / 0	18 / 2
Aircraft flew into a hillside in poor weather, following a previous landing attempt.						
Jun 28	BAe 748 B Super 2B	Cameroon Airlines	Yaounde, Cameroon	Landing	1 / 2	43 / 7
Aircraft crashed at runway end during attempted go-around in bad weather.						
Jul 21	Twin Otter 300	Talair	Near Porgera, Papua, New Guinea	Climb	1 / 2	20 / 2
On departure, the aircraft made a steep climbing right turn, veered left and crashed into trees.						
Aug 15	AN-24	CAAC	Hongqiao Airport, Shanghai, P.R. China	Takeoff	28 / 6	34? / 6?
Aircraft overran runway into river.						
Aug 25	Fokker F-27 Mk. 200	Pakistan Int'l Airlines	Missing between Gilgit & Islamabad, Pakistan	Cruise	49 / 5	49 / 5
Aircraft disappeared en route.						
Sep 15	Twin Otter 300 PK-NUE	Merpati Nusantara Airlines	Missing between Manokwari & Bentuni Irian Jaya, Indonesia	Approach?	19 / 3	19 / 3
Aircraft failed to arrive at Bentuni on completion of a flight from Manokwari. The last contact with the flight, ten minutes before it was due to land, was routine.						
Sep 23	Dornier 228-201	Vayudoot	Near Pandharpur, India	Cruise	8 / 3	8 / 3
Aircraft crashed into a reservoir behind a dam, reportedly at a steep dive angle.						
Sep 26	Metro III	Skylink Airlines	Terrace-Kitimat Airport, Terrace, British Columbia, Canada	Approach	5 / 2	5 / 2
Pilot may have broken off an approach to begin a go-around. Aircraft struck tree tops, went out of control, and crashed. Accident occurred in daylight, but with fog and smoke present.						
Sep 27	Twin Otter 300	Grand Canyon Airlines	Near Grand Canyon National Park, Ariz., U.S.	Landing	8 / 2	19 / 2
Aircraft landed in normal touchdown zone, bounced, and pilot attempted a go-around. Aircraft struck wires and trees and crashed.						
Oct 28	Twin Otter 300	Aloha Islandair	Halawa Valley, Molokai, Hawaii, U.S.	Cruise	18 / 2	18 / 2
Aircraft flew into high ground in darkness.						
Dec 26	Jetstream 31	NPA	Pasco, Washington, U.S.	Approach /Landing	4 / 2	4 / 2
Aircraft went down in a field just short of the runway and burst into flames.						

Non-Scheduled Commercial Passenger Jet Flights

Feb 8	B-707-331B	Independent Air	Mt.Pico Alto, Santa Maria, Azores	Approach	137 / 7	137 / 7
Aircraft flew into a mountain while positioning for visual approach in daylight.						
Sep 3	IL-62M	Cubana	Havána, Cuba	Climb	115 / 11	115 / 11
Aircraft crashed into a residential area shortly after takeoff at night with heavy rain strong gusting winds. Fourteen people on the ground died.						

Non-Scheduled Commercial Passenger Turboprop Flights

Sep 8	Convair 580	Partnair	Off Hirtshals, Denmark	Cruise	50 / 5	50 / 5
Aircraft crashed into the sea.						
Nov 21	An-24	Aeroflot	Near Tyumen, USSR	Approach or Landing	28 / 6	36 / 6
Reportedly crashed in poor visibility.						
Dec 21	C-130 Hercules	Bolivian Air Force	Near Guayaramerin, Bolivia	Takeoff or Climb	16 / 8	18 / 10
No further details.						

Occurrences Involving Sabotage, Hijacking or Aircraft Being Shot Down: Commercial Passenger Flights

Jun 18	An-26	Ariana Afghan Airlines	Near Zabol, Iran	Cruise /Landing	6 / 0	35 / 5
During attempted hijack, copilot was shot in the shoulder and a rear door was opened, making control difficult. A forced landing was made on an unsuitable strip and the aircraft overturned.						

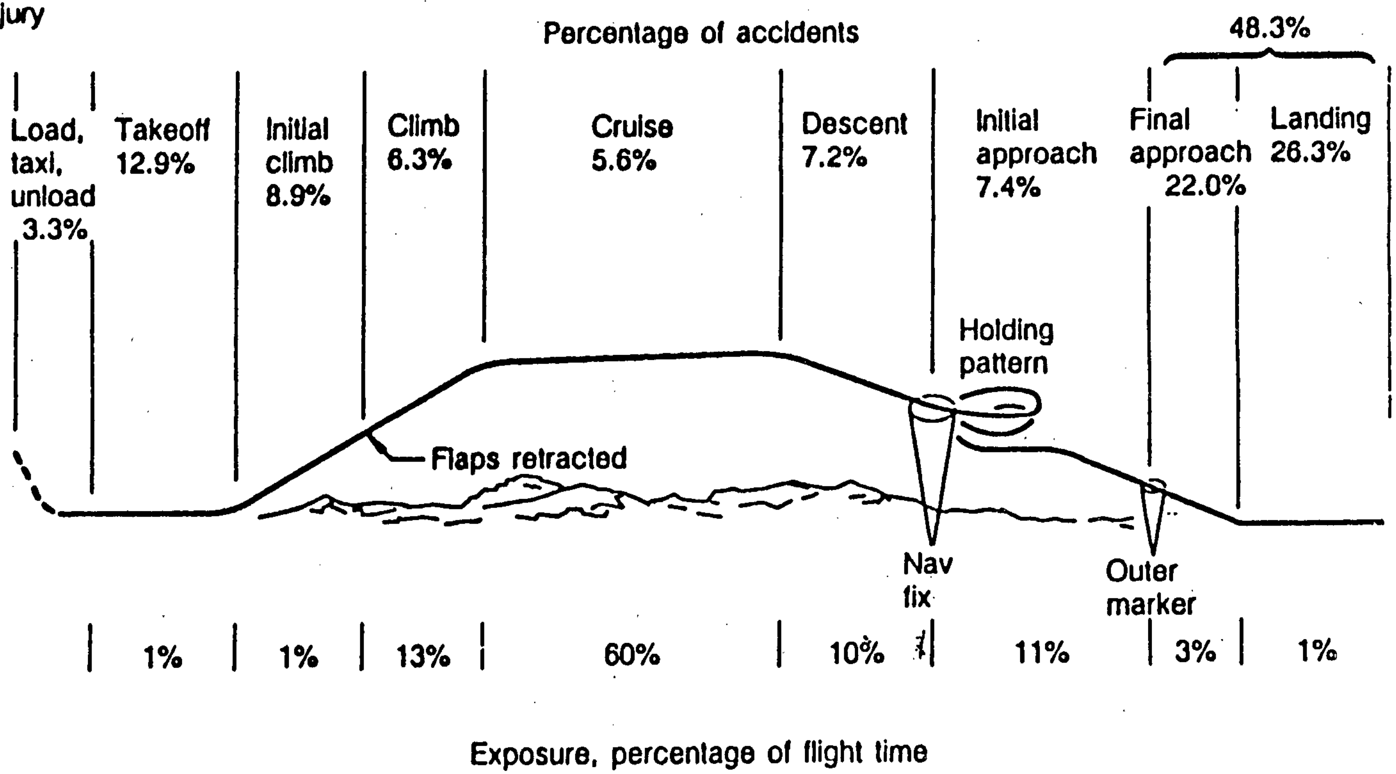
All Accidents*

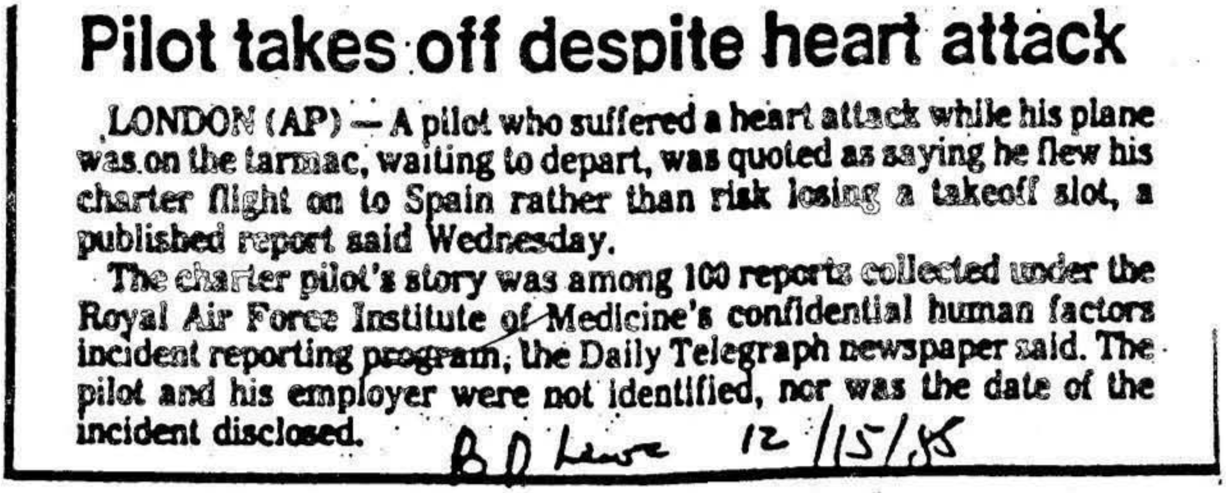
Worldwide Commercial Jet Fleet—1959-1988

Source: Boeing

Exposure percentage based on an average flight duration of 1.6 hours

*Excludes
- Sabotage
- Military action
- Turbulence injury
- Evacuation injury





Pilot takes off despite heart attack

LONDON (AP) — A pilot who suffered a heart attack while his plane was on the tarmac, waiting to depart, was quoted as saying he flew his charter flight on to Spain rather than risk losing a takeoff slot, a published report said Wednesday.

The charter pilot's story was among 100 reports collected under the Royal Air Force Institute of Medicine's confidential human factors incident reporting program, the Daily Telegraph newspaper said. The pilot and his employer were not identified, nor was the date of the incident disclosed.

BD Lewe 12/15/85

Bangor Daily News

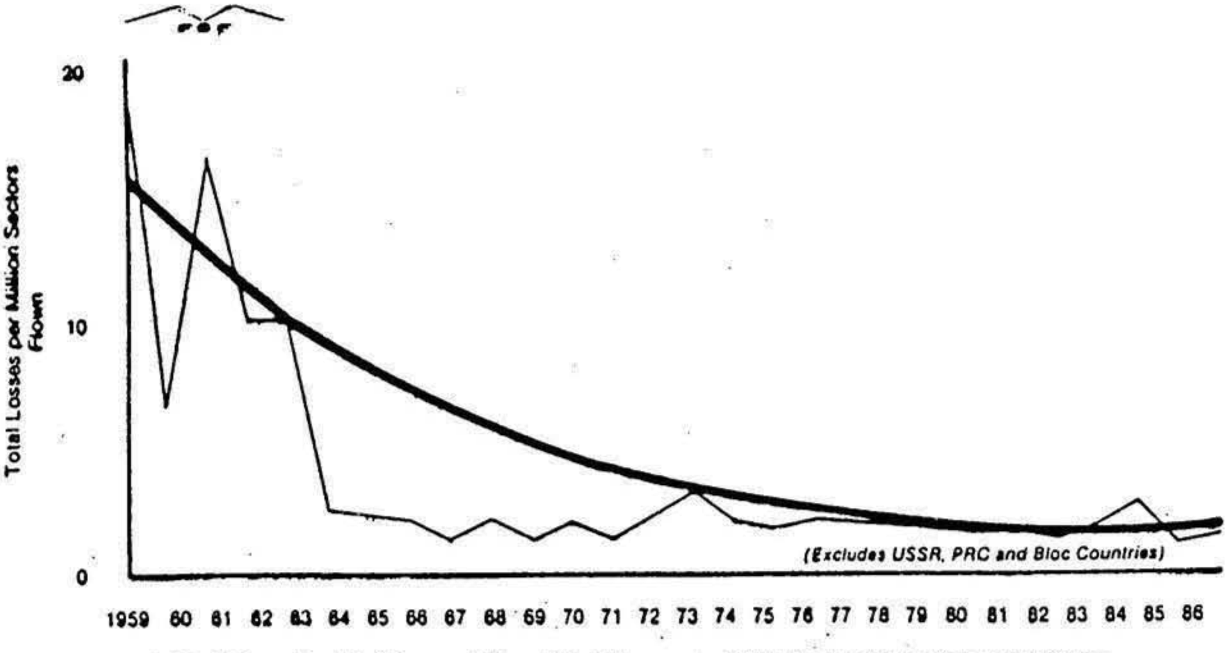


Fig. 2: World Operational Jet Transport Aircraft Total Losses per Million Sectors Flown, Scheduled Service, 1959-1986. (Source: FSF, IATA).

Table 1

Significant Crew-Cause Factors and Percentage of Presence in 93 Major Accidents

33%	Pilot deviated from basic operational procedures.
26%	Inadequate crosscheck by 2nd crew member.
9%	Crews not conditioned for proper response during abnormal conditions.
6%	Pilot did not recognize the need for go-around.
4%	Pilot incapacitation.
4%	Inadequate piloting skills.
3%	Crew errors during training flights.
3%	Pilot not trained to respond promptly to GPWS command.
3%	Pilot unable to execute safe landing or go-around when runway sighting is lost below MDA or DH.
3%	Operational procedures did not require use of available approach aids.
3%	Captain inexperienced in aircraft type.

THE MARCH OF COCKPIT AUTOMATION: WILL HUMANS EVER REPLACE COMPUTERS?

(Keynote Address)

Earl L. Wiener
Department of Management Science
University of Miami
Coral Gables, Florida 33146 USA

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TITLE SLIDE
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Ladies and gentlemen, it is my great pleasure to be invited to speak at the opening of this historic conference. We convene today at an exciting time in East-West cooperation and communication, and I wish to add my voice of thanks to our Soviet colleagues who have invited us here.

In my thirty years in this profession I have seen the field of human factors go from obscurity, gradually to grudging acceptance by traditional professions, and finally to the exalted level that we enjoy today. We are consulted by industry, government, and operational people; we are asked to speak at a bewildering array of meetings, and are encouraged to pursue our research. If there is any criticism one hears today of the efforts of the human factors profession, it is that we are not moving fast enough. Unfortunately there is some truth in that.

The practice of human factors in aviation is largely a matter of trying to keep up with rapidly advancing technology, and always to some extent losing the race. The World War II aircraft far outstripped the capabilities of the pilots who had to operate them. Human factors arrived on the scene too late to make much of an impact on aircraft of this era, but the lessons learned during World War II were not forgotten, and following the war human factors flourished in government, in the military services, in universities, and in manufacturing. By the end of the decade of the 1960's the profession had closed the gap. Tangible benefits to both transport and military aircraft could be demonstrated, and the human factors researchers and engineers could point with pride at their achievements.

But our complacency was soon to be shattered, and done so by a device so small that hundreds could be held in the human hand. The microchip ushered in the age of sophisticated aircraft automation, and once again the human factors researchers and the aviation industry struggle to catch up with the capabilities of the new devices. It is as if the clock had been set back to the 1940's.

There are fundamental truths that we do not understand about the human factors of automation. For example, the most fundamental, the relationship between automation and workload, has not been established. It is far from true to assume as a general statement that "automation reduces workload." In fact there are very possibly conditions under which the opposite occurs, that automation induces workload. Furthermore, there is not a single experiment that I am aware of that investigates the relationship between automation and fatigue.

Our challenge today is to develop a "philosophy of automation" which will allow us to integrate the new technologies and devices as they become available. We must also develop operational doctrine, training methods, and management techniques which will allow us to exploit the positive features of automation, and control the negative aspects. I will be speaking to you again on Wednesday morning on this topic, and will outline some of the approaches that we might take to achieve a better understanding and utilization of the remarkable capabilities of cockpit automation.

For some years I have been studying the relationship between highly automated systems and human error, particularly the manner in which automation may induce or invite human error. I have spoken of what I call "fallible humans and vulnerable systems." For example, the keyboard, so prevalent and apparently irreplaceable in digital systems, is a wellspring of human error. In 1987 two jumbo jets flying from Europe to the U.S. passed within thirty feet of each other over the Atlantic in Canadian airspace. The cause? A single keystroke error in the inertial navigation system.

The examples of the vulnerability of modern systems to human error are endless, as one can see from this slide.

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INCIDENTS AND ACCIDENTS

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Training is another issue which impacts flight safety and automation. With the rapid expansion of airlines and the drying up of traditional pools from which pilots have been hired, airlines face the greatest peace-time training challenge in history. At the same time airlines will be retiring their traditional cockpit aircraft. Thus two trends will converge: increasing sophistication of cockpits, and decreasing experience of pilots entering these cockpits.

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TRAINING

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Still I would caution that there is a temptation to think that all problems can be solved by training. Often the training department becomes the dumping ground for poor design and conceptualization.

****

IRON LAW

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Meanwhile the next decade will witness an endless parade of new devices: TCAS, GPS, MLS, wind-shear detection, envelope protection, and mode-S are in the immediate future, and many more

****
NEW TECHNOLOGIES
****

developments will emerge in early years of the next century.

Cockpit resource management training offers the solution of a class of problems that have plagued commercial aviation, and I salute those from both the aviation community and the academic and scientific world who have made remarkably rapid advances in only one decade. But I would caution that my own field studies have convinced me that CRM training should no longer be considered model-independent, and that crew communications and coordination in the highly automated aircraft may differ in significant ways from traditional aircraft, upon which current CRM programs are based. I hope that our current research, a cooperative effort between NASA, the University of Miami, and Delta Air Lines, will clarify these issues.

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COCKPIT RESOURCE MANAGEMENT
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In recent years economic production pressures have caused the industry to stretch the capability of our airliners and crews to what may prove to be the limit. Already we have extended operations (ETOPS) of two-pilot, two-engine aircraft flying long over-water segments. With the recent introduction of the B-747-400, and shortly the MD-11, two-pilot crews will be stretched ever further. Now airlines are beginning to augment the two-pilot crews with one or possibly two extra pilots. The individual authority, and role relations of these mixed crews of primary and relief pilots pose a new challenge to cockpit resource management (CRM). One can imagine a variety of interesting scenarios, especially when the two seats are occupied by relief pilots and the captain, perhaps two captains, are off-duty.

The popular British novelist and former politician Jeffrey Archer once authored a book entitled, Shall We Tell the President? The phrase we may soon be hearing in the cockpit will be, "Shall we wake the captain?"

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WAKE THE CAPTAIN?
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These are exciting times to be in the field of human factors. We must confront the remarkable challenge of new technologies, or we will face the 1940's all over again: machines whose capabilities are more advanced than the humans who must control them.

I commend ICAO for convening this important meeting, and again thank our Soviet hosts.

UNIVERSITY OF Miami

COCKPIT AUTOMATION:

WILL HUMANS EVER REPLACE COMPUTERS?

Earl L. Wiener

INCIDENTS AND ACCIDENTS

AVIATION

- NWA 255
- DAL 1141

MARINE

- Herald of Free Enterprise
- Exxon Valdez

PRODUCTION

- Three Mile Island
- Chernobyl
- Bhopal

MILITARY

- U.S.S. Vincennes/Iran Air 655

TRAINING AND TRANSITION

- Rapid movement of low-time pilots into hi-tech, two-pilot cockpits
- Lack of experience or research on how to achieve this
- Possible sources of guidance:
  - Military
  - Extrapolation from present aircraft
  - Research studies

WIENER'S IRON LAW

If human factors work is done properly at the design phase, the cost is high, but it is paid only once. If poor designs must be compensated for by training, the cost is paid every day.

NEW TECHNOLOGIES WITH HUMAN FACTORS IMPLICATIONS

TCAS, MLS, GPS
Wind-shear detection
Envelope protection
Mode-S data link

CREW COORDINATION ISSUES IN HIGH TECH AIRCRAFT

- WHO DOES WHAT
- SUPERVISION
- SHIFT OF AUTHORITY
- INDEPENDENCE OF CREW MEMBERS
- CRITICALITY OF FAILURE TO COORDINATE

"SHALL WE WAKE
THE CAPTAIN?"

Human Factors: the operational challenge

Frank H Hawkins

Transcending National Frontiers

The 1975 Istanbul IATA Technical Conference is seen by many as an important event in civil aviation Human Factors history. For the first time most of the world's major airlines expressed their serious concern at the role of human behaviour and performance in air safety. Perhaps this 1990 Leningrad Seminar will in time be thought of as the event demonstrating that this concern really transcends all national boundaries.

Activity in academia, government agencies and international bodies provides a vital foundation for progress. But the final test of achievement is what is happening in the real world of air transport. And not least, on the flight deck.

The dominant role of inadequate human behaviour in accidents has been known for half a century. Yet only in recent years have we seen significant signs of practical progress and even this has been quite patchy.

Looking from the air transport flight deck, several issues seem to call for particular attention. Time allows just a few to be mentioned here.

Tuning to the same frequency

A prime requisite to ensure fruitful international collaboration and progress is that we must communicate with each other on the same conceptual frequency. There must be broad agreement on the meaning of the technology of Human Factors. It is unreasonable to expect a busy flight deck design specialist to travel around the globe to listen to papers on, say, medical screening techniques. Neither is it productive for a physician to spend his time attending presentations on, for example, pilot behaviour in an automated flight deck.

We must narrow and clarify the field. In some countries this has already been accomplished. In others, confusion still reigns. In the Human Factors Society, psychology is the most dominant background discipline with medicine representing less that 4% of members. Yet in some countries, Human Factors is still seen as a branch of medicine, with progress inhibited as a result.

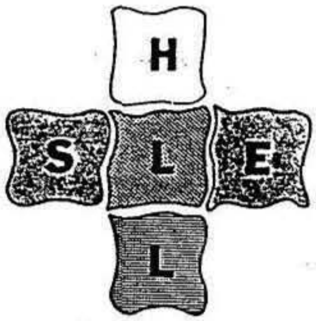

Fig 1. A ***model*** *of* ***Human*** *Factors**

A model illustrating the interfaces between the components of the complex flying system and reflecting the technology of Human Factors. In this model we see the human component, or the ***Liveware****, in the centre. A sound understanding of its characteristics -- its capabilities and limitations -- is essential if a proper matching of the other components is to be achieved. These other components are the* ***Hardware*** *(eg displays & controls),* ***Software*** *(eg procedures & symbology),* ***Environment*** *(eg noise, heat/cold, circadian dysrythmia) and other Liveware (eg other members of the team).*

Developing Credibility

A second problem, viewed from the flight deck, is one of credibility in the Human Factors message. Not only credibility to flying personnel but also to airline managements and regulatory agencies.

This was well illustrated in a Human Factors seminar I conducted for 16 European airlines just a few years ago. The Training and Safety Manager of one airline delivered the challenge. "In my company's opinion", he declared "Human Factors is just an excuse for incompetence". We must be saddened by the ignorance and complacency which such a declaration reveals. But we must also reflect on our own failure to convey with adequate credibility the Human Factors message to those in air transport in a position to influence events.

We must make clear that Human Factors is NOT concerned to reduce or remove the concept of individual responsibility. Neither does it condone undisciplined, incompetent, complacent or negligent behaviour.

On the other hand, it recognises that crew members do not overnight abandon good professional behaviour to become undisciplined, incompetent, complacent or negligent. This often reflects long exposure to an operational environment which tolerates such behaviour. This, in turn, usually reflects a management which is indifferent to the need for a more enlightened approach to human behaviour and performance.

Optimising the Hardware

Human Factors also recognises that many of the human errors which occur are system-induced rather than operator-induced. Air transport operators and their technical pilots are now prepared, as they always have been, to make their operational experience available to aircraft designers. This may be done individually and through organisations such as the SAE S-7 Committee.

However, the state-of-the-art is now such that basic Human Factors issues of flight deck design and systems should be resolved BEFORE the aircraft comes into service. We should not have to wait for an accident or incident to generate corrections in such aspects of design.

The impact of automation on pilot performance and flight deck tasks is now under increasing scrutiny and this attention must extend to pilot selection criteria.

Sleep and Biological Rhythms: Performance and Behaviour

Variations in performance and behaviour associated with sleep and biological rhythm disturbance have been known for many years. Confidential pilot reporting schemes in recent years have been removing the covers from some of the hazards associated with these variations. The public and regulatory agencies are now taking increased notice of this aspect of flight safety.

The introduction of extended range operations and the suggested use of drugs to enhance sleep in such situations, raises serious and fundamental issues which have not yet been fully resolved.

Education and Training

Another basic area which presents a challenge to the enlightened airline, is how to ensure proper education and training in Human Factors -- the key to progress. Education provides a general background of knowledge of a subject which lays the foundation for later training for specific applications.

We would not consider training pilots in flight planning without their having had a formal background of education in arithmetic. Neither would we try to train them in meteorology or aircraft systems if they had received no original education in physics or general science. Why, then, is this eminently sound concept not applied in the case of Human Factors? Its proven relationship to air safety would certainly justify this.

All over the world today we find airlines, often backed by regulatory agencies, trying to short-cut this learning process. They are applying short-term training in aspects of human behaviour without any educational foundation amongst the staff concerned. This particularly applies to what is sometimes called Cockpit Resource Management or CRM. This is currently a fashionable term in civil aviation for a branch of non-technical training. It essentially means the leadership and crew cooperation which many in the industry have always recognised as being a pre-requisite for air safety. Air crews being trained in CRM -- and often even those teaching them -- have usually had no formal background of education in human behaviour and performance. Furthermore, expectations in modifying personality and strongly held attitudes by such programmes are sometimes set quite unrealistically high and disillusion then follows failure. The solution in some cases is in pilot selection rather than in-service training.

Airlines believe that when they recruit pilots, the formal educational process should have been completed. Their task is then simply to train this educated recruit to fill his specific slot in the airline's operations. This assumption is sadly an illusion in most airlines in most countries. Where *ab initio* flying schools have integrated Human Factors education into their programmes, such as in Australia and the Netherlands, the educational problem is well on the way towards solution. Yet even there, the airline is still faced with the need to introduce Human Factors to pilots already in service. For most other countries the problem is more severe. A rather new flying college advertising 935 hours of ground school for training airline pilots, listed not one single hour devoted to Human Factors. Airlines taking pilots from flying schools should insist on a proper basic level of Human Factors knowledge. While ICAO Annex 1 now requires this in general terms, precise interpretation is left to national civil aviation authorities, many themselves lacking Human Factors expertise.

We can expect progress in this area to be unacceptably slow until the relevant ICAO Annex 1 clause is clarified and applied universally as a mandatory requirement. In all such activity we must keep our eyes focused on the main areas of Human Factors deficiencies as revealed by accident and incident investigations and by confidential pilot reporting. We must not be diverted into allocating resources where they are likely to have little impact on air safety and efficiency.

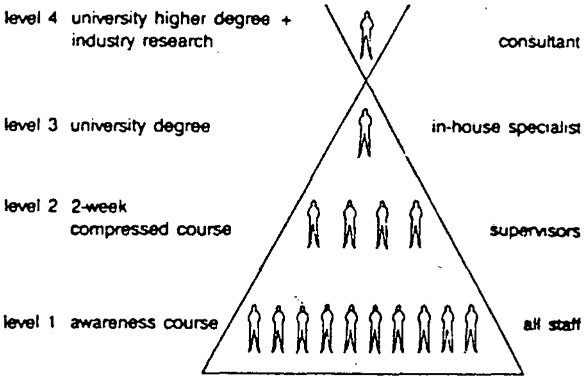

*Fig 2. Levels and Sources of Human Factors Expertise**

A model suggesting the degree of Human Factors expertise required in an aviation organisation and the sources of this expertise. Courses are currently available to meet all of these requirements.

Can and Will do

We have for long been able to demonstrate the capability of the pilot, in terms of flying skill, in supervised and highly structured proficiency checks. We are demonstrating, that is, what he ***CAN*** do. We can even asses to some extent leadership and teamwork capability through Line-Oriented-Flight Training where a crew as a team faces a simulated routine flight.

What we have demonstrably failed to do, is to predict what a pilot ***WILL*** do when he is on a normal, unsupervised line flight. It seems probable that most pilots killed in a human error aircraft accident -- if they had been able to return for a test -- would have passed a conventional proficiency check at the time of the crash.

Some progress has been made, with union agreement, for the use of flight data recorders in analysing adherence to a specific operating envelope. Acceptance of this procedure is not universal. This progress was reviewed in the Flight Safety Foundation Workshop in Taiwan in March 1989. However, this technique gives little information about non-technical performance of the crew. It may demonstrate WHAT was done but gives little clue as to HOW or WHY it was done and may not reveal potentially hazardous behaviour. Investigators are sometimes surprised at the scale of violation of standard operating procedures, lack of leadership and inadequate crew cooperation revealed by the Cockpit Voice Recorder. In most countries, the curtain over this window on cockpit performance in the real world of routine flying can only be pulled aside after an accident or serious incident. This remains an important challenge in the search for improved flight safety.

Bridging the Gap

Professor Hywell Murrell who coined the word "ergonomics" about 40 years ago, later wrote that the lift (or the elevator) between the ivory tower of academia and the shop floor appears to have got stuck halfway.

If we are to make adequate progress in the future it is essential that we have enough properly qualified lift attendants available to keep the lift moving -- up as well as down. We need not only to ensure a flow of research information to the airlines, but we also need to ensure that the real problems facing the airlines are being properly addressed in centres of research.

Few of the world's airlines have even a single such figure, possessing skills of flight deck operations combined with formal qualifications and expertise in Human Factors. And few airline managements feel inclined to stimulate the development of such creatures or give them adequate responsibility even when they do exist.

But there is light on the horizon. The 1980s have seen the introduction of Human Factors expertise into such influential bodies as the FAA and NTSB. In Australia, the government Bureau of Air Safety Investigation has for many years benefited from such expertise -- it is perhaps no coincidence that Australia is consistently around the top of the air safety league. ICAO has finally and tentatively made a move in the right direction in pilot licensing. This also recognises that in today's world of air transport, knowledge and skill requirements must be made mandatory to be universally applied.

Yet many other bodies display resistance to enlightened progress. Too many lives have been lost unnecessarily as a result of inadequate application of the technology of Human Factors in civil aviation. Too often we are seeing the same human performance and behaviour deficiency cards simply reshuffled and dealt out again in a somewhat different sequence for the next accident. It is the task of delegates to seminars such as this to tackle boldly and effectively, nationally and internationally, the type of challenges outlined in this short address.

--ooOoo--

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УЧЕТ ЧЕЛОВЕЧЕСКОГО ФАКТОРА В ПРОЦЕССЕ ИССЛЕДОВАНИЙ ПЕРСПЕКТИВНЫХ СИСТЕМ УПРАВЛЕНИЯ (СССР, ЛЕТНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ)

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Уровень безопасности полета и качество пилотирования самолета в значительной степени определяются характеристиками тех систем, которые образуют контур управления и с которыми непосредственно взаимодействует летчик. Поэтому учет человеческого фактора (ЧФ), т.е. всех особенностей взаимодействия летчика с этими системами, необходим на всех стадиях их создания. При этом наиболее объективная оценка степени учета ЧФ может быть дана в летных исследованиях. В число таких систем, непосредственно взаимодействующих с летчиком , входят система индикации пилотажно-навигационных параметров, рычаги управления и система управления, точнее законы управления, непосредственно определяющие динамику современного самолета. Быстрое совершенствование бортового оборудования привело к внедрению в гражданской авиации цветных электронных дисплеев для отображения пилотажно-навигационной информации (ПНИ,), боковых ручек управления и мини-штурвалов. Сложные цифровые законы управления придали принципиально новые качества характеристикам управляемости самолета, обеспечили автоматизацию ряда функций управления и возможность гибкого сочетания ручного и автоматического управления (рис.I). Все эти средства позволяют полнее учитывать ЧФ в процессе пилотирования, однако требуют тщательных исследований с целью исключения возможных отрицательных факторов, которые могут проявиться в условиях реального полета. Требуется комплексная оценка таких показателей как точность пилотирования, загруженность летчика, его утомляемость, степень адаптации и т.п., в том числе с учетом возможного разброса характеристик самого летчика как в нормальном полете, так и в отказных ситуациях.

Опыт Летно-исследовательского института (ЛИИ) показал, что эффективным инструментом решения такой задачи является летающая лаборатория (ЛЛ) с возможностью гибкого и оперативного изменения характеристик управления и динамики самолета в полете с целью непосредственного сравнения различных вариантов характеристик и выбора оптимального их сочетания. Подобная ЛЛ была создана в ЛИИ на базе среднего магистрального самолета Ту-I54М. ЛЛ оборудована оперативно репрограммируемой в полете цифровой ЭВМ управления рулями и двигателями, позволяющей моделировать в полете законы управления любой сложности и имитировать динамику опытных самолетов. Кроме того установлена аппаратура передачи и приема телеметрической информации, обеспечивающая управление ЛЛ с помощью наземной ЭВМ по тракту "борт-земля-борт", рис.2. Место левого летчика-экспериментальное (рис.3). Пилотирование осуществляется от боковых ручек управления (правой или левой) или центрального мини-штурвала. Характеристики загрузки-изменяемые. На приборной доске левого летчика установлен имитатор цветного электронного пилотажно-навигационного дисплея. Графическая информация для него синтезируется в бортовой ЭВМ в реальном времени полета на основе полетной информации. Программное обеспечение позволяет представлять летчику в полете практически неограниченное число форматов ПНИ для непосредственного сравнения, либо корректировать их в полете с целью определения оптимального варианта. Правое место (командир экипажа) обеспечивает страховку в полете с помощью штатной механической системы управления. Такая организация ЛЛ позволяет проводить комплексные исследования перспективных систем и динамики гражданских самолетов (рис.4). Остановимся на некоторых результатах исследований.

Несмотря на положительные результаты проведенных в предшествующие годы в ЛИИ исследований БРУ, а также опыт эксплуатации самолета А-320, мы считали необходимым провести на ЛЛ дополнительно исследования БРУ в комплексе с цифровой высокоавтоматизированной системой управления для подтверждения высокой степени надежности и качества пилотирования при использовании такой ручки.

Результат здесь непосредственно определяется степенью учета ЧФ за счет выбора оптимального соотношения параметров рычага управления, пилотажных характеристик самолета и характеристик летчика. Основными вопросами здесь были:

- влияние типа и расположения БРУ на процесс управления;
- оптимальные характеристики "усилия-перемещения" БРУ;
- загруженность летчика, в том числе при длительных полетах;
- степень адаптации летчиков к БРУ.

Особый интерес, учитывая различный класс летчиков, представляла оценка возможности пилотирования самолета левой рукой, как в штатных, так и в нештатных ситуациях (при концепции компоновки кабины, предусматривающей левое расположение БРУ у левого летчика).

С целью получения объективной оценки к летным исследованиям БРУ привлекалось 30 летчиков-испытателей различных фирм, летного стажа, класса и возраста. В полетах принимала участие и группа летчиков-испытателей, имеющих большой опыт испытаний маневренных самолетов. Исследования проводились в различных погодных условиях на всех режимах полета, включая заход на посадку по позиционным и директорным приборам, а также посадку.

Исследования БРУ различных форм выявили на основе оценки подавляющим большинством летчиков преимущество ручки, представленной на фиг.5. По объективным данным и оценкам летчиков целесообразно управление от БРУ в каналах тангажа и крена; подключение дополнительно канала рыскания нарушает привычный стереотип управления и затрудняет реакцию летчика в нештатных ситуациях.

В процессе полетов определялась оптимальная область расположения БРУ в кабине. В результате осреднения оценок летчиков с различными антропометрическими данными было признано целесообразным расположение основание БРУ на подлокотнике кресла с обязательной индивидуальной регулировкой положения ручки по высоте и вдоль подлокотника.

Принципиальным является вопрос о степени подвижности БРУ и ее соответствия диапазону управляющих усилий. Для БРУ выбранной формы оптимальные значения характеристик загрузки в основной области режимов полета составляют в продольном канале 0,9+I,I кг/см и поперечном канале 0,7+0,9 кг/см. В процессе летных исследований эти результаты были подтверждены практически всеми летчиками. Интересно отметить, что отдельные летчики из группы летчиков-истребителей давали одинаковые летные оценки при уменьшении диапазона перемещений БРУ от указанных значений до нуля (управление "по усилиям").

Выполненные на ЛЛ полеты с левым расположением БРУ показали, что несмотря на существовавшие до полетов опасения и скептическое отношение части летчиков к такому варианту БРУ и в этом случае обеспечивается уверенное и эффективное пилотирование самолета на всех режимах, включая заход на посадку и посадку.

Следует отметить быструю адаптацию к управлению самолетом с помощью БРУ, мало зависящую от класса и летного стажа летчика. Как правило, I-I, 5-часового полета и 3-4 заходов на посадку было достаточно для приобретения уверенных навыков пилотирования самолета с БРУ в штатных ситуациях.

В целом выбранные в процессе летных исследований оптимальные параметры загрузки и перемещений БРУ обеспечили легкое комфортное управление самолетом. Выполненные при управлении самолетом от БРУ достаточно длительные полеты (продолжительность 3-4 ч) показали, что даже в условиях, соответствующих случаю отказа системы автоматического управления, пилотирование самолета, по оценкам летчиков, вызывает существенно меньшую утомляемость, чем со штурвалом.

Преимущества мини-рычагов управления, и в частности БРУ, проявляются в еще большей степени при их комплексировании с высокоавтоматизированной системой управления. Существенно возросший уровень бортового оборудования с включением в его состав цифровых ЭВМ позволяет реализовать концепции управления пассажирским самолетом, предусматривающие гибкое разделение функций ручного и автоматического управления с целью максимального учета человеческого фактора. Концепции, предлагаемые для нового поколения опытных неманевренных самолетов, прошли апробацию и соответствующую оценку летчиками на ЛЛ Ту-I54М В частности, исследовался цифровой интегральный закон управления. Он обеспечивает необходимое качество управления при минимальной загруженности летчика. При этом реализовывалась концепция так называемого "безопасного" пилотирования, означающая невозможность даже преднамеренного вывода самолета на предельные режимы полета (за счет алгоритмического ограничения соответствующих полетных параметров) или же выработку надежных признаков приближения к предельным режимам для сигнализации экипажу (рис.6). Опыт проведенных на ЛЛ исследований показал, что летным составом положительно оцениваются особенности предложенной схемы системы управления.

Особый интерес и сомнения вызывала приемлемость рассматриваемого закона на режимах разгона и торможения самолета, где этим законом обеспечивается практически нейтральность рычага управления по скорости (его положение в этом случае уже не является для летчика дополнительным индикатором о величине текущей скорости полета). Однако все летчики однозначно положительно оценили это качество отметив заметное упрощение пилотирования самолета при изменении скорости и отсутствие необходимости триммирования рычага управления.

Испытания показали, что реализованные свойства автоматического ограничения больших углов атаки, крена и скорости полета в совокупности с "естественными" динамическими признаками их достижения (а также дополнительные усилия на рычаге управления и соответствующая сигнализация в кабине самолета) являются надежными средствами ограничения (рис.7). Они не нарушают привычного стереотипа пилотирования самолета и естественным образом воспринимаются экипажем. По отзывам летчиков, принимавших участие в полетах на ЛЛ Ту-154М, исследованные законы управления упрощают пилотирование, позволяют экипажу чувствовать себя психологически более уверенно и большее внимание уделять оценке состояния систем самолета и наблюдениям за внекабинным пространством, что повышает безопасность пилотирования, особенно при маневрировании в зоне аэродрома.

Наиболее ответственным этапом полета является заход на посадку. Поэтому он подвергался наиболее тщательным исследованиям, включая оценку как штатных ситуаций, так и нештатных. При этом имитировались заходы на посадку в различных условиях видимости, а также в условиях возможных боковых и вертикальных отклонений от начальной точки входа в глиссаду, связанных с ошибками экипажа.

Как показали летные исследования, эффективным средством разгрузки экипажа при одновременном повышении точности пилотирования является использование системы управления в режиме так называемого совмещенного управления. При этом в системе устанавливаются пороговые значения управляющих сигналов, при превышении которых летчиком система управления работает в режиме ручного пилотирования. В противном случае система работает в режиме автоматической стабилизации заданных параметров. Результаты анализа объективных данных (рис.8) и отзывы всех летчиков свидетельствуют об их существенной психофизиологической разгрузке: реже происходит вмешательство в управление, большее внимание уделяется контролю траекторного положения самолета, работы оборудования и т.д. В то же время заметно возрастает точность пилотирования. По оценке летчиков режим совмещенного управления должен быть основным режимом работы системы управления пассажирских самолетов

Современная концепция предполагает представление летчику всей пилотажно-навигационной информации в интегральном виде на цветных электронных дисплеях. При этом задача состоит не в "механическом" объединении необходимых параметров в определенной части приборной доски, а в определении оптимальной формы графического представления, взаимной увязки и логики работы параметров, обеспечивающих информированность (а значит и эффективность) работы экипажа при его минимальной психофизиологической загруженности.

Наиболее сложной и динамичной, связанной с определенным сложившимся стереотипом восприятия информации и методами пилотирования с ее использованием, является пилотажная индикация. Объективная ее оценка требует помимо оценки качества пилотирования, количественной оценки загруженности летчика на основе точных медико-биологических и психо-физиологических показателей.

Поэтому в процессе летных исследований на ЛЛ используется комплекс эргономической аппаратуры. Тем не менее в условиях влияния на оценку летчика большого числа противоречивых полетных факторов для многих элементов графического представления пилотажной информации выявить их прямую количественную связь со степенью загруженности летчика не удается и различные альтернативные варианты оказываются вроде бы равноценными. Поэтому для выбора оптимального варианта здесь необходимо участие, опыт и взаимное сопоставление оценок различных вариантов индикации большим числом летчиков.

Концепция рассмотренных перспективных законов управления предполагает решение летчиком главным образом задачи траекторного управления и навигации; задачи стабилизации заданных параметров, ограничения их максимально допустимых значений и т.п. решаются автоматикой. Эта концепция должна отражаться и в логике представления ПНИ на дисплее летчику и базируется на использовании в первую очередь информации о величине и направлении вектора путевой скорости самолета (рис.9). Экспериментальные исследования показывают, что использование этого принципа позволяет обеспечить посадку самолета в условиях метеоминимума 0 х 0 м и повысить вероятность безопасного парирования отказов, особенно на посадке.

Проведенные исследования показали, что идеология, структура и параметры всех систем, образующих контур управления, непосредственно зависят от ЧФ и требуют обязательного его учета. Летные исследования являются обязательным этапом при отработке новых концепций, связанных с ЧФ . Наиболее гибким инструментом для таких исследований является специально созданная ЛЛ, позволяющая выявить положительные и отрицательные стороны ЧФ в условиях реального полета.

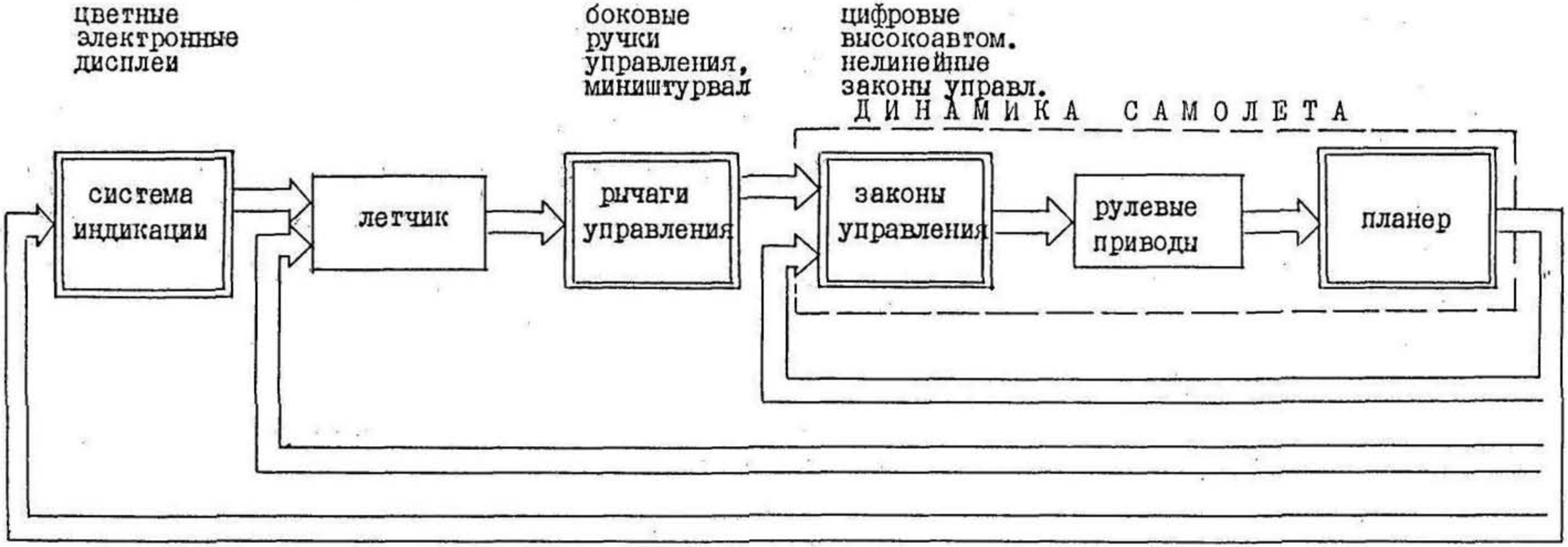

Рис. I Основные элементы контура штурвального управления самолетом.

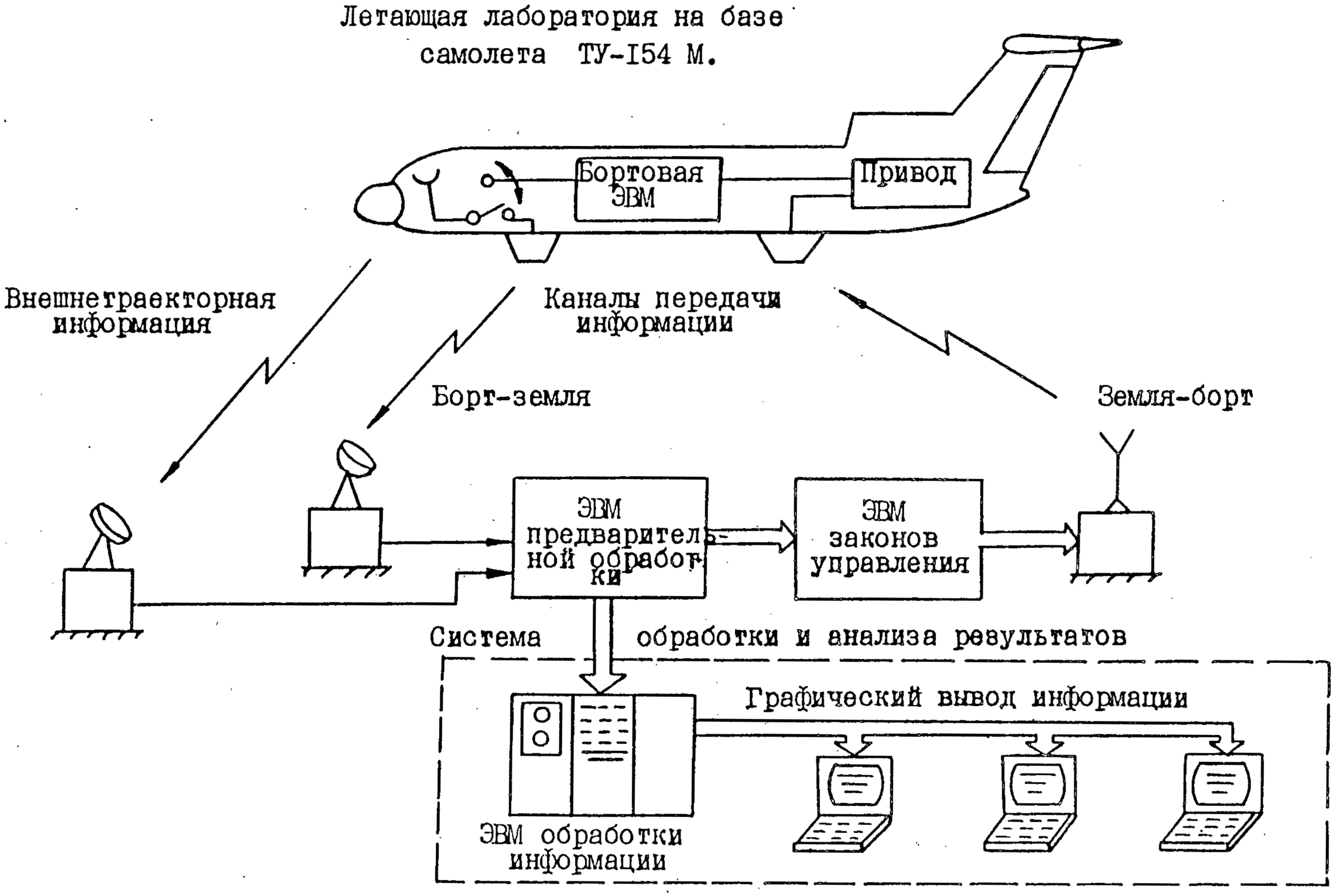

Рис. 2 Структурная схема взаимодействия ЛЛ и наземного комплекса.

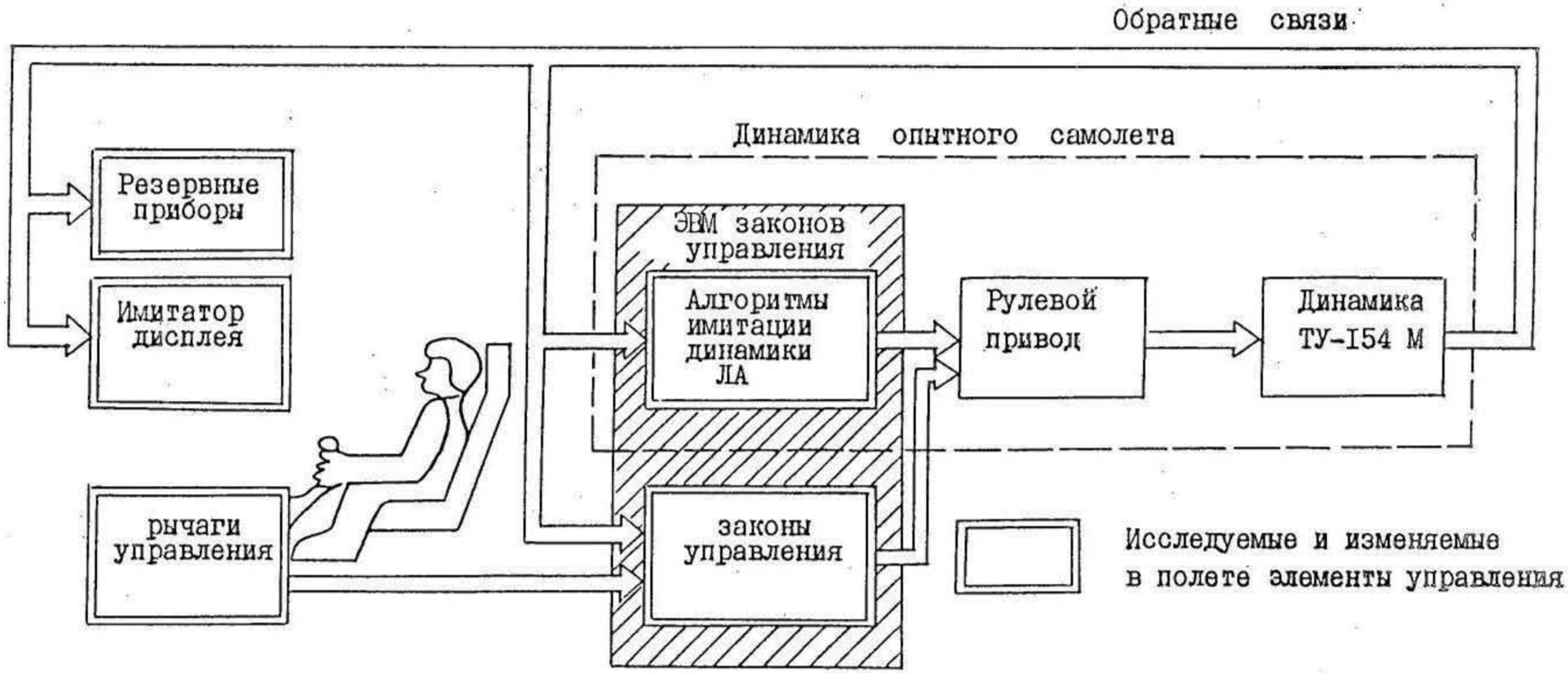

Рис. 4 Блок-схема имитации на ЛЛ динамики опытного ЛА и перспективных систем управления.

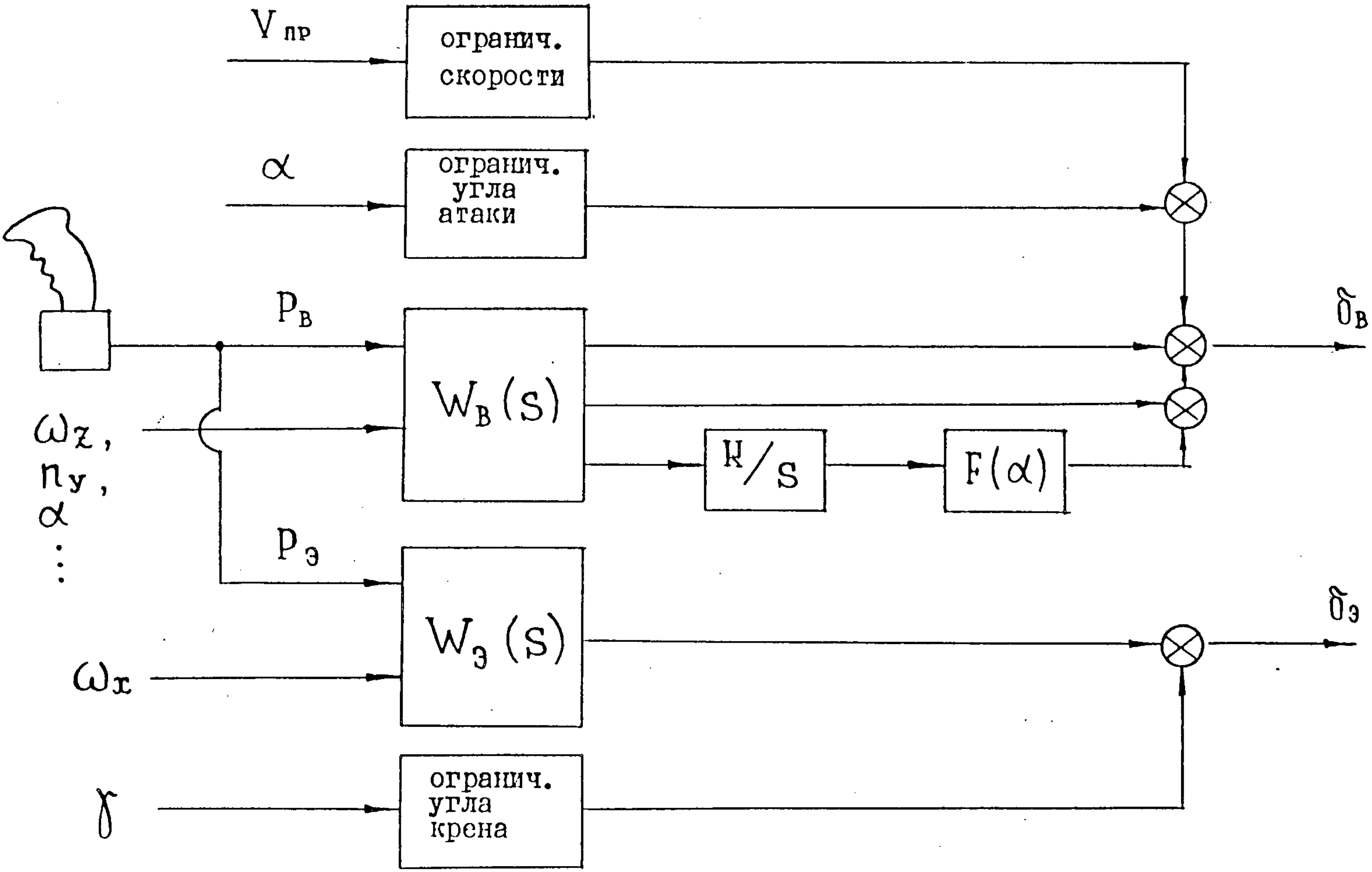

Рис. 6 Структурная схема системы управления ЛЛ.

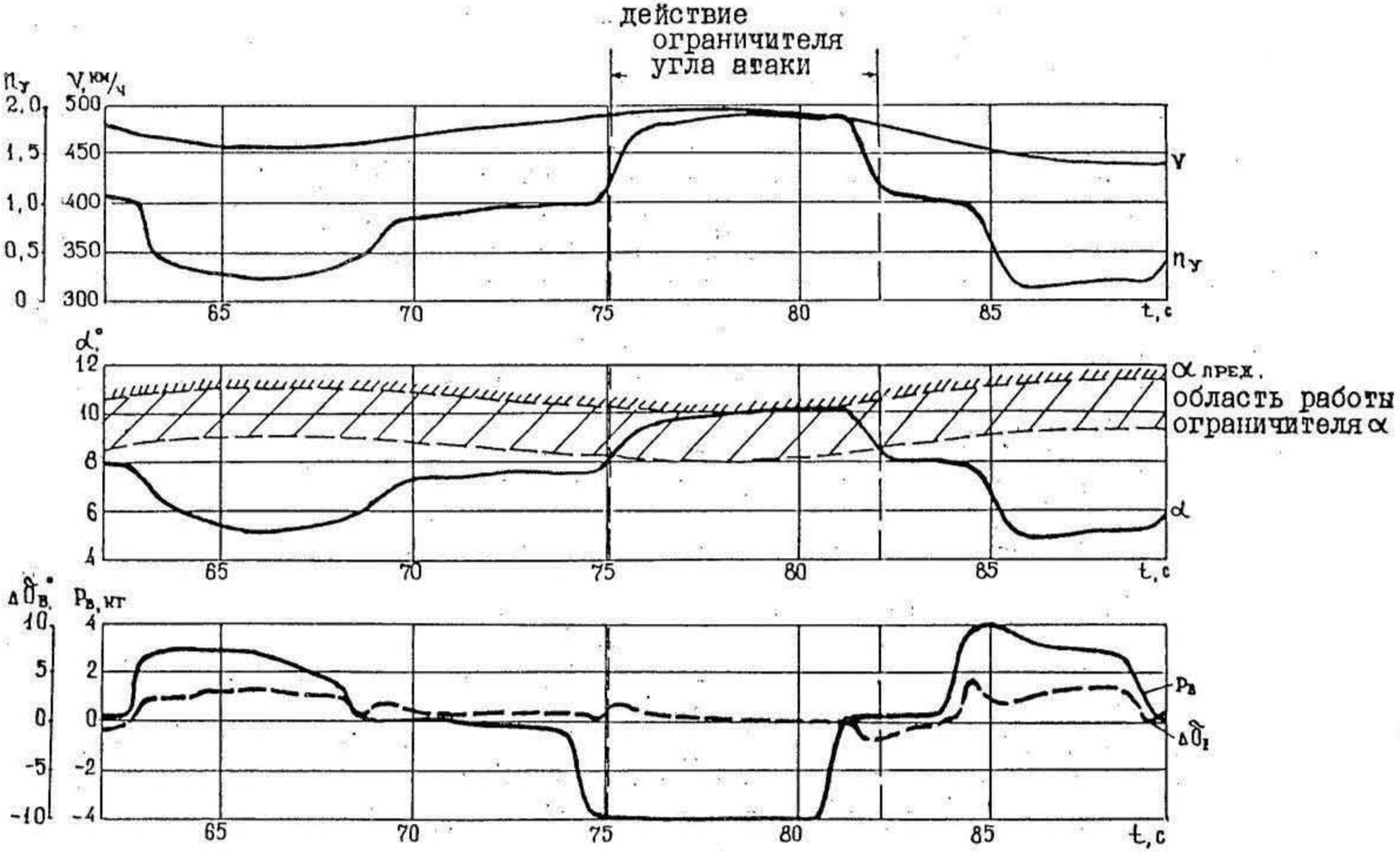

Рис. 7а Иллюстрация действия алгоритмического ограничителя угла атаки.

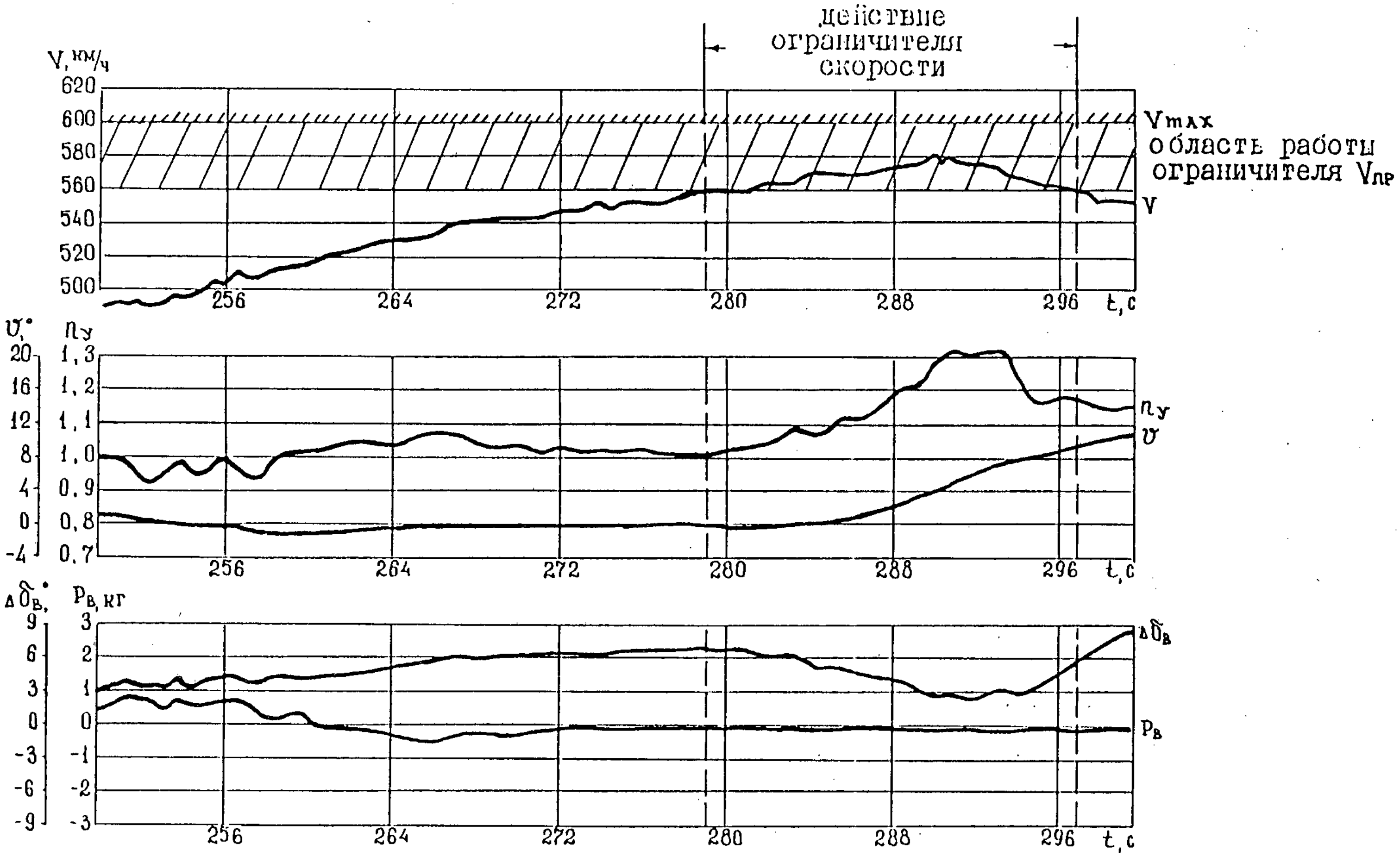

Рис. 76 Иллюстрация действия алгоритмического ограничителя скорости полета.

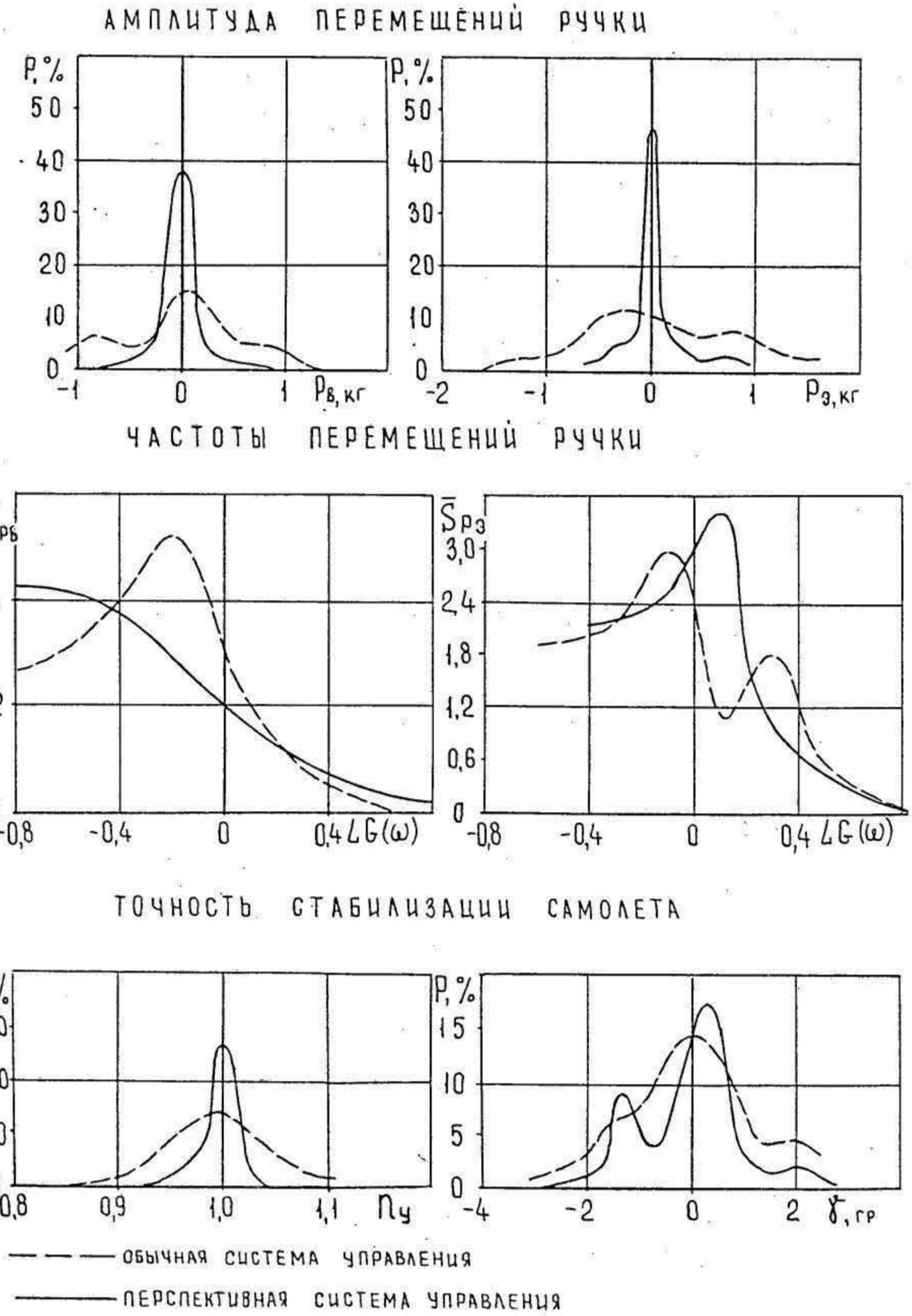

Рис. 8 Статистические оценки пилотирования, полученные из режимов захода на посадку.

Критерии оценки учета человеческого фактора в процессах управления самолетом.

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> Теория всегда осторожна,
> потому что практика
> неумолима.

Горькая статистика ошибочных действий членов экипажей ОДЭ гражданской авиации показывает ,что она определяет в настоящее время общую картину безопасности полетов.(Сл I).
Минимум каждая 4-ая катастрофа, каждые 2-а из 3-х авиационных происшествий и каждая 10-ая предпосылка к ним совершаются в результате ошибочных действий экипажа.Установить реальную причину, формирующую ОДЭ исключительно трудно. Сегодня -это скорее искусство расследователей,чем ремесло.Объясняется это прежде всего отсутствием реально записанных характеристик деятельности и состояния членов экипажа,возможности сравнить их с нормированными, профессионально -необходимыми. Вот почему до настоящего времени мы не можем с необходимой точностью определить даже область формирования причин ОДЭ.Что является первопричиной ОДЭ: некачественный отбор, плохое обучение экипажей, подготовка и организация полетов, или низкий уровень эргономичности кабин самолетов?

Это первая проблема ,решение которой необходимо для повышения безопасности полетов, и решать ее необходимо через учет ЧФ на всех перечисленных этапах. Структурно это выглядит следующим образом (сл.2). На основании формулировки понятия ЧФ, принятой исследовательской группой ИКАО, определяется конкретный вид базовых (профессионально- необходимых),индивидуальных и предельно-возможных характеристик деятельности и состояния экипажа. Обеспечивается регистрация и сравнение индивидуальных характеристик в любой момент времени с нормированными. В случае ОДЭ несоответствие индивидуальных характеристик базовым однозначно определяет область формирования ОДЭ, в плохом отборе, обучении или организации летной работы. Если ОДЭ сопровождались незначительным отклонением или превышением индивидуальных характеристик относительно базовых - это основной признак низкой эргономичности рабочего места экипажа. Приведу пример (сл.3). Для различной последовательности размещения сигнализаторов о пожаре в силовых установках (вариант №1; и №2) экспериментально определялась последовательность и время операций по выключению " горящей " силовой установки. При одинаковых (близких к предельным) характеристикам деятельности по времени одних и тех же пилотов, ошибочных действий в варианте -2 по определению номера горящего двигателя было намного больше.Это определялось эргономическим несовершенством компановки сигнализаторов, установкой слева индикатора вспомогательной силовой установки,используемой редко. Был не учтен ЧФ, связанный с тем,что мы начиная отсчет слева направо считаем с единицы ,а не с нуля. Как же исключить проявление этих досадных эргономических ошибок,как учесть ЧФ на самых ранних этапах формирования эргономического облика кабины самолета? Возможным путям решения этой второй проблемы мне и хотелось бы посвятить основную часть моего доклада.

Детальный анализ ОДЭ показывает,что более 50% всех авиационных происшествий связаны с выходом за эксплуатационные ограничения, установленные в руководстве по летной эксплуатации (сл.4). Соотнести текущие и граничные значения контролируемых в эксплуатации параметров можно только в приборном полете.

Это однозначно определяет влияние на формирование ошибочных действий экипажа эргономических характеристик приборной информации . Вот почему снизить процент ОДЭ только за счет внедрения новых методов и средств подготовки, обучения и отбора оказывается затруднительным и даже невозможным.

Исторический путь развития авиации привел нас от полетов, когда единственным прибором пилота были очки, к полетам с сотнями приборов и параметров (сл.5) .

На вопрос и в каком виде она должна быть представлена, сможет ли пилот надежно воспринимать всю эту информацию,до сих пор отвечали и отвечают сами пилоты, используя свой личный опыт и интуицию. Поэтому вопрос определения количества и качества предъявляемой членам экипажа информации решается на этапах летных испытаний на уже готовых образцах техники.На этом заключительном этапе ,в условиях жесткого прессинга изготовителей, не заинтересованных в изменении уже готовых образцов,редко удается получить оптимальные результаты.

При этом отрицательную роль оказывает различный характер мотивации каждого эксперта, их принадлежность к различным организациям.

Вот почему возможность теоретического учета человеческого фактора в эргономических решениях кабин на самых ранних этапах создания авиационной техники крайне необходима.

Учитывая,что в эргатических системах ,с одной стороны имеется человек, с легкодоступными и широкоиспользуемыми в психологии методами его изучения (наблюдение, эксперимент, беседа), а с другой стороны - техника, в основном с расчетными методами ее изучения, целесообразно за методологическую основу исследования эргатических систем принять расчетно- экспериментальный метод. Суть метода может быть изображена структурно(сл.6) .
Получая через приборы информацию о состоянии самолета ,Пилот работает , как Регулятор,обеспечивающий по условиям безопасности полета нахождение летательного аппарата в заданных эксплуатационных ограничениях по всем параметрам полета и самолетных систем
$/ P_i(t) / < M_i$

где $P_i(t)$ - переходные процессы самолета и его систем.
$M_i = Const$ - постоянные или функциональные эксплуатационные ограничения
$M_i = \mathcal{F}(t)$

Таким образом для процесса пилотирования эргатическая система может быть представлена в виде традиционной структуры:
Объект управления в виде Самолета и Регулятор ,роль которого исполняет Пилот.

В соответствии с теорией автоматического регулирования законы работы Регулятора должны формироваться на основе динамических характеристик Объекта управления с учетом заданного характера ограничений.

Используя данную аксиому ,можно утверждать,что Приборы являются элементами ,отражающими динамику Объекта в виде Переходных процессов по контролируемым параметрам.

В реальном режиме управления самолетом Пилот компенсирует возмущения $F(\omega)$ управлением $И(\omega)$ за счет получения с Прибора информации $P(\omega)$ во всем допустимом спектре частот $\underline{\omega}$.

Учитывая практическую необходимость оставаться в пределах заданных ограничений , Пилоту необходимо подавить только ту часть гармоник $F(\omega)$, которые без подавления их могут привести к выходу самолета за эксплуатационные ограничения.

Таким образом теоретически существует минимальная частота $f_{инф}$ в спектре возмущений $F(\omega)$, подавление которой и всех частот ниже ее исключает неконтролируемый выход летательного аппарата за пределы эксплуатационных ограничений. Эта частота называется информативной для пилота частотой ,поскольку наблюдать процессы с большей частотой нет необходимости (сл.7).

При этом минимально - необходимым условием формирования своевременных управляющих действий ,исключающих неконтролируемый выход Л.А. за установленные ограничения ,является наличие хотя бы одного зрительного обращения к контролируемому процессу на каждом из полупериодов, и,если контролируемый процесс характеризуется частотой $f_{инф}$, то минимально- необходимая частота зрительных обращений пилота $m \geqslant 2f_{инф}$.

Следовательно, период между обращениями ,допускающий максимально - возможное время отсутствия фиксаций взгляда на контролируемый процесс $Тоф^{max} \leq \frac{I}{2f_{инф}}$.

Произведение необходимой частоты зрительных обращений Пилота "m" на время фиксаций взгляда Тф в безразмерном виде будет представлять собой загрузку Пилота λ

$$\lambda = 2f_i \cdot Тфт_i \leq I.$$

Предполагая для кабин самолетов с электромеханическими Приборами ,что Пилот собирает информацию последовательно перемещая взгляд с обного Прибора на другой ,получим:

$$m \geqslant 2\sum f_u \; ; \quad Тоф^{max} \leq \frac{I}{2\sum f_u}; \qquad \lambda = Тф \cdot 2\sum f_u .$$

где $\sum f_u = f_I + f_2 + \dots + f_n$ где n - количество Приборов.

Наличие теоретической зависимости То ф ^{max} предполагает возвращение взляда *к любому* Прибору через *определенное время* т.е. предполагает Цикличность зрительных обращений.

Результаты экспериментальных исследований с использованием специальной аппаратуры (сл.8), которой было зарегистрировано более 50 тыс. фиксаций взгляда у I7 экипажей в реальных полетах на самолетах ТУ-I54,ЯК-42 и на тренажере ИЛ-86 показали высокий уровень сходимости теоретических расчетов и практических показаний в режиме захода на посадку.

Статистически обработанные маршруты взгляда Пилотов представляют из себя строго циклические маршруты с опорным Командно-Пилотажным Прибором, теоретическое отсутствие времени фиксаций взгляда на котором минимально и составляет Тоф $\leqslant 0{,}8 \div 0{,}9$сек. При этом подавляющее большинство маршрутов 67% соответствуют 2-х приборным маршрутам, трехприборные маршруты занимают 27% ,а более длительные практически отсутствуют. Это объясняется тем,что работа с минимально возможным временем фиксаций Тф$^{min} \approx 0{,}4$сек ограничена и поэтому Пилот за время $0{,}8 \div 0{,}9$сек успевает осмотреть не более 2-х дополнительных Приборов, вот почему 4-х приборные маршруты практически отсутствуют.

Практическое подтверждение теоретических расчетов дает возможность их использования в следующих направлениях: (сл 9)

I.Выбора принципа индикации:

Обеспечить условие Тоф $\leqslant$ Тоф $^{\text{зад.}}$ можно, сконцентрировав все необходимые параметры в центральном поле зрения. Известно,что центральное поле зрения ограничено телесным углом в 10°. Сконцентрировать все параметры в таком ограниченном поле можно только с использованием интегрального индикатора на электронно- лучевой трубке ЭЛТ.

Таким образом развитие электронной индикации имеет и теоретическое обоснование.

2.В направлении компановки параметров на ЭЛТ.

Теоретически определено и практически подтверждено,что вторым Прибором по частоте обращений к нему является вариометр. Зрительных маршрутов с ним наибольшее количество. Вот почему мы стремимся приблизить изображение параметра вертикальной скорости к основному узлу авиагоризонта. Это эргономическое решение отличается от решения , принятого в индикации аэробуса А 320 ,где узел вариометра размещается после узла барометрической высоты, практически на самом краю ЭЛТ. И здесь мы учитываем человеческий фактор через реальные и профессионально - необходимые характеристики зрительного внимания.

3.В направлении минимизации цифровых счетчиков быстроменяющихся параметров.

Исходя из зависимости $m \geqslant 2$ и Тоф $\leqslant \frac{1}{2f}$ интенсивность необходимых зрительных обращений к контролируемому параметру тем выше ,чем выше частота его изменения. Использование цифровых счетчиков требует релейной смены цифр в каждом разряде, что приводит к искусственному повышению частоты смены информации, а следовательно и к повышению интенсивности зрительной деятельности. Поэтому, целесообразно отказаться от цифровых счетчиков , заменив их шкалой и индексом отсчета. Сказанное утверждение в первую очередь относится к параметру скорости, быстроизменяющегося особенно на этапах взлета.

4. В направлении формирования вида индикации.

Параметр скорости характеризует в основном длиннопериодеческие движение ,особенность которого -относительно низкая информативная частота колебаний. Это, с одной стороны, допускает большой перерыв во времени контроля этого параметра и, с другой стороны, требует максимального для однопараметрических приборов времени фиксации взгляда

Объясняется это тем, что шкалы с индексом и с тем более цифровой счетчик не позволяет оценить тенденцию изменения скорости. Это обстоятельство требует дополнительных средств отображения узла по скорости в виде элемента отражающего наличие ускорения (производной скорости).

5.Одним из возможных направлений, использующих теоретические результаты, может быть определение допустимого для одного человека количества контролируемых параметров.

Заменив в теоретической зависимости $Тоф^{max} \leq \frac{I}{2\Sigma f}$, как профессионально необходимой характеристики распределения зрительного внимания, исключающей неконтролируемый выход самолета за пределы эксплуатационных ограничений $Тоф^{max}$ время минимально необходимое для снятия информации $Тф^{min.} \approx 0,4 \div 0,3$ сек. определим максимально возможное количество контролируемых параметров

$$0,4 \leq \frac{I}{2\,(f_1 + f_2 \cdots + \cdots f_n)}$$

где (n + I) количество одновременно контролируемых параметров.

Результаты теоретического расчета показывают, что в директорном режиме захода на посадку количество контролируемых левым Пилотом электромеханических параметров близко к предельному. При этом соблюдаются все теоретические зависимости и самолет не выходит за пределы эксплуатационных ограничений (сл I0).

При вынужденном дополнительном контроле тем же Пилотом параметров силовой установки реальное время То.ф превысило расчетное, что привело к существенному изменению траектории полета. Углы крена и вертикальной скорости при этом вышли за пределы эксплуатационных ограничений.

Таким образом в заключении следует сказать, что учет ЧФ в виде реальных и профессионально - необходимых характеристик распределения зрительного внимания требует уже, сейчас определенных эргономических решений, а в дальнейшем стандартизации этого направления до разработки Стандартов по минимально - необходимым эргономическим характеристикам. И этого не надо бояться .

Подтверждением этому служат положительные примеры деятельности Аэронавигационного Комитета ИКАО в области стандартизации эшелонов и, следовательно, точностных характеристик высотно - скоростного оборудования. Это разработка минимально необходимых требований к аэронавигационному оборудованию и другие примеры, показывающие на эффективный путь повышения безопасности полетов.

Используемая литература:

[I] Столяров Н.А. " Основные составляющие человеческого фактора в летной деятельности".Сборник ИКАО I989г.

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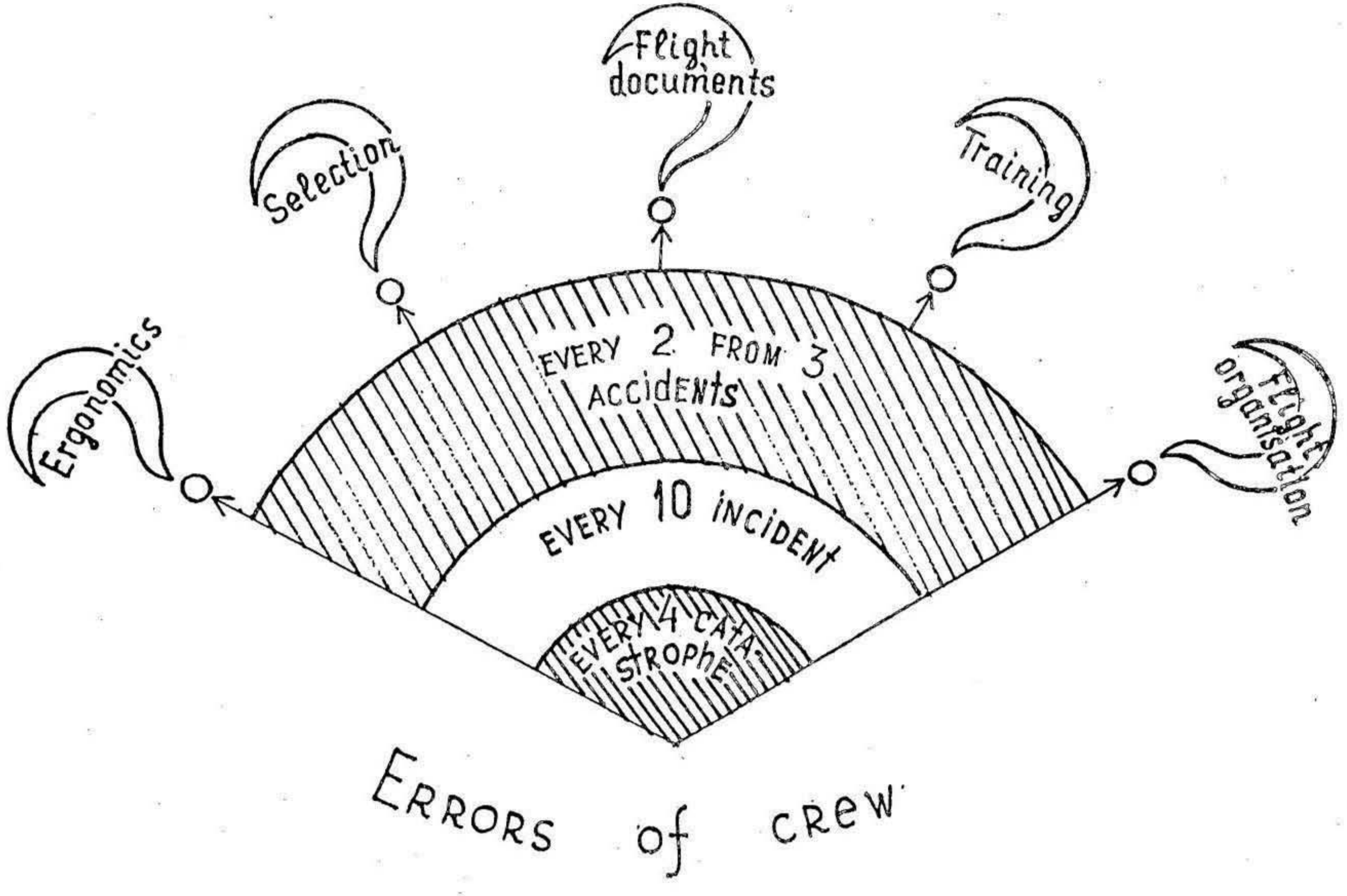
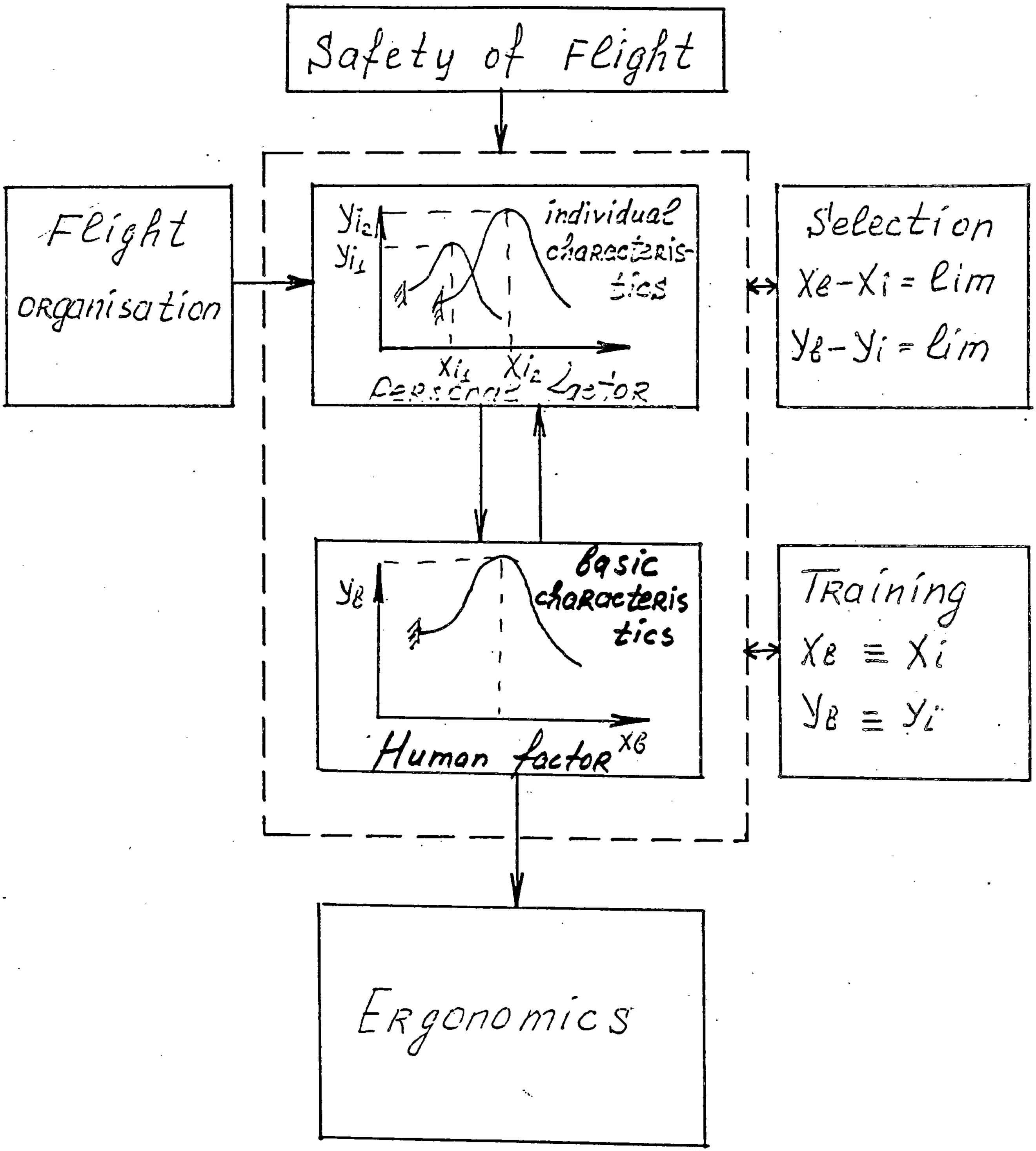
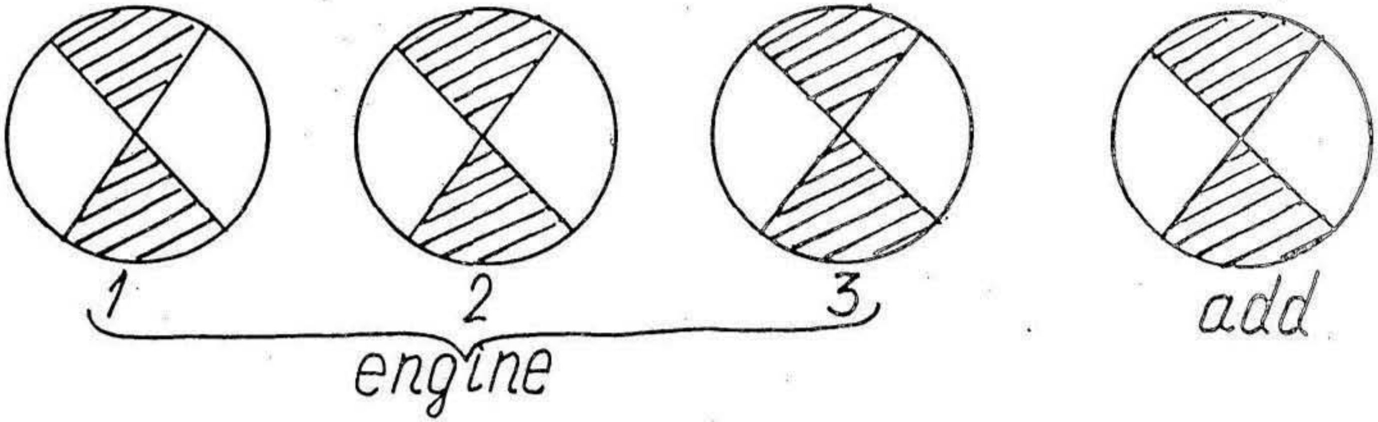

Flight documents
Selection
Training
Ergonomics
Flight organisation
EVERY 2 FROM 3 ACCIDENTS
EVERY 10 INCIDENT
EVERY 4 CATASTROPHE
ERRORS of CREW

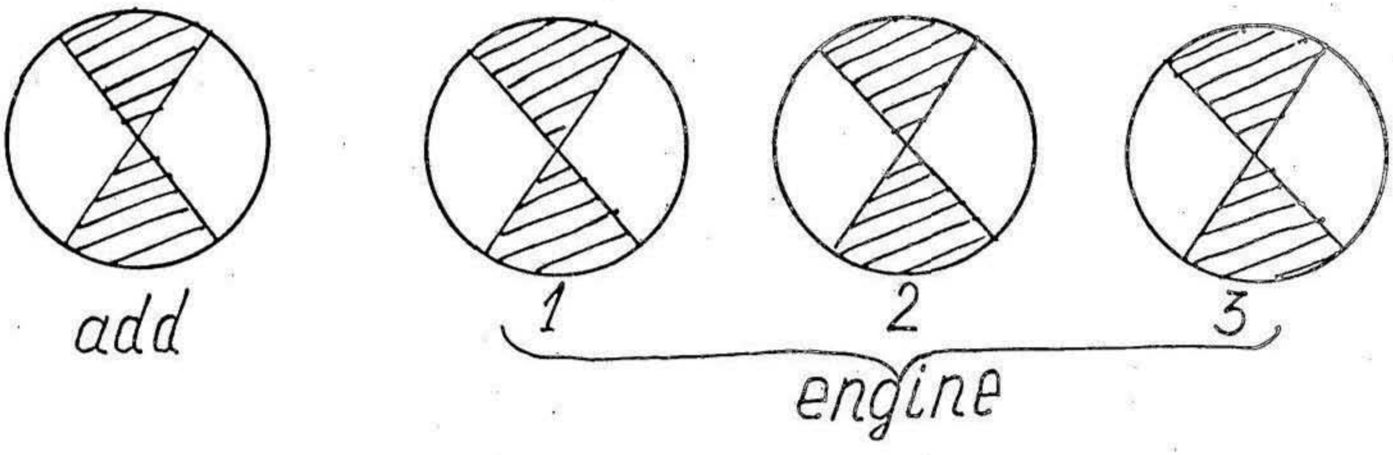

Safety of Flight
Flight organisation
Yi2
Yi1
individual characteristics
Xi1
Xi2
Personal factor
Selection
Xe-Xi = lim
Ye-Yi = lim
YB
basic characteristics
Human factor
XB
Training
XB ≡ Xi
YB ≡ Yi
Ergonomics

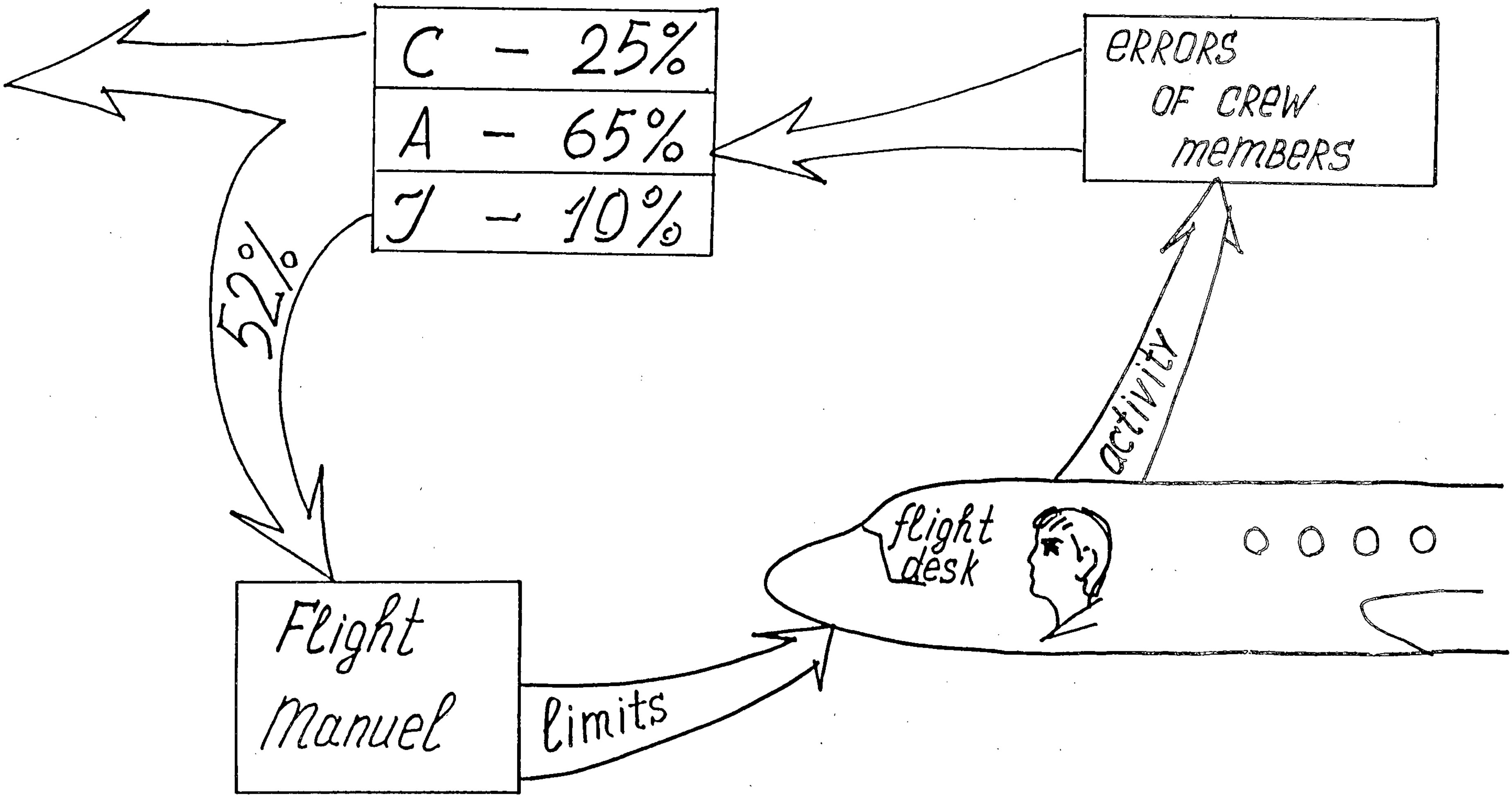
ARRANGMENT OF SIGNALISATION

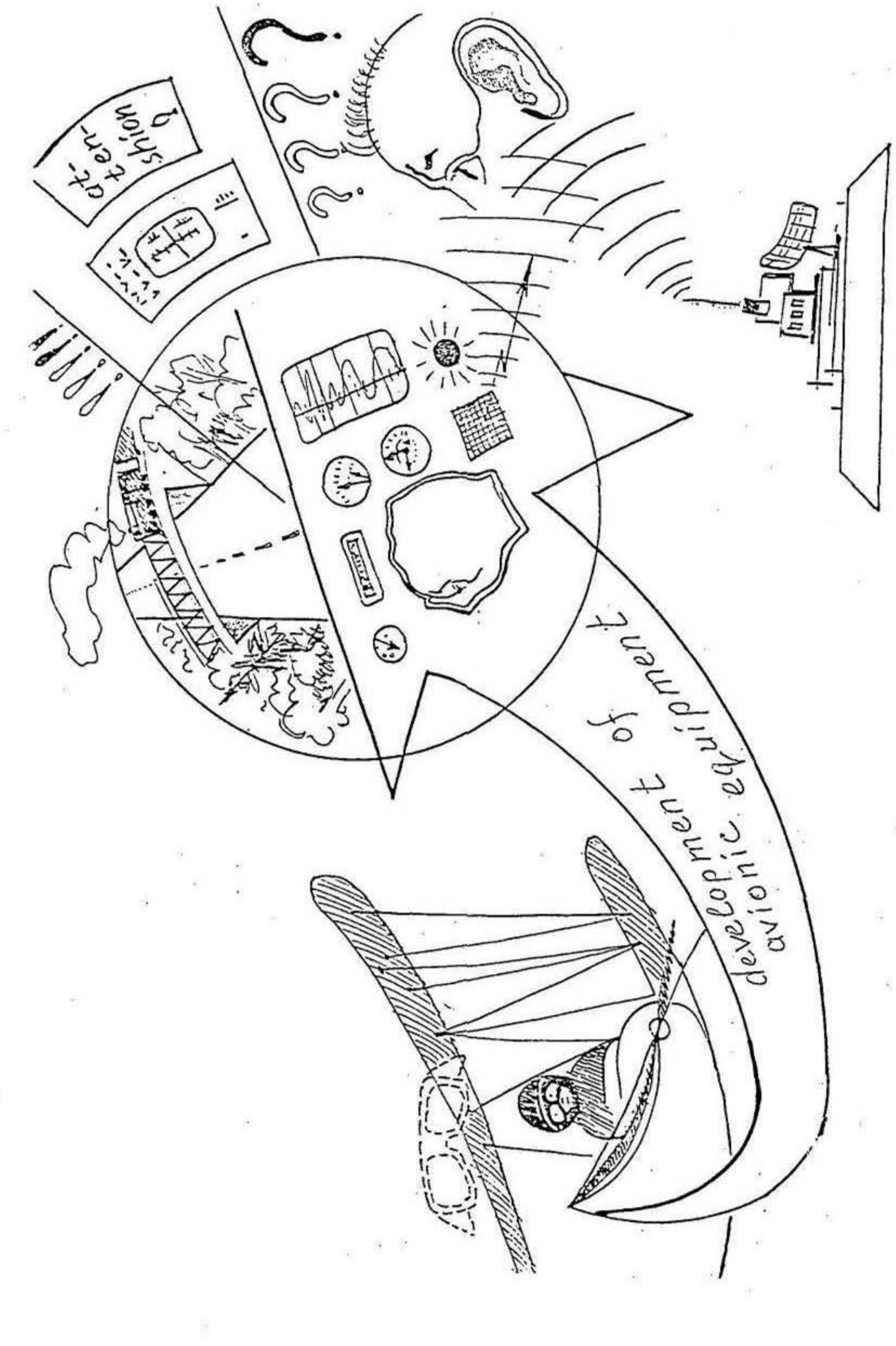
VARIANT 1

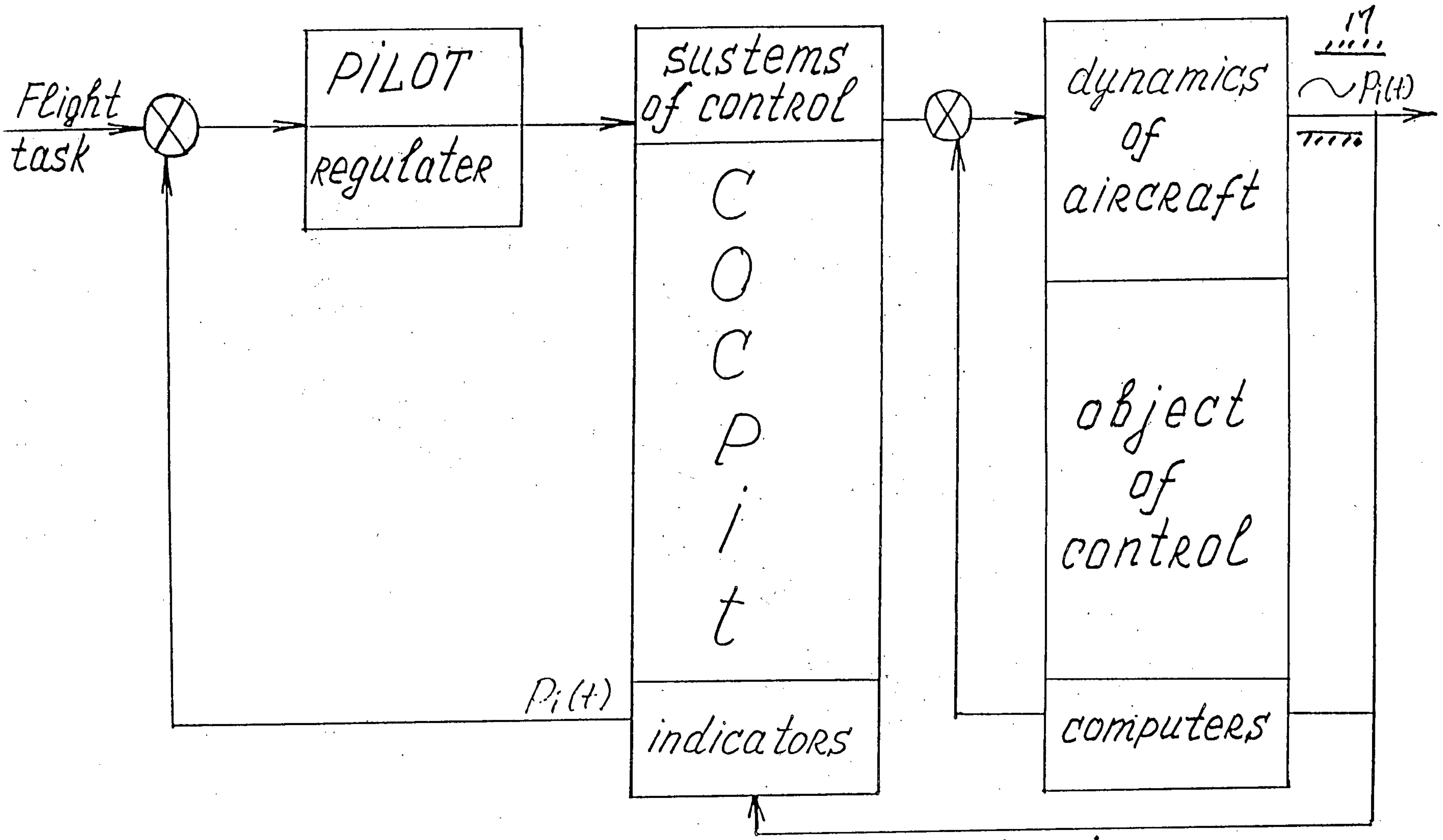


VARIANT 2

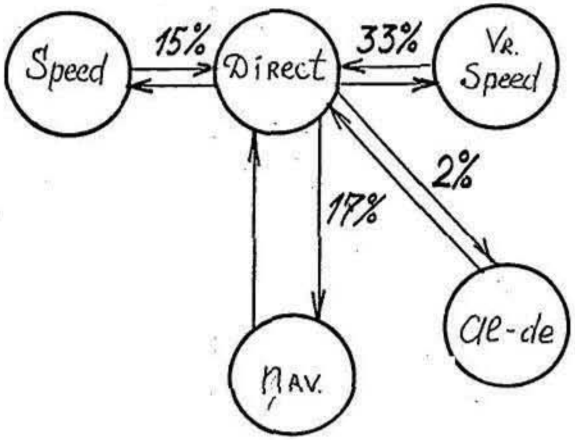


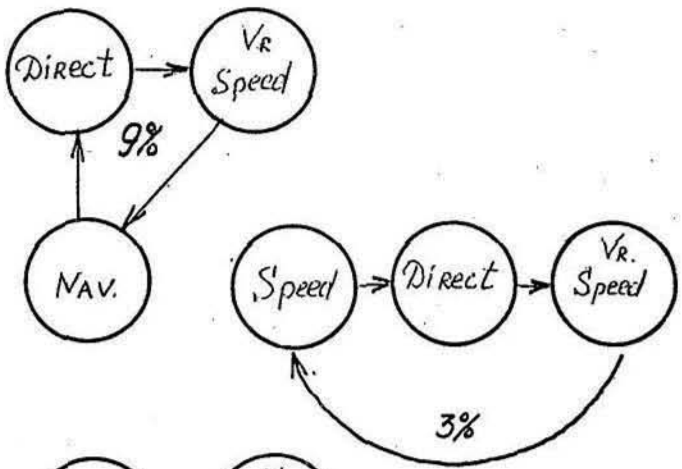

C - 25%
A - 65%
J - 10%
errors of crew members
activity
flight desk
52%
Flight Manuel
limits

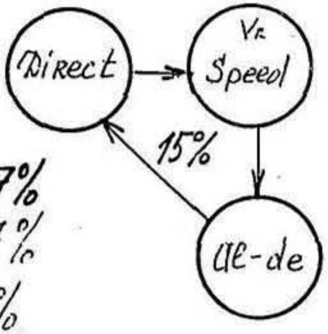

development of
avionic equipment
at-
ten-
shion
?



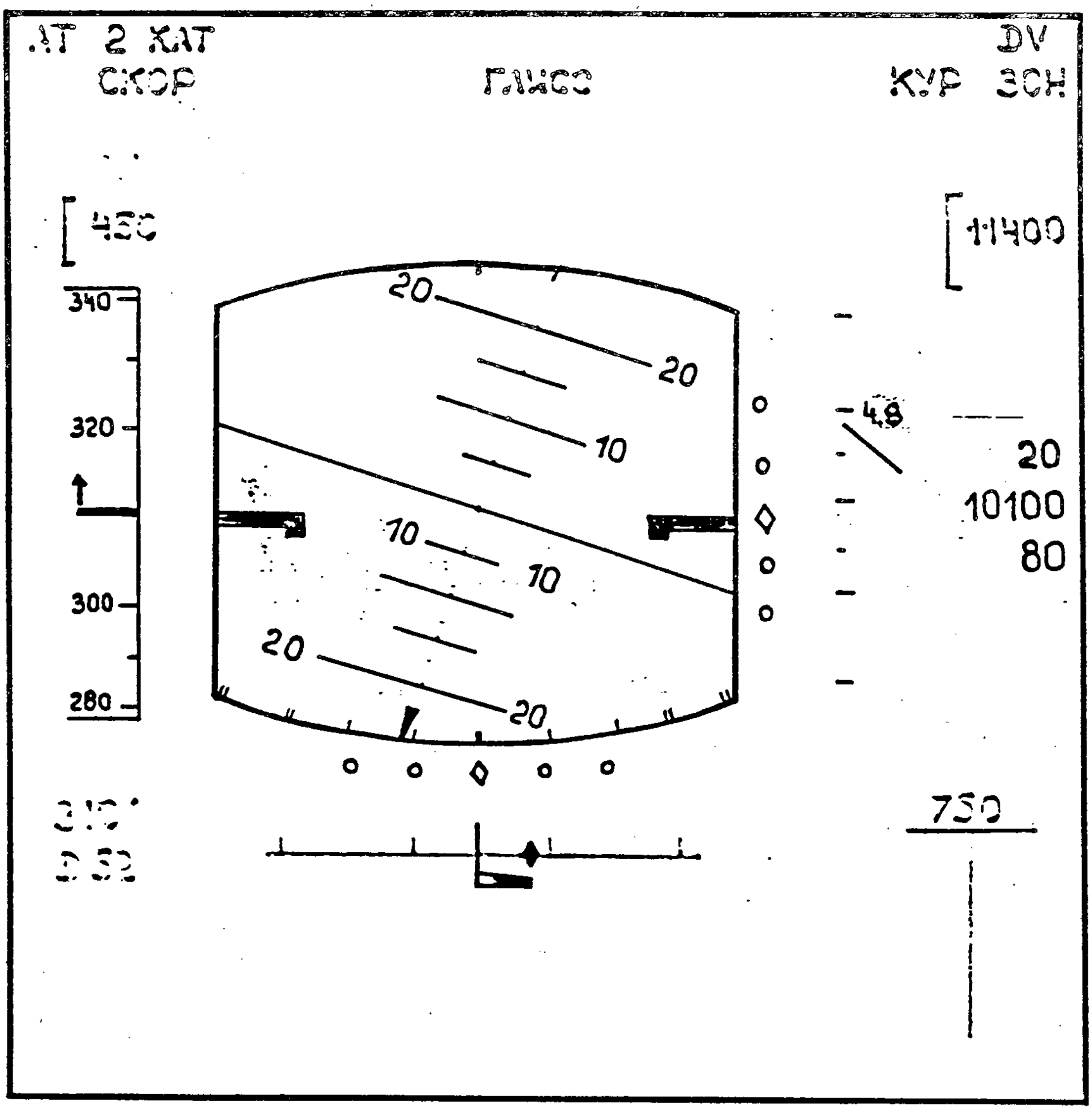
$$|P_i(t)| < M_i \qquad M_i = \frac{Const}{F_i(t)}$$







eyes movment
2 instrumental route – 67%
3 " —— " —— " 27%
4 " — – 6%


AT 2 КАТ
СКОР
ГЛИСС
DV
КУР ЗСН
450
11400
340
320
300
280
20
20
10
10
10
20
20
20
4.8
20
10100
80
750

Results

	experiment	calculations	
	$T^{max}_{o.\varphi}$ sec	$T_{o.\varphi}$ sec	limits Real
directiv instrument $\gamma, \vartheta \dots [^\circ]$	0,8	0,4 0,54 0,41 0,42	$\lvert \quad \rvert > \lvert \quad \rvert$
		0,83	$\lvert 17^\circ \rvert < \lvert 40^\circ \rvert$
instrument of vertical speed V_y [m/sec]	5	3	+
		8,2	$\lvert 4\ m/sec \rvert < \lvert 10\ m/sec \rvert$
		4,3	+
		4,7	+
		6,1	$\lvert 14\ m/sec \rvert < \lvert 18\ m/sec \rvert$

$$T_{o.\varphi} = T_{\varphi} = 0,3 \div 0,4 \text{ sec}$$

$$\boxed{0,4 \leq \frac{1}{2(f_1 + f_2 + \dots + f_n)}}$$

Communicating Human Error Causes Through Accident Investigation: Promises and Limitations

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Accident investigation reports and their supporting data constitute a major portion of the information we have on how humans make errors in real world situations. Unfortunately, the very nature of most accidents hampers our search for the causes of the errors. Laboratory research tells us a lot about human behavior, but if it gave us all the answers we wouldn't have accidents to investigate. Since accident investigations are not laboratory experiments, our methods of data collection and analysis are different, and our experimenters (investigators) have different skills and qualifications. Data gathered in laboratory experiments are affected by the research techniques employed and by permanent and transient environmental influences. The strength with which research findings can be generalized to the real world depends upon the limitations effected by these factors. The same can be said for the applicability of findings from an accident investigation. In this paper, I will discuss the human performance aspect of aviation accident investigation -- and how investigative methods and outside influences can affect the content and impact of investigative findings.

INVESTIGATIVE METHOD

The National Transportation Safety Board (NTSB) is responsible for determining probable cause of every aircraft accident in the United States, as well as the investigation of selected accidents in other modes of transportation (railroad, marine, highway, and pipeline). When responding to the scene of an aircraft accident, NTSB specialists with various areas of expertise head up investigative groups. They are joined by approved parties to the investigation, for instance the airplane manufacturer, the airline, unions, airport authorities. Our Federal regulations prohibit attorneys from participating in our investigation. For a major accident, the investigative force will consist of 10-15 Safety Board investigators, serving as group chairmen, and over a hundred participants from outside the NTSB who participate as members of the investigative groups.

The NTSB "Go Team" consists of an Investigator in Charge (IIC), who is assisted by NTSB technical specialists with expertise in power plants, operational factors, aircraft systems, structures, crash survivability, weather, and air traffic control. And in 1983 the NTSB expanded to include a

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[1] The views expressed herein are the author's, and may not reflect the views of the National Transportation Safety Board.

division of specialists dedicated to investigating human performance aspects of transportation accidents. These investigators were true pioneers: They had to develop their own methods for investigating human performance factors because there was no existing model. The following are some issues that had to be addressed by NTSB, and which must be considered by anyone doing human performance investigation or analyzing human performance data:

- Who should conduct human performance investigations?
- What facts should be collected? What should be ignored?
- How should human performance data be analyzed?
- What is the role of human factors research in investigation?

How we approach these issues certainly affects what we find out about the contribution of human error to an accident.

Who Should Conduct Human Performance Investigation?

No matter how comprehensive the investigative protocol, and no matter how strictly it is followed, the conduct and the outcome of a human performance investigation depends largely upon who is doing the investigating. This is a fact of life. For as long as human performance data has been collected there have been disagreements as to the necessary qualifications of the person collecting it (Figure 1).

Historically, the medical community was responsible for the human related information after an accident, because the information collected (toxicology, altitude/pressure phenomena, autopsy reports) was generally medical in nature. As the focus on human involvement in accident causation evolved, the information collected was broadened, and a different type of person was required to collect it.

Many have argued that the human performance investigator be an individual experienced in aeronautics. The argument proffered is that a pilot can be more easily taught principles of human behavior than a psychologist can be taught principles of flight operation. This argument has its merits, but it ignores the rigorous behavioral analytic perspective that comes from a sound education in the behavioral sciences. Also, given the staffing limitations at a very small agency like the NTSB, which examines human performance factors in five modes of transportation, the argument for primary expertise in aeronautics, or any other specific mode, becomes unreasonable. The Safety Board's experience may be instructive:

When the NTSB Human Performance Division was formally established, it was staffed by six investigators. Three had Ph. D.'s, two had masters degrees, and one had a bachelors degree, all in psychology. Although 3 had commercial pilot licenses, none had commercial airline experience. The verdict on these investigators' suitability for the job would probably differ, depending upon who you asked. I would venture a guess that the investigators with no aviation background (I was one of the three) would now admit, looking back, that they were at an initial disadvantage. Some might say this disadvantage was never overcome. However, most of these investigators proved to be very skillful over time, because they utilized proven interviewing and analysis strategies (advanced education in psychology is an advantage for this), and made effective use of outside resources to fill in the gaps in their operational knowledge and experience.

Present staff includes a former professional mariner, former air taxi and military pilots, and former police detectives. Each uses skills and knowledge gained from their previous occupations; for instance, the former police detectives make substantial use of their training in interviewing and criminal investigation. Several of these investigators also hold advanced psychology degrees, but the emphasis has switched to more operationally-oriented backgrounds.

These investigators still investigate accidents in all modes of transportation, so even though there is more operational expertise, it is being applied cross-modally. That has not presented a significant problem because many of the stressors affecting human behavior are common to all modes. For example, railroads, commercial marine vessels, and airlines share comparable management-labor relation problems, and similar experiences with the introduction of automated "cockpits", reduced manning, duty and rest time limitations, fatigue, stress, and much more. The human performance investigator brings more insight to each successive accident as a product of what he/she has learned by examining the human in the context of a wide variety of complex systems.

The human performance analysis of an accident must consider the underlying system causes of human error in the context of a very large system. In an aircraft accident, that context includes the cockpit environment, crew influences, the outside environment, the air traffic control system, the home environment, recent life events, airline management and regulatory influences, as well as the classic physical health influences. Psychologists are trained to observe human behavior systematically.

But knowing the right questions to ask in an investigation requires both a solid understanding of the system perspective in analyzing human behavior[2], and an appreciation for the significant system elements in the accident under investigation. While aeronautical knowledge is not essential for studying the system aspects affecting the human in an aircraft accident, one does have to know which components of the system are the significant ones. This is where, in an NTSB investigation, the outside parties play an invaluable role. Often other parties to an NTSB investigation, for instance, the pilots' union, the airline, and the airplane manufacturer, supply participants to Human Performance investigation. These participants are pilots, mechanics--operating personnel -- they seldom possess academic training in human factors, yet they can greatly affect the NTSB investigator's success in determining and gathering the relevant technical and operational data that

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[2] C.O. Miller's chapter on "System Safety" in Wiener and Nagel's <u>Human Factors in Aviation</u> (1) describes this approach.

defines the system in which the humans operated. They do not, however, participate in the analysis of the human performance data. The NTSB is the independent, neutral investigative body in this process, and conducts the only official analysis. As far as the Safety Board is concerned, this condition is not debatable (although it is debated elsewhere).

Sending a Human Performance Investigator to the Scene

Just as important as whom should be a human performance investigator is the question of when to send a human performance investigator to the scene of an investigation. Since it is well accepted that about 80% of all transportation accidents involve human error, it might be assumed that a Human Performance investigator would be part of the Go Team on almost every accident. This is not the case at the NTSB, and the limited staff resources do not always account for the omission of a human investigator from the team.

It seems that the Human Performance investigator is still not a fully accepted member of the NTSB Go-Team. In some cases, the IIC, who generally selects the specialties needed for the particular investigation, does not appreciate the value of a human performance investigator on scene, and thus does not request that specialty. In some cases, the IIC or other NTSB management figures choose not to send a human performance investigator to the scene, because they think the mere act of assigning a human performance investigator will send a message to the other parties that the NTSB suspects a substandard performer. Unfortunately, what usually happens in this case is that the IIC and the Go-Team return from the scene, and weeks later, when they realize that human performance analysis is essential to uncovering the underlying causes of the human errors which occurred (and they are not necessarily due to any substandard performance), they request that a Human Performance Investigator be assigned to the accident. At this point, "the trail is cold", and the human performance investigator is left to draw conclusions with incomplete data. This is a major problem with human performance accident investigation at the NTSB, and one that can be fixed with appropriate consideration of the matter by NTSB management and others in the aviation industry.

What Facts Should Be Collected? What Should Be Ignored?

Many experts on accident investigation recommend a "systems analysis" approach. In order to do a thorough systems analysis of an accident, a great deal of factual information must be collected, much of which may not seem directly relevant to the accident. The NTSB does collect a great deal of factual information, but the public generally only sees the final "blue cover" report. Few are familiar with the volume of data which finds its way only into the public docket, but not the report. This suggests we don't do a strict system analysis. However, we are moving more in that general direction, and the probable cause of the Cerritos midair collision(2) reflects that movement:

> "The National Transportation Safety Board determines that the probable cause of the accident was the limitations of the air traffic control system to provide collision protection, through both air traffic control

procedures and automated redundancy. Factors contributing to the accident were (1) the inadvertent and unauthorized entry of the PA-28 into the Los Angeles Terminal Control Area and (2) the limitations of the 'see and avoid' concept to ensure traffic separation under the conditions of the conflict".

The outline depicted in Figure 2 is paraphrased from an unpublished NTSB Human Performance Investigation document. These are data collection guidelines for our investigators. The complete guide goes into much greater depth as to questions to be asked about training, selection, and other subjects. The major headings: EXPERIENCE, EQUIPMENT DESIGN, SENSORY-PERCEPTUAL, CREW INTERACTION, PHYSIOLOGICAL-MEDICAL, and CLINICAL, are major categories of factors which can influence human behavior. The lists under each major heading represent the sources for the data collected, i.e., Cockpit Voice Recording (CVR), Logbooks, Company Records, Interviews with Family, Friends, Coworkers, Training Personnel. Note that some data sources provide information for several different factors. For instance, we use CVR data to assess Crew Interaction, but it may also be used to assess Sensory Factors such as workload and environment, or even for evidence of critical life events, or stress.

Depending on the circumstances, these data or subsets thereof may be collected on all aircraft crewmembers, several air traffic controllers and supervisors, and mechanics. The investigator uses common sense to determine whether to go into greater or lesser depth of data collection about particular individuals. Because of resource limitations, fewer data are collected on more peripheral players in an accident.

Of course a full system analysis would require all data on all players. Whether that is constructive is debatable. Dr. Walter Sipes recently presented a paper at Ohio State (3) in which he outlined the data collected for the psychological profile in Air Force aircraft accident investigation. These data included information on crewmember siblings, and athletic performance in high school. Data are just beginning to be computerized, and the Air Force has yet to provide convincing evidence for usefulness in determination of accident causation (although it may be used some time in the future for job selection purposes). NTSB investigators try to get the most for their effort, given the resource and time limitations they work under. Admittedly, it takes a skilled investigator to know how far to go, and when to discontinue a particular portion of an investigation.

There will always be factors which will be missed -- some because the facts are volatile (people forget), some because they are impossible to gather (critical witnesses are deceased, or witnesses' portrayals of facts are colored by personal biases and the like), and some because we still don't know enough about human behavior to have defined all the significant factors.

This last point demonstrates why it is so difficult to use engineering or math models to analyze human error. While some systems analytic engineering approaches can be helpful, they often can't accommodate the full range of those uniquely human behaviors that constitute the reason why we still want at least two pilots in an aircraft.

ENVIRONMENTAL INFLUENCES ON INVESTIGATION - SOME "STICKY ISSUES"

The issues listed Figure 3 are examples of some of the major factors which make it difficult to study human factors in aircraft accidents. To adequately discuss each issue would require a symposium dedicated to accident investigation. I will only briefly introduce them here.

1. THE POLICY FACTOR

Gerry Bruggink (4), in 1985, published the first of several articles emphasizing the importance of management policy-making:

> "A policy factor becomes an inherent part of the causal mechanism when top management of manufacturers, air carriers, professional organizations, airports, or regulatory agencies helped set the stage for the accident by ignoring the lessons from predictive incidents and similar accidents in the past, or by tolerating unwarranted compromises for reasons of self-image, economy, or ineptness."

Bruggink goes on to say that policy factors have not gained sufficient recognition because our mandate to determine cause is interpreted to mean the spelling out of accountability, rather than the preventability, of accidents. As Bruggink admits, the NTSB has identified policy factors, in its reports, but they have not often found their way into the probable cause. They were cited in the Cerritos probable cause and will surely be cited more in the future. The policy factor is getting more visibility. Still, it is hard to document, and it is even harder to get full Board agreement on assigning causal weight to these factors. Bruggink and many others believe a top-down approach would be more effective in preventing errors. What we need is top down agreement with this approach from industry and government.

2. ALCOHOL AND DRUGS

Alcohol and drug involvement in transportation accidents is a frequent subject in the news these days and new regulations will mandate more drug testing, giving us more data than we've ever had before. The problem is knowing what to do with the data once we have it. Laboratory research gives us a pretty good picture of the effects of various levels of alcohol intoxication on human perceptual and motor skills. What we don't often know for sure is whether the perceptual or motor deficits are causal to an accident.

Positive drug findings present greater difficulties than alcohol for analysis. At this time, there is very little data associating performance deficits with blood levels of illegal drugs. Most existing research describes performance in terms of amounts of drug ingested -- we are unlikely to discover this information in an accident investigation.

The 1988 Trans Colorado Airlines accident in Denver (5) was the first in which drugs were found to be a factor in a commercial passenger airline accident. A blood sample from the captain of that airline showed 22 ng/ml of the principle metabolite of cocaine, and a urine sample showed 22 ng/ml of cocaine. Other evidence collected during the investigation, and other knowledge about the metabolism and effects of cocaine gave us some additional information on which to base a conclusion about the probable effects of the cocaine relative to the accident: Reports of the captain's drug use indicated that he was not a novice user. That information helped the pathologists determine that the captain had ingested the drug at least 10 hours before the accident, most likely in the period 12 to 18 hours before (that finding matched witness testimony that the captain and his girlfriend had "done a bag" the night before the accident).

No research could tell us the performance effect of a specific amount of cocaine metabolite resulting from an unspecified amount of cocaine ingested an uncertain amount of time previous to the accident. The Safety Board decided that the captain was probably fatigued because the cocaine, which has a stimulant effect, had interfered with his sleep. The Probable Cause statement listed "the degradation of the captain's performance resulting from his use of cocaine before the accident" as contributory.

As alcohol and drug use become more and more prominent in the news, another problem presents itself. Sometimes the distinction between blame and cause becomes obscured. Surely a person is "wrong" to use an illegal drug, and a drug user may be blamed for the accident by media, the public, and sometimes even accident investigators. But presently we cannot, for the most part, reliably associate positive drug results with accident causation. We look to the research community to aid us in the future.

3. FATIGUE

Most of us here would agree that fatigue is a significant factor affecting human performance. But we have yet to determine fatigue to be causal in a major air carrier accident. This is probably not because there have been no fatigue related accidents. A more plausible explanation is that we have difficulty documenting fatigue outside of the laboratory. Post-hoc self-report is not the most desirable evidence of fatigue, and often in a major accident with crew fatalities, we don't even have this much information.

In 1985, a China Airlines Boeing 747 en route from Taipei to Los Angeles suffered an upset in flight(6). During an attempt to recover and restore normal power to one of the four engines, the airplane rolled to the right, nosed over, and entered an uncontrollable descent. The captain was only able to restore the airplane to stable flight after it had descended from 41,000 feet to 9,500 feet, a descent which took 112 seconds, in which the aircraft pulled more than 5 g's.

The flight, which left Taiwan at 1622 local time, was due to arrive at Los Angeles at 0322 local Taiwan time the following morning. According to the captain, he had gone to sleep fairly consistently at around 2100 to 2200 local Taiwan time for six nights prior to the accident. As a result, the incident occurred some four to five hours after the time that he had been accustomed to going to sleep.

The captain had experienced alterations to his regular sleep cycle in the week preceding the flight as a result of his return to Taipei (GMT+8) from Jeddah, Saudi Arabia (GMT+3). In addition, the conditions of the flight had caused him to stay awake for a prolonged period. Although he slept for two hours during the flight (during which a relief captain flew), he still had remained awake several hours beyond the time he would ordinarily be deeply asleep. There was a high probability that he was affected by circadian desynchronosis at the time of the accident. In addition, the long duration of the flight, mostly conducted in automatic pilot, would certainly involve elements of fatigue, boredom, and most probably, a decrease in vigilance. But it is interesting to note that no mention was made of fatigue or boredom in the Safety Board's Probable Cause. Since the accident was not a controlled experiment, the flightcrew was not monitored by electronic sensors, and the NTSB could only infer the causes of the crew's degraded performance from the Flight Data Recorder (FDR), which records parameters of the airplane's flight path and pilot control inputs, and from personnel records and interviews with the involved crewmembers. Communication with the crew was difficult because of language difficulties.

We have asked the research community for help in determining effects of fatigue and circadian factors on transportation system safety (7). We need creative investigative tools for determining levels of fatigue, and we need more information from the research community about the effects of fatigue in operational settings such as those encountered in our investigations.

4. Cockpit Voice Recordings

The Safety Board has gone on record deploring the use of the CVR tape for anything other than its intended use: accident investigation. But the tape's release in the Delta 1141 accident raised another issue. What information is "relevant", or "pertinent"? The NTSB has typically deleted operationally nonpertinent text from the published transcript, putting in its place a symbol indicating "nonpertinent word". Seven minutes and forty-two seconds of "nonpertinent conversation between the flight crew and a flight attendant" was deleted in the official NTSB CVR transcript of the Delta 1141 accident. Release of the actual tape by a Texas state court in response to a Freedom of Information request made the public aware of the extent of information the NTSB may consider nonpertinent, and many were outraged that the conversation was deleted. The nonpertinent conversation was not relevant to the operational environment, but was enlightening in terms of the crew's attendance to their duties.

Many of us consider "nonpertinent" conversation very pertinent in terms of what it tells us about crew interaction, adherence to operational procedures, personality factors, -- factors which can contribute to accidents. In fact, investigators use the complete CVR in their analysis of human performance. Several researchers looking into the role of crew interaction and communication in causing errors and accidents would also like to have the benefit of the actual CVR audio tape for their analyses. We could probably benefit from their research, but it is unlikely that researchers will gain access anytime in the near future. On the other hand, if there is a successful campaign to put CVR tapes in the public domain, a population uneducated about aviation operations will have a wealth of data it has no way to properly interpret. This type of misinterpretation by the lay public wreaks havoc for the official investigation. Should/can the CVR be used by researchers? It's a sticky issue!

5. *PRIVACY, LIABILITY, OBSTACLES TO INVESTIGATION*

The NTSB does not determine legal liability, and in fact, the NTSB final report may not be used as evidence in civil court proceedings. This situation does not really present much of an obstacle to lawyers involved in civil suits; attorneys regularly use NTSB factual reports and depose NTSB investigators for factual information, although they cannot make use of any NTSB analysis, written or oral, for evidence. Realistically, the data collected by the NTSB for an accident investigation is used extensively for liability determination, and this fact of life has a significant impact on our ability to investigate all the relevant facts. All data collected by NTSB investigators, including their factual reports, but excluding their expert analytic reports, are placed in a public docket, and are open to public scrutiny. Additionally, the FAA certification branch typically conducts a parallel investigation during the NTSB investigation of an accident, in which they attempt to determine if certification action against the pilot or airline is warranted. Not surprisingly, the NTSB can run into difficulties getting the information needed because of various roadblocks, some set up by the very organizations which stressed the need for us to delve more deeply into the underlying causes of "pilot error".

In 1985, the director of the Air Line Pilot Association's (ALPA) legal department wrote an article for Air Line Pilot Magazine (8) instructing pilots to avoid giving statements to the NTSB or FAA immediately after an accident, and to give no statements until the pilot is recovered from the shock, and has reviewed the details of the event "in a thoughtful way", and sought competent advice and aid. He states, "Unless served with a subpoena, *the pilot is under no legal obligation to make a statement to any government* official. Therefore, although cooperation with the investigators is usually appropriate, taking the above mentioned precautions first make good sense." This feeling was reinforced by Henry Duffy, president of ALPA, in the October 1989 issue of Air Line Pilot, who indicated that "until pilots recover and *regain composure so they can offer rational answers to NTSB or other* authorities"..., they will give "erroneous answers." This statement followed the onscene investigation of USAIR's Flight 5050, a Boeing 737 which overran the runway during an aborted takeoff at LaGuardia airport. The pilots were not available to NTSB investigators until more than 36 hours after the accident.

The unavoidable legal issues, although supposedly separate from NTSB's investigation, certainly obstruct our investigation. Even discounting the legal concerns, personal privacy is inevitably breached in an accident investigation. We will always delve too deeply into people's personal histories in the minds of some, and too shallowly in the minds of others. Those who think we go too far have sometimes used the term "psychological autopsy". In fact, the NTSB doesn't do those; they don't really serve its purpose. In the real world, everyone comes to work with "personal baggage" of some sort. Systems must be designed to tolerate a reasonable amount of individual variation, even if it is due to a transitory emotional state or stress. Systems may not be expected to tolerate extreme variations, but then these are not so hard to uncover (we should not have to resort to a "psychological autopsy" to discover them).

SUMMARY

It should be clear from the ratio of questions I've asked to answers I've given that human factors accident investigation is still evolving; so is our understanding of the fundamentals of human behavior.

One thing we can do to improve our understanding of human error is to strengthen the tie between research and investigation findings. Human factors research provides many of the analytic tools we need to properly analyze the information we collect, and to formulate the probable causes of accidents. We need additional research to improve our analyses. In turn, data from our investigations can provide useful input for research. Researchers working on fundamentals of cockpit communications and resource management have made extensive use of CVR transcripts (9,10,11) and other investigative data. And NASA Aviation Safety Reporting System (ASRS) research reports have provided useful data for accident investigation analysis (12). Other data from our accident investigations haven't yet been tapped by the research community -- some because it isn't available to this group, and some because the investigative and the research communities have not had as close a working relationship as they should. This is difficult to accomplish; resources on both sides are limited. But we have seen progress.

Accident investigation contributes significantly to our knowledge about human error. Recommendations resulting from NTSB investigations help to decrease or positively manage human error. If we improve our investigative and analytic methods by addressing the issues presented here, we can go a long way in better managing human error. Because the information gained by good human performance investigation can be so valuable in preventing further accidents, the aviation community should be giving as much weight to the development of better accident investigative and analytic techniques as it does to workplace design and human factors training.

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Figure 1

WHO SHOULD CONDUCT HUMAN PERFORMANCE INVESTIGATION?

- AERONAUTICAL KNOWLEDGE vs. ACADEMIC BACKGROUND
- EXPERIENCE EXAMINING HUMANS OPERATING IN COMPLEX SYSTEMS
- EXPERIENCE ON THE JOB
- OUTSIDE EXPERTS

Figure 2

DATA COLLECTED

EXPERIENCE FACTORS - EXPERIENCE IN SIMILAR SITUATIONS

LOGBOOKS
COMPANY RECORDS
PERSONAL RECORDS, CERTIFICATES, LICENSES
INTERVIEW COMPANY TRAINING PERSONNEL, FELLOW OPERATORS,
INTERVIEW FREQUENT PASSENGERS

EQUIPMENT DESIGN FACTORS - WORKSPACE, DISPLAY-CONTROL, WORKLOAD

DISPLAY/CONTROL LAYOUT
MANUFACTURER DRAWINGS - HUMAN FACTORS DESIGN PHILOSOPHY
COMPANY MAINTENANCE RECORDS, BOOKS, LOGBOOKS
SIMULATOR TRAINING SYSTEMS

SENSORY/PERCEPTUAL FACTORS - LIGHT, SOUND, VIBRATION, WEATHER, WORKLOAD

NATIONAL WEATHER SERVICE OBSERVATIONS
COMPANY RECORDS, PRE-FLIGHT BRIEFS
ATC REPORTS / PIREPS
LOGBOOKS
SIMULATOR TRAINING SYSTEM RECORDS

CREW INTERACTION FACTORS - AGE, EXPERIENCE, PERSONALITY, COMMUNICATION STYLE

FAA CERTIFICATES
COMPANY AND PERSONAL RECORDS, LICENSES, LOGBOOKS
INTERVIEW FELLOW CREWMEMBERS, INSTRUCTORS
SIMULATOR TRAINING SYSTEM RECORDS
OPERATOR MANUALS
CVR

PHYSIOLOGICAL AND MEDICAL FACTORS - HEALTH, MEDICAL HISTORY, REST, DRUGS

MEDICAL CERTIFICATION RECORDS
PRIVATE PHYSICIAN RECORDS
POST-MORTEM EXAMINATION
TOXICOLOGICAL ANALYSIS
INTERVIEW AME, PRIVATE PHYSICIAN, FAMILY, FRIENDS

CLINICAL FACTORS - JOB STABILITY, LIFE HABITS AND RECENT EVENTS,

INTERVIEW FAMILY, SUPERVISORS, COLLEAGUES, NEIGHBORS, FRIENDS
CVR

Figure 3

STICKY ISSUES

- THE POLICY FACTOR
- ALCOHOL AND DRUGS
- FATIGUE
- CVR
- PRIVACY, PSYCHOLOGICAL AUTOPSY

Presented by
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SAFETY AWARENESS TRAINING IN CANADA

ONE GOVERNMENT'S APPROACH

GENERAL

The Aviation Safety Programs Branch of Transport Canada has the mandate to raise the level of safety awareness in Canadian aviation and encourage safe operating practices. This requires that our programs support the efforts of the regulatory programs, such as company audits and surveillance, while, at the same time, maintaining a relationship with the aviation community which allow for the effective delivery of such educational programs.

In establishing this mandate for the Branch it was important to assess the priorities of the safety awareness program within the overall context of Departmental responsibilities and obligations. First, we had to establish the government's mandate under the law and identify what requirement it had in delivering various programs. As well, some basic philosophical questions had to be answered. For example, is any government responsible for everything that happens in aviation, be it good or bad, or do all participants involved have a stake in supporting and paying for certain aspects such as safety awareness programs? To what extent should a safety program command limited resources?

MANDATE OF THE DEPARTMENT OF TRANSPORT OF CANADA

The mandate of the Canadian Department of Transport, commonly known as Transport Canada, is probably not unlike that of most other countries. The Canadian Aeronautics Act states that, "the Minister is responsible for the development and regulation of aeronautics and the supervision of matters connected with aeronautics." The Act has recently been rewritten to emphasize the requirement for the Minister to "control" aeronautics.

The emphasis on "control" suggests that we should be developing only those programs designed to exercise the control required over the industry and reduce expenditure on those programs which tend only to influence. Certainly, it is far easier to justify those programs which result in the delivery of navigation aids or personnel licences than it is the safety education program which always seems to have great difficulty in providing empirical data in support of its own utility.

The setting of regulatory standards and the enforcement of those standards forms a major part of the Canadian government's approach to ensuring a safe air transportation system. However, at the same time Canada has recognized the effectiveness of educational programs in dealing with the Human Factor.

Having decided to develop an approach to safety education, it was then necessary to embrace a safety philosophy upon which the program could be built. This philosophy went beyond the usual "mission" statement and tried to establish a framework within which analysis and educational programs could be developed. More than a safety philosophy, we actually developed a number of assumptions to form the foundation for our program.

Current safety philosophy within the Aviation Safety Programs Branch is based on the concept that not all factors which come together to cause an occurrence can be eliminated by regulations and regulatory action alone. And, of course, in this regard we are thinking particularly about the Human Factor.

The Canadian safety education program is based on the following premises:

(a) Preventive action can only be effective when the root cause of the problem is known and understood.

(b) Historically, we have wasted much time, effort and resources developing solutions for the effect and not the cause. (i.e. A pilot departs with ice-contaminated wings and the resulting loss of performance causes the aircraft to crash. Is the "cause" of the accident the contamination on the wing or the pilot's faulty judgement in thinking that conditions were such to allow safe flight? Although both conditions were necessary to cause the accident, one of these conditions is the root cause.)

(c) Human factor is the number one cause of accidents in the world today and is the only remaining area in which major gains may be made in accident reduction.

(d) We are all responsible for our own safety, to the extent that we are conscious of the risk.

(e) Within an organization, the leader is responsible for setting the standard of safety. (A key to our philosophy is that the leader's ultimate responsibility for system safety cannot be delegated.)

Once the decision was made to develop some form of safety education program the structure of Transport Canada's organization was eventually modified to allow the various programs to interact. Primary considerations were the the problem areas identified and the demographics of the aviation community which needs to be served.

CANADIAN STRUCTURE

The Canadian government's aviation program is divided into three main areas of responsibility.

Air Navigation Systems - Provides the "way" through Air Traffic Control, navigational facilities and the development of navigation procedures. (about 6000 people)

Aviation Regulation - Provides the control of the aviation system through aviation licensing, airworthiness, regulatory enforcement, certification and legislation development. (about 1000 people)

Aviation Safety Programs - Provides safety awareness training and develops safety education programs as well as analyzing the problem areas in aviation. (about 50 people)

The three organizations (no matter how big or small) are structured in such a way that the head of each reports to the top (leader) aviation person within the group. This gives the safety organization added visibility and increased input within the organization. It also provides the leader with independent safety advice, if needed.

WHERE ARE THE SAFETY PROBLEMS?

I mentioned that one of the first things to be done is to identify the problem. That is an ongoing concern of most safety organizations. The search for useful and valid indicators of the level of safety goes on as we speak. We devised what we believe to be a very useful and effective system for our use.

The System Analysis and Functional Evaluation (SAFE) Program allows analysis of the results of investigations conducted by the Canadian Aviation Safety Board and ,in the case of Air Traffic Services operating irregularities, Transport Canada to determine the root cause of occurrences. Or, more correctly, the program allows us to identify those factors which came together to cause the occurrence.

The system deficiencies are categorized under the main headings of personnel, machine, environment, management and regulatory authority with a number of sub-systems and components being used to further detail the specifics of the problem. The analysis technique can also be applied to other forms of input such as air carrier audits reports, enforcement action results and coroner's reports. The largest number of factors in our system deal with the Human Factor.

To the best of my knowledge this is the one of the only analysis systems being used today which provides a direct link between the deficiencies identified following an occurrence and the component of the aviation system which failed. As well, from our point of view, it is the only system which allows for the development of preventive programs which address the root cause of accidents.

In our analysis of over 2800 accident reports over the past four years we have confirmed that, as we all know, about 70% of all factors involved in an occurrence are the result of human failure. (69.6% to be exact).

The SAFE analysis says that 70% of all factors are human failures. This includes 21% which are pilot judgement and another 18% which are pilot technique. This is not too astonishing since the pilot is the one human who influences events throughout the history of any flight. However, the results do highlight where programs can be developed to correct the major problems.

PROGRAM FOCUS

Both of these factors, judgement and technique, are most difficult to regulate and don't lend themselves to more aggressive enforcement action. The simple fact is that putting an enforcement specialist in every cockpit or flight deck, or at every airport 24 hours per day is extremely labour intensive.

In the area of pilot technique it may be possible to set higher standards of performance and develop tougher licensing requirements but in the area of judgement or decision making, devising a suitable regulation to require correct responses to various situations is not possible.

To this end, our aviation safety program has been directed towards non-regulatory safety action. The program emphasizes the advantages of operating within the rules and encourages participation in safety management programs.

CANADIAN DEMOGRAPHICS

I also mentioned that any safety education program must consider the demographics of the aviation industry it is trying to serve. Foe example, Canada is a widely diverse country with 90% of its population living within 90 miles of the Canada-US border. This ribbon of civilization is well served by navigation facilities, airports and first level air carriers , such as Air Canada and Canadian Airlines International. These carriers are characterized by well-developed maintenance organizations, excellent training facilities and a company safety management program. They also have a corresponding excellent safety record.

The accident rate for Canadian first level carriers over the past years has remained at a consistent low level for a number of years.

However, Canada is a large country with diverse flying conditions *and the majority of our flying falls outside of the large* air carriers. Of the 60,068 licenses in force in the country as of October 1, 1989, 19,966 are commercial, senior commercial or airline transport pilot licences while the remainder are private.

glider, gyroplane or free balloon licences. Of the commercial pilots, the majority are hired by small operators and fly on charter and northern operations.

I should point out that most of our regulatory resources within the government are directed towards the large air carriers. Since they carry about 90% of the passengers in Canada they represent the largest number of people at risk.

However, just a few miles north of where I live in Ottawa, one enters what we euphemistically call the "sparsely-settled region". The aviation picture changes dramatically and the requirements and pressures change accordingly. The airports are not served with the latest in approach aids, are not as well maintained and, in most cases, do not have hard surfaces. The navigation aids are fewer and further apart and usually are older. There is a great reliance on the Non-Directional Beacon (NDB) as opposed to the Very High Frequency Omni-Directional Radio (VOR).

But the biggest differences are the pilots and the companies for which they fly.

We have just entered "bush pilot" country. The aircraft are older, the pilots younger and less experienced and the companies struggling, in some cases, to survive economically. There are totally different pressures on these operators than those which exist "down south". Young pilots trying to build up flying hours to allow them to move on to bigger and more modern equipment are flying trips which may literally ensure or negate the companies profit margin for the week. Mission accomplishment takes on a whole different meaning when the only mode of transportation is by aircraft and each paying customer becomes vital to the economic stability of the company.

There is also a mystique about the "bush pilot" based, to a great extent, on the historical traditions and perceived glamour of the trade. The macho, independent, "it can't happen to me" pilot is encouraged and thrives on life in the bush.

Of more importance to our safety programs is the fact that many bush operations are not large enough to support a safety management program even if we can convince them that such a program is essential to safe flight.

Therefore, there should be no surprise that we try to direct our safety awareness programs towards these operators.

THE TARGET AUDIENCE

Our target audience, then, has been identified as the level 2 and level 3 carriers as well as general aviation. It is in this sector of the industry that more problems exist, the people involved have less infrastructure with which to develop their own programs and the operating conditions are less regulated. It is also in this segment of the community where the greatest safety gains may be made.

Generally, in the context of governmental resource constraints we have to develop more effective programs which will reach a wider audience and will motivate that audience in a shorter period of time. Company representatives can not attend long courses or seminars, neither can the government continue to provide the number of separate courses which we now offer.

Of greater concern is how we can reach those who are the major cause of accidents. Since our courses are voluntary in nature we are concerned that we are preaching to the converted. The individuals who have a need to be motivated are not among those who actively participate in our programs. We are very much dependent upon the ripple effect of safety training in helping to spread the safety message. In the area of human factor education everyone who attends a session must be encouraged to become a safety educator.

FORMAL PROGRAMS

Our current challenge is to identify those factors which indicate a declining safety level and take appropriate action in conjunction with the operators to ensure the problems are resolved in the most efficient and effective way possible.

Formal awareness training programs are delivered in three main areas. They are the Company Aviation Safety Management (CASMP) Program, the Pilot Decision Making (PDM) Program and the Civil Air Search and Rescue (CASARA) Program.

The CASMP starts with an Executive Safety Seminar (ESS) which is directed towards the Chief Executive of the company. The message of the seminar is simple and straightforward. The Chief Executive is ultimately responsible for safety within the company and this responsibility cannot be delegated. The second part of the message is, "If you think safety is expensive, try an accident."

The objective of this seminar is to encourage the company senior management to develop a company safety management program and appoint a company safety officer.

We also offer a Company Aviation Safety Officer (CASO) course. Having convinced the Chief Executive to start a safety program, we now provide training to the designated safety officer. The courses includes the development of a safety feedback system, how to conduct company safety surveys and the legal and financial implications of having an accident.

We also provide safety survey services and continuing support to the designated company safety officers.

The Pilot Decision Making Program was developed using research conducted in Canada, France, the United Kingdom and the United States. The program is designed to enhance the decision making skills of licensed pilots.

The program consists of three modules which concentrate on pilot attitudes towards risk taking, stress and its effect on the decision making process and teaching how to evaluate information to reach a conclusion and make a decision. The program has been successful for all levels of pilot experience and we are now working on the development of Pilot Decision Making II.

CASARA is a specific program directed toward those private pilots and flight crew engaged in supporting the Search and Rescue activities of the Canadian Armed Forces. We provide awareness training to allow the crews to operate safely in the dangerous search and rescue environment. At the same time, we take advantage of their attendance to introduce themto our normal safety courses. Since the implementation of this course we have seen a reduction in the number of SAR missions of about 25%.

PRESENT CONCERNS

The first concern we have is the constant one of resource constraints. No matter how many employees we have, we would always like to have more. Particularly, when the programs we offer seem to be so well received. However, the reality is that we just don't have a bottomless pit of resources.

There are obvious constraints on the government to reduce expenditures. The fact that this need to reduce spending isn't always accompanied by a similar desire on the part of the public to reduce services doesn't make the job any easier.

At present, we are able to reach about 20% of the licensed pilots in Canada on a yearly basis. Ideally, we would like to see that coverage increased to 30%.

We also have concerns for the credibility of our safety officers who actually deliver the programs. As the number of experienced pilots is reduced and airlines expand it is becoming increasingly difficult to acquire and retain individuals with the expertise needed to deliver these motivational programs. The need to ensure that our safety officers have a full and credible industry background is of constant concern.

There is also an ongoing need to continually update the programs to ensure they are providing the best possible information based on the latest research. We have to continually respond to the changing knowledge base of the human factor problem.

There are a number of initiatives we are considering. We need to deliver the human factors message better to those who are in the greatest need while integrating our work effectively with other government programs.

The idea of using our safety awareness programs as an alternative to fines or license suspension will be explored. The advantage of such an approach is that we would have an opportunity to address the pilots who are creating the problems as well as those who attend our voluntary sessions. The provincial government of Ontario has used this idea effectively in dealing with driving violations. Instead of paying the usual fine, the individual is given the choice of paying the fine or attending a safety education session. Since I was given a first hand look at the program during a recent trip to Toronto and I am convinced that it is worth trying.

This, of course, leads to the question of mandatory safety training. We have resisted this approach based on the theory that if someone doesn't want to learn they won't learn. We were also concerned that our apparent involvement in regulatory or enforcement activity would damage our credibility as safety officers.

However, we are now contemplating a two-tiered safety education program. One tier would be our normal voluntary programs designed to increase the margin of safety while the other tier would be directed at the violators and would be more directed towards encouraging compliance with the regulated standard as a first step in developing a safer operation. Opening a dialogue with those individuals who we are not reaching at the present time is extremely important.

Working with the companies to establish mandatory safety training requirements is also another initiative. The company may be able to impose a requirement which we don't want to regulate industry wide . For example, a number of companies have recently adopted our Pilot Decision Making Program as a prerequisite to upgrading to aircraft captain. One of the advantages with this approach is that we avoid the difficulty of having the program accepted if it is made mandatory through government regulation.

THE FUTURE

We will be trying to cover a wider audience with less safety officers. Therefore, our courses will be streamlined to reach a broader audience. To ensure the specific course requirements are not neglected we will be challenging industry to become partners in the delivery of the program and share in the cost. In this way, larger, more developed companies can support smaller companies. Since the smaller companies employ and train the future pilots of the large air carriers, this expense should be seen as an investment in the future.

I believe we have to proceed with a two-tiered safety program. One directed towards the conscientious operator where we can make strides in improving the level of safety and the other directed towards the violator where we can encourage a basic acceptance of the need to fly by the regulations. I doubt that the individuals who attend our voluntary sessions would abandon their commitment to safety because we also have a mandatory program in place. Using mandatory training as an alternative to enforcement action would have a longer lasting and more positive effect and may be more effective in leading to behavioural change.

We have to increase the participation of industry in the development of our safety programs to ensure they are responsive to industry's needs. To this end we will be establishing a steering committee which will include industry representatives to detail the type of program we should be developing for the 1990's.

CONCLUSION

The problem of human factors has been recognized for longer than I've been involved in aviation. When I started in the 1950s we called it airmanship. Then we explained away most failures with the term "pilot error". Now it's labelled human factors and we don't dare mention "pilot error".. There is so much documentation on the subject it's hard to believe we need any more.

What we do need are usable educational programs which are easily understood by both the presenters and the students. We need presenters who have operational credibility as well as the ability to deliver the safety message. And we need to develop an analysis system which will allow us to identify safety problems. We have to use that analysis system to justify the development of specific programs.

We must start by educating those who train and regulate the aviation community in human factors and ensure that they are provided with the proper information to help solve the problem. Research papers and scientific documents must be decoded and put into layman's language so the message can be delivered by peers and trainers in such a way that it is clearly understood and operationally accepted.

The problems we experienced in developing our Pilot Decision Program are a prime example of this conecern. We found that the pilot community was turned off and tuned out when words such as "cognitive" were used in a safety presentation. Technical jargon is fine if it has to do with airplanes but not when it comes to human factors.

But, most importantly, we, the safety experts, have to recognize that human factors problem solving is a hard sell. It is a hard sell to governments as well as industry. It isn't easy to convince someone to spend money on a program whose effectiveness is difficult to quantify. It is particularly true for the Civil Aviation Authority employee who is surrounded by bigger programs with a clearer legislated responsibility..

But, I submit that the government organization does have a primary stake and a responsibility in initiating and providing safety awareness programs, particularly to those areas of the industry who do not have the resources to do so themselves. This responsibility may not be clearly articulated in the enabling legislation or supported by others but, morally and realistically, the need exists.

To ignore or reject this need is to deny the impact on human factor problems of such programs as the Cockpit Resource Management and Pilot Decision Making programs.

HUMAN FACTORS IN AIR TRAFFIC CONTROL PRESENTATION FOR LENINGRAD - APRIL, 1990

P.G. Harle

Introduction

Since its inception in 1984, the Canadian Aviation Safety Board (CASB) has been concerned over the level of safety in the provision of air traffic control services in Canada. The Board has consequently conducted two special investigations aimed at reducing the risk of collision between aircraft. The first special investigation concerned risk of collision on the ground and the second concerned risk of collision in the air. Both of these special investigations underlined serious shortcomings in human performance - including both unreasonable expectations on individuals and human errors.

Aim

I hope today to review the results of these two special investigations, with particular emphasis on those aspects where the regulatory authorities may be able to improve the human performance of air traffic controllers.

Risk of Ground Collisions

In 1986, a public inquiry was held to examine the risk of collision involving aircraft on or near the ground at Canadian civil airports. Human performance problem areas that were addressed in that report included visibility problems such as:

- restrictions to line of sight from control towers,
- shortcomings in the teaching and use of the most effective scanning techniques by personnel involved in operations on airport manoeuvring areas,
- the conspicuity of aircraft and vehicles,
- the "sea-of-blue" effect created by the maze of blue taxiway edgelights at night, etc.

The report noted problems with respect to the information transfer process, including:

- the timing and wording of air traffic control clearances and instructions,
- the adequacy of current procedures for effecting intra-tower coordination between the ground and airport controllers,
- ambiguous or confusing R/T phraseology and the use of non-standard phraseology by pilots, controllers, and vehicle operators,
- shortcomings in the verbatim read-back of instructions to enter, exit or cross or hold-short of an active runway,
- background noise in cockpits, vehicle cabs and control tower gondolas,
- problems with respect to the assignment and use of call-signs, and
- congestion problems on the ground radio frequencies.

The report concluded that vigilance is an important factor in collision avoidance; many potential ground conflict situations can be directly linked to breakdowns in vigilance by pilots, vehicle operators, and air traffic controllers. The Board noted that the cumulative effects of physiological, psychological, psychosocial, and pathological variables create stresses on pilots, controllers, and vehicle operators which can seriously degrade their alertness, judgement, and performance. In view of the absence of a good understanding of these effects, the Board recommended that the Canadian Department of Transport undertake a multi-disciplinary review of all the human performance variables, including those related to the information transfer process, which may compromise the effective performance of controllers, vehicle operators and pilots during the ground phases of operations. Unfortunately, to date little of the necessary research has been accomplished.

Risk of Collision in Flight

Background

Following a series of serious losses of separation between large aircraft at Canada's busiest airport in late 1988, the Canadian Aviation Safety Board conducted a special investigation into air traffic services in Canada in 1989. A special data base was created including 710 occurrences which took place between January 1, 1985 and December 31st, 1988. A sample of 217 incidents involving large transport-category aircraft on IFR flight plans was selected from this data base for a detailed file review by our safety analysts. More than 80 interviews were conducted with representative controllers, supervisors, and managers. Discussions were held with representatives of the Canadian Air Traffic Controllers Association, the Canadian Airline Pilots Association, the Air Transport Association of Canada, the Canadian Business Aircraft Association, and the Canadian Owners and Pilots Association.

Contributory Human Factors

Of the 217 incidents studied in the detailed file review, the safety analysts found one or more contributory human factors in

192 or 88% of the cases. In total, human factors were assigned *401 times, as distributed below:*

Distribution of Contributory Factors

TYPE	FREQUENCY	PERCENT
PLANNING	88	21.9
JUDGEMENT	75	18.7
INATTENTION	73	18.2
WORKLOAD	35	8.7
FORGETFULNESS	34	8.5
INFO TRANSFER	23	5.7
DISTRACTION	22	5.5
LACK OF KNOWLEDGE	16	4.0
FATIGUE	4	1.0
PERS PROBLEM	3	0.7
MORALE	1	0.2
PILOT RELATED	27	6.7

Note: Occurrences are often assigned more than one cause factor.

Vigilance

Although many different human factors were identified in this special investigation, one general area seemed to be overriding. Inattention, forgetfulness, lack of vigilance, or whatever one chooses to call it, appears to be contributory in approximately 50% of all loss of separation occurrences. Unfortunately, *problems associated* with maintaining constant vigilance are difficult to resolve because man is inherently badly suited for the monitoring function. It appears that man's reliability in performing tasks which require constant attention is poor.

A Federal Aviation Administration team *in the U.S. led by* psychologist Richard Thackray discovered that vigilance tasks are stressful. People feel less attentive and more fatigued, irritated and strained after doing a vigilance task than they were before. Thackray also examined the effects of age on the ability to sustain attention to a complex monitoring task. He found that the performance decrement in tests requiring a visual scanning requirement was significantly related to age, with performance declining earlier in the session in the oldest group of subjects. Simple habituation concepts do not appear to explain this difference, since numerous vigilance studies using auditory tasks or visual tasks lacking a scanning requirement have failed to show age-related change in performance. Fatigue then must be tied to the visual search requirement. Since the *average* age of Canadian air traffic controllers today is 42, we can expect vigilance-related occurrences to continue at a high rate.

Closely related to the problem of vigilance is distraction. Twenty two cases *of distraction were specifically noted during* the file review. The multiple tasks of the controller (i.e. monitoring, communications, flight data preparation, interaction with the computer, etc.) are highly vulnerable to distraction. In one study, several controllers indicated that they were aware of the potential for a situation to involve less than the prescribed minimal separation. However, since the distance between the aircraft was considerable, they decided to wait before they altered the course of one or both of the aircraft. Their attention then became focused on the other aircraft, and they forgot to issue the instructions that would have ensured adequate separation.

There is a paradox in air traffic control that many occurrences happen during periods of light, non-complex traffic. In Canada, nearly 75% of the inattention errors occurred on a relatively low workload and complexity situations. As system design leads to ever-increasing automation, the requirement for human intervention and innovation become less and less. This is already particulary noticeable in the control of oceanic traffic where large numbers of aircraft move east bound across the Atlantic on predetermined routings that have been cleared of conflict by the Gander Automated Air Traffic System computer. Although there are some changes to these routings and some aircraft require manual handling, the oceanic controllers' job is essentially one of monitoring progress reports on 40 or 50 paper strips; the potential for boredom creeping in can be seen.

Shift-Work

One of the realities that an air traffic controller must face is the requirement for shift work. Not only does the ATC system operate 24 hours per day, but in some centres handling transoceanic flights, workload actually increases during what are normally the quiet hours at other locations. *Much has been* written about the effects of working outside of the period when the human body is normally expected to be at rest. Although this type of information is interesting in an academic sense, the question remains how to define a system which minimizes the adverse effects of the disturbances of body rhythms related to shift work.

In Canada, controllers enjoy a very generous work shift cycle, generally comprising 5 days of work followed by 4 days off. Typically, a controller would work two evening shifts, followed by two day shifts, followed by one night shift. The advantages of this system are that time off is at a maximum and the fatiguing effects of the one night shift are left to the end of the cycle when a longer rest period is available. If the 4 days off are days of rest, then the effects of shift work are minimized. If, however, a controller works during what is supposed to be a period of recuperation, then there is cause for concern.

Overtime

A serious shortage of qualified controllers at the busiest Canadian centres requires that management fill approximately 20% of the required controller positions with controllers working on voluntary overtime. The financial incentives are sufficiently great that many controllers are now working an excessive amount of overtime - particularly during their 4 days off. Cases were noted where controllers were working five, six and even seven complete workshifts on a voluntary basis during their four days off. Excessive overtime is considered to be an inappropriate use of time off, as it only exacerbates the naturally fatiguing effects of shift work.

Many controllers acknowledge that they often worked 12 to 14 overtime shifts per month in addition to their regular shifts. This works out to an average work week of approximately 60 hours. This number may not seem excessive for someone performing routine tasks, but when coupled with shift work and the requirement to be mentally alert, it should be cause for concern. Most controllers on this type of schedule admitted to feeling fatigued. They likened it to being on a treadmill; "all I do is work, eat and sleep" was a common comment. There were controllers who described a kind of high when they were in the cycle and felt that their mental processes were particularly acute, that they were "in the groove". Some admitted to difficulty in returning to normal family life and that it was simpler to keep on working.

A universal view was that this pace could not be kept up. While the controllers liked the overtime pay and volunteered for it, they believe that further restrictions on controller working hours is required. They indicated that they would like to see a reduction to 7 or 8 days of maximum consecutive days worked. They believe that what they are doing is reducing their longevity as controllers, leading to early burn-out.

Fatigue

The subject of fatigue has been widely studied and considerable controversy surrounds the impact of fatigue on human performance. During the file review phase of this special investigation, it became evident that few of the investigations into losses of separation occurrences systematically evaluated the conditions conducive to fatigue. Hence fatigue was assigned as a contributory factor in only four of the 117 incidents examined in detail. Nevertheless, it is believed that many of the controller errors in planning, judgement, and attention were made under conditions of fatigue. While the need for regulating controllers' work and rest periods has long been recognized, it is believed that some of the underlying reasons have been largely overlooked. For example, there has been considerable research on the effects of circadian disrhythmia on pilots' performance. However, the literature on the effects of circadian disrhythmia on air traffic controllers is less well documented.

Basic research shows that human beings naturally have a circadian low in their physiological cycles sometime in the very early morning. During such lows, performance can be seriously affected. For example, it has been demonstrated that short term memory is adversely affected during the circadian low temperature of the body. Indeed, anecdotal information received from controllers interviewed would confirm difficulties in memory of such things as coordinating with an adjacent unit or making simple arithmetic calculations during midnight shifts.

Research has also demonstrated that the human being is fairly tolerant in changing workshifts, but is less tolerant of changing sleep cycles. In particular, working a midnight shift seems to maximize the circadian disruption to normal body cycles. Some controllers spoke of difficulties in getting to sleep following a midnight shift. Research has shown that the ability to fall asleep is related to the circadian rhythm of the body, rather than the number of hours already awake. Hence, regardless of the controller's desire to get to sleep following a night shift, he may have difficulty sleeping for a useful period of time. These effects can be aggravated by the normal noise and rhythm of family and household affairs.

Perhaps the whole discussion of shift work, overtime, fatigue and circadian disrhythmia can best be summarized by the following excerpt from a recent FAA study:

> "Many studies point to performance impairment associated with desynchronosis. As mentioned previously, when body temperature is lowest, error proness is greatest. This would then translate to the mid-shift period between 3:00 AM and 7:00 AM as being a critical period. However, in actual practice, controllers' errors do not occur in any great number here. This can probably in part be explained by low traffic during mid-shifts. ... The general statement can be made, that people experiencing desynchronosis are temporarily in a state of internal disarray. Glandular secretion rates vary and become greatest or least at inappropriate times of the day, thus rendering the person ill-equipped either to deal with crisis or to go to sleep... In some professions, such as air traffic control and medicine, error-free performance is the expected norm. There is evidence that such error-free performance, when attained by greater than ordinary effort, occurs at a commensurately greater physiological and psychological cost, sometimes called stress."

Stress

There is a wide spread public perception that controlling air traffic is a highly stressful occupation. However the interviews of this special investigation suggest that the challenge of dealing with heavy and complex traffic is one of the major satisfiers for controllers. According to the ICAO Manual of Civil Aviation Medicine, the generally preconceived factors thought to be stressful are not necessarily so. For example, responsibility for safety and lives was not a stressor, whereas being overloaded was. High workload was not, but boredom was. Failure of pilots or other controllers to conform to a standard operating procedures was, but shift work itself was not.

On the other hand, evidence was heard from the controllers that their shift work and overtime work requirements contributed to family lifestyle stressors. Having become accustomed to the extra financial compensation from long overtime hours, additional financial commitments may also be creating added stress outside the work place. In Canada, there is an Air Traffic Control Occupational Health Program in operation at all of the Area Control Centres. The program is staffed with medical doctors, nurses, and psychologists, usually on a part-time basis. Counselling is available for those who request it. Interviews with these professionals indicate that there has been a steady increase in stress-related complaints, usually the result of excessive overtime. Doctor Roman Jovey, a consultant physician for the Toronto Area Control Centre, describes a typical patient as follows:

- 20 year old controller
- *feels tired but can't sleep*
- working too much overtime but likes or needs the money
- no other activities and therefore lacks balance in his life

Doctor Jovey points out that the average controller age at Toronto is 46 and that older controllers find it increasingly difficult to cope. There is also a high incidence of marital problems and a sense of frustration from a labour/management standpoint.

The occupational health staff indicated that their second major concern after fatigue related problems was controller/management communications. Controllers feel that they are not consulted about changes *which directly affect them, that their opinions are* not respected. This comment was not entirely borne-out by the interviews, but it does underline the need for continuing managerial attention towards establishing and maintaining a good controller/management working relationship.

Motivation

Controllers seem to possess a unique set of skills and attributes which have been difficult to adequately qualify or quantify. This has undoubtedly exacerbated the current difficulties in finding a suitable selection or screening process for new controllers in Canada. Certainly, controllers must have exceptional skills in solving three dimensional time/space problems in real time; they must be able to assimilate and adhere to a complex matrix of prescribed procedures; they must be able to articulate clearly; and today they must have a high sense of commitment to their profession. A controller must be largely intrinsically motivated, gaining personal satisfaction from the job itself; there is little positive reinforcement given to a controller for a job well done. On the other hand, there is considerable negative feedback if the job is done poorly.

Our interviews showed that there is a certain "macho" image among many controllers who believe they can handle all the traffic that the system presents to them. They candidly admit that they have to cut a few corners to do so. Sometimes they take on additional responsibilities, such as accepting hand-offs outside their designated areas of responsibility or trying to provide services that are not mandated. In other words, many controllers today appear to be trying too hard to please the users. To the extent that the "macho" syndrome exists, it imposes difficulties for new controllers. The macho controller may have developed personal techniques for coping with complex situations which are extremely difficult, if not impossible, for a new controller to emulate. The new controller, undergoing on-the-job training, is not only faced with trying to be accepted into an established team, but depends on that acceptance for the quality of his instruction and thus his eventual qualification as a controller.

Visual Flight Limitations

In Canada, there is still a significant amount of air traffic conducted under visual flight rules in and around the busiest terminal areas. In this special investigation, approximately 9% of the reported occurrences involving IFR traffic, involved a second aircraft operating under VFR. A typical occurrence of this nature involves a large aircraft on an IFR approach just outside a positive control zone conflicting with a light aircraft operating VFR and not in communication with the terminal or tower. A second (less common) type of occurrence is an IFR aircraft, inside a control zone, cleared for a visual approach, which conflicts with other IFR traffic cleared for a visual approach or with VFR traffic. In both of these cases the primary responsibility for collision avoidance rests with the pilots using the "see and be seen" principle. While this principle has served the aviation community well over the years, for a number of reasons it does not work as well when faster IFR traffic is involved. For example:

- The mind-set of the IFR pilot that radar separation is being provided from all other traffic. This is particularly true near large airports which have control area extensions (formerly TRSAs).

- The increasing dependence of controllers on secondary radar returns with digital data tags as more and more small aircraft are equipped with transponders.

- The possibility of controllers assuming that non-Mode C returns which appear within the horizontal confines of the control area extension represent aircraft operating below the floor of Class C airspace.

- Increasingly complex arrival procedures combined with automated aircraft systems both of which tend to keep pilots' attention inside their cockpits, thus reducing lookout.

- The generally higher speeds of IFR aircraft reduce the time available for conflict recognition and evasive manoeuvres. At a relative closing speed of 310 knots if a conflicting aircraft is seen inside two miles it is unlikely that there is sufficient time to avoid it.

- As traffic densities build up, the pressure to utilize visual approaches may increase, thus placing more aircraft in a "see and be seen" situation.

At issue is whether it is reasonable, given the technology presently available, to entrust large numbers of lives to a system which depends to a large extent on the human eye and all its natural limitations?

Information Transfer Problems

Another common source of human errors which can create risk-of-collision situations is the information transfer process. A 1981 study conducted by NASA in the United States found that, during the period 1976 to 1981, problems in the transfer of information within the aviation system were noted in over 70% of the 28,000 reports submitted by pilots and air traffic controllers to the Aviation Safety Reporting System. These problems were related primarily to voice communications. Of the 362 Fact Finding Board reports included in the data base of our special investigation, in 197 cases there was a contributory cause factor relating to communications as shown in the accompanying table.

Communications Contributory Factors

Incorrect/Unclear Phraseology	17
Failure to Acknowledge or Verify	19
Inadequate Coordination	77
Inadequate Sector Briefing	17
Transposition Error	8
Incorrect Radar Hand-off	3
Data Posting Error	21
Data Processing Error	21
Data Not Available	4
Other - Communications	10
TOTAL	197

Inadequate coordination was assigned 77 times reflecting a failure to properly transfer information to another controller. Furthermore, while 'forgetfulness', 'constant vigilance not maintained', or 'inattention' were assigned as contributory factors 172 times, communications-related problems were also cited in 94 of these occurrences. For example, inadequate coordination was related to 'inattention', 'forgetfulness' or 'constant vigilance not maintained' on at least 35 occasions.

In one loss of separation occurrence that we investigated, congestion on the ground frequency at Toronto was considered to be a contributing factor. In the 4 minute and 30 second segment leading up to the issuance of taxi instructions for a Boeing 737, the South Ground controller transmitted or received 77 separate radio transmissions. This controller was placed in a situation of having to do too much in too little time. Under such non-stop radio communications, pilots are understandably reluctant to exacerbate frequency congestion by requesting any necessary clarification.

According to Doctor A. T. Lee of the NASA Ames Research Centre in the United States, there are natural limits in the human processing speed for speech, due to short term memory capacity and interference of similar sounding information in recall (for example alpha-numerics). While normal conversation is at approximately 140 words per minute, Dr. Lee has noted speech rates of 300 words per minute in American air traffic control centres. All of such speech is very compact in terms of its alpha-numeric information bearing elements.

In the United States there has been an industry-wide call for action to reduce the 12 most common sources of breakdowns in oral communications. These common issues are as follows:

- Similar sounding alpha-numerics
- Controller hearback problems
- Phraseology
- Enunciation
- Headsets vs speakers
- Radio discipline
- Intra-cockpit communications
- Inter-controller coordination communication
- Blocked or simultaneous transmissions
- Stuck microphones
- Readback problems
- Initial radio contact.

While no quantatative analysis of these factors was conducted in in our investigation, there is evidence that these same phenomena are at work in Canada. Similar sounding aircraft callsigns result in controller and pilot confusion with potential for serious consequences. Controllers frequently are so busy that they miss pilot errors in the readback of clearances or instructions - probably due to hearing expectancy. The use of non-standard phraseology is common for both pilots and air traffic controllers; this can lead to breakdowns in the communications process. The reluctance of some pilots and controllers to routinely wear their headsets, relying instead on speakers, compromises their effective receipt of messages. Most of these problems can be overcome by increased attention and discipline by controllers and pilots alike towards ensuring an effective information transfer; this requires an understanding and sensitivity towards the problems of both sending and receiving messages.

Gander Oceanic Control

Our special investigation revealed unique problems with respect to information transfer in oceanic control areas - specifically the Gander Oceanic Control Area. The absence of direct controller/pilot communications or any means of direct surveillance throughout most of the airspace in the Gander

Oceanic Control Area creates a unique set of communications problems for transatlantic travel. Gander relies very heavily upon HF radio communications and all their attendant problems, including the need for third party involvement in the communications process. In the absence of radar coverage, surveillance of the airspace depends on timely pilot position reporting and an antiquated system of recording and monitoring these positions on paper flight data strips. Given the operating characteristics of HF radios, at the best of times, communications on HF are very time consuming. Controllers reported that delays in relaying a simple message can take up to 30 minutes; routinely, position reports are received 15 to 20 minutes after the fact. Extra support staff are therefore required to process these messages. The international flight service station at Gander is reported to be handling 2,000 to 3,000 HF messages per day, concentrated into the few hours of the peak easterly and westerly air traffic flows. Copying or typing errors occur at this intermediary level as the requisite information is recorded for onroute transmission to the pilot or to the controller. Given this antiquated system of pilot/controller communications and flight following, gross navigation errors go undetected from time to time thereby compromising the overall safety of the system.

Given the increasing volume of traffic over the North Atlantic, is it reasonable to expect a controller to maintain an accurate mental picture of the evolving air traffic situation, relying upon his personal scanning of a tray with 40 or 50 flight progress strips on a tray before him? When a potential conflict between two aircraft is identified, is it reasonable to rely upon a system of pilot/controller communications with up to 30 minute delays in it? With the technologies available today, direct controller/pilot communications is feasible either orally or through data link, and surveillance systems which present a real-time air traffic situation presentation to the controller are feasible. It will take considerable international cooperation and funding to implement the necessary communications and surveillance systems to bring the oceanic controllers' job back within the reasonable bounds of expected human performance.

Regulatory Perspective

From a regulatory perspective, what does all this tell us in Canada, and perhaps elsewhere?

Our understanding of human factors as applied to air traffic controllers appears to be limited. The literature is incomplete, and in some cases additional basic research is required to improve our understanding of natural limitations on controllers' work performance. For example:

- Better means must be found to sustain controller vigilance - particularly during periods of light to moderate workload.
- We need to examine the short-term and long-term effects of constantly rotating work-shift and sleep cycles on controller performance; it would appear that too much is being assumed about what can reasonably be expected of controllers during midnight shifts, during extended work periods without days-off, and consecutive work shifts with only 8 hours off between shifts.
- We need to examine the effects of acute and chronic fatigue on controller performance. We understand these phenomena generally about pilots, but less well about controllers.
- Although stress levels concerning controllers' job performance have undoubtedly been grossly exaggerated in the media, it would appear that at least in Canada the controllers' work-rest patterns and life-style create stressors outside the workplace. We believe that such extrinsic stressors may carry over to the work place - even if we could not demonstrate this. In this regard, the occupational health programs available for controllers should be enhanced to promote life-style modification, as required on an individual basis.
- Because there are significant shortcomings in the data available that has been acquired through the investigation of loss of separation occurrences, a more structured approach to occurrence investigation is required. We need to systematically capture and record the most relevant data pertaining to controller performance in order to facilitate long term macro-analysis and understanding. Only then will the regulatory authorities be able to intelligently alter the controllers workplace, patterns and procedures. Today we are not learning enough from the human errors that are daily compromising the margins of safety in air traffic control.
- With respect to the information transfer process, both pilots and controllers continue to make fundamental errors that could precipitate a mid-air collision. Industry-wide there is a need to sensitize controllers and pilots to the fragility of the oral communications process to misunderstanding. The regulatory authorities can play a lead role in promoting safer interpersonal communications.
- Over Oceanic Control Areas, controllers may be faced with a nearly impossible task today. It would appear that in some respects we have taken "out of sight, out of mind" approach to the control of trans-oceanic flights. Given the increasing volume of intercontinental travel, controllers require a real-time surveillance capability and Direct Controller/Pilot Communications to preserve the traditional safety margins. International cooperation and funding will be required in this regard. Current

efforts by ICAO's Special Committee on the Future Air Navigation System will need to be invigourated by nations.

Conclusion

In summary, the traditional focus of human factors in aviation has been on pilot performance. We must broaden this focus to include another potential weak-link in the air transportation system today - the performance limitations of air traffic controllers.

"Human Factors in Aviation

A Senior Airline Captain's Viewpoint"

by
Captain R. Macdonald
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The term "Human Factors" has, in recent years, been used in many variations particularly after an aircraft accident or incident.

During investigations of aircraft accidents or incidents, the concept of human factors generally relates to the performance of a flight crew immediately prior to and during the problem period, which does not always adequately cover the entire process which has led up to the problem.

There are many definitions of human factors, perhaps the easiest to understand coming from Chapanis in 1985 where he states,

> "Human Factors discovers and applies information about human behaviour, abilities, limitations and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable and effective human use."

If we are to accept this definition we can clearly see that the study of human factors in an aircraft accident or incident must encompass the total concept of the Chapanis definition.

Training programmes have changed considerably over the years and the introduction of the "specific behavioural objectives" or "need to know" has eliminated a lot of unnecessary verbiage being given to the pilot. However, tied together with individual training consoles, it has also removed much of the human factor of a classroom and many pilots feel inadequately prepared for the technicalities of flight operations.

It is also interesting to note that during an accident investigation the technical expertise of a surviving crew member is expected to be at, or above, the level of the aircraft designer, irrespective of the very minimal training given during the pilots' "need to know" ground school, so have we really helped the pilot?

This type of pilot training may make the cost accounts look good but, when an immediate response to a problem is required, the lack of a complete understanding of an aircraft system or component may put such an unacceptable load on the pilot's decision-making process that an incident becomes an accident. Some airlines have tried to compensate for these inadequacies by giving further specific systems training during annual refresher courses, but during the pilots initial flying period after check out on new aircraft (particularly if his other crew members are newly checked out as well) the human factor stresses can thoroughly disrupt what should be a fully coordinated crew effort.

I would not advocate returning to the old ground school system, however, a few days in the classroom to review what has been taught at the console would certainly help to consolidate a better understanding of the aircraft systems and their operation. What we must appreciate and understand is that the graduating pilot must know at least everything the instructors know, both ground school and flight school, as he is the one who must then go do the job in the "real world" and be faced with "real problems."

During a pilot's career, he is exposed to many reports expounding the precise procedures to be used in the event of a specific problem, but such procedures very often are written by engineers who do not understand the human factors involved in the operation of an aircraft.

If we look at the rejected take-off, for instance, we can clearly see that irrespective of the precise procedures laid down in the aircraft operating manuals they very rarely work as planned. Why is this?

We must remember that all the data presented to a pilot with regard to a rejected take-off was supplied by the manufacturer whose test pilot was operating under the following factors:

i) Was rested within his own circadian rhythm normal sleep pattern.

ii) Knew he was going to do the rejected take-off.

iii) Was using a new aircraft with new tires and new brakes.

iv) Probably did the test in ideal weather conditions, with non contaminated runways.

If we review past rejected take-offs that did not work out we will find a consistent similarity in the causal factors.

How many years have we been talking about stopping on contaminated runways? Many years of testing have been done but the results have been generally ignored (FAA tests, NAFEC Atlantic City, Walter Horne). The average airline pilot basically knows that, on a maximum weight take-off, on a rainy or snowy day, his accelerate stop distance will probably exceed his runway length available. Yet when it happens, the industry immediately expresses shock and tries to indict the pilot rather than accept the fact that with the present day rules for the rejected take-off accelerate stop distance these accidents will continue to happen.

Let's look at some of the factors that cannot be precisely defined:

i) The physical and psychological status of the crew.

ii) Crew rest relative to circadian rhythm, days on duty and the length of the duty day.

iii) Effects of enroute delays, weather problems, ATC factors.

iv) Effects of deferred snags.

v) Aircraft status such as all tires and brakes at limits, poor throttle response, etc.

vi) Incompatible cockpit crews causing poor cockpit coordination.

vii) Difficulty in making an immediate assessment of the severity of a problem and reacting immediately in a precise manner often because of the lack of definitive information in the cockpit.

Some accidents where lack of cockpit information caused problems were:

1. Air Canada DC8 Toronto. Engine ripped off wing. No definitive cockpit indications.

2. American DC10 Chicago. Engine tore loose. No definitive cockpit indications.

3. PWA B737 Calgary. Severe engine damage, fire and wing fuel tank damage. No immediate definitive cockpit indications.

4. British Airways B737 Manchester. Severe engine damage, fire, wing and fuselage damage. No immediate definitive cockpit indications.

The record goes on and on and although line pilots have been advocating some technology to view our wings and engines it is only now being considered. Personally, I have not seen the wing or the engines from the cockpit since the Viscount days.

When Wilbur and Orville first flew, they also had to contend with human factors. The environment in which they experimented rapidly proved to be hostile, and even though the mechanics of flight were understood the vagaries of the elements clearly indicated that more precise information had to be given to the pilot in order for him to adequately perform his task of pilotage.

As aircraft have become larger and more complex, we have seen the economic push to reduce cockpit crews to the two-man concept. In some cases, this has been achieved by engineering out the pilot from some systems, either by making them completely automatic or giving the pilots no control over them. Again, however, if an incident or accident occurs, the pilot is expected to have full knowledge of such systems and how they operate. This is like expecting someone to play poker without seeing his cards.

We also seem to be producing cockpit crews who are totally dependent on the cockpit computer systems to do their thinking during times of stress, instead of being pilots and flying their airplanes.

Are we the administrators, the aircraft companies, the airline managements and the pilot groups losing the human factors interface of man and machine in our quest for economics? Are we really examining the true human factors of the professional airline pilots' environment or are we sticking our heads in the sand and hoping it will all go away?

We must reassess our attitudes to the real complexity of the airline cockpit. Accident investigations that provide no answers except to blame the flight crew do nothing for anyone. Pilots do not deliberately plan to have accidents. They are always the result of many factors including "Human Factors" so our discussions must encompass every factor of the pilots' environment, be it training, cockpit design, crew duty times or other factors.

AN OPERATOR'S HUMAN FACTORS CONSIDERATIONS

Alan H Roscoe MD
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Introduction

It is now technically possible - according to research engineers - for aircraft fitted with advanced systems to fly thousands of miles from one airport to another without the assistance of a human pilot. However, it seems most unlikely that the general public is ready to accept the pilotless airliner, even though it appears to accept driverless rail transport. The pilot continues in overall control, and is likely to remain so for several years to come, but the methods he uses to operate the aircraft have changed markedly with the increasing use of automation. The airline pilot of today is much more of a monitor and systems supervisor than an active controller.

But, despite the great technological advances that have taken place during the past 30 years, the proportion of accidents to passenger transport aircraft attributed to flight crew error has remained about the same at just over 70%. It is still most important that the manufacturer and the operator continue to monitor the human factor aspects of flying the aeroplane and be prepared to take action if problems are identified.

For example, the introduction of advanced automation using sophisticated flight management systems, improved autopilots, and electronic displays has generally reduced pilot workload and improved performance; yet, especially in the light of recent accidents, it is being suggested that safety may occasionally be compromised by too much reliance on new technology. Clearly, even though new systems and operating procedures are shown to improve performance most of the time, the possibility that performance may be degraded, even if rarely, should be cause for concern and action.

In this paper some of the issues related to pilot performance and safety will be examined, and a number of examples taken from 'real world' studies carried out over the past 20 years (mostly involving the assessment of pilot workload) will be presented where appropriate. In this respect, it is convenient to use workload as a 'common thread' to connect the different areas of interest.

Pilot Workload

There is no generally accepted definition of the term pilot workload and so it is usually worthwhile defining what is meant whenever the subject is to be discussed.

Nine years ago Ellis and Roscoe (1), using a questionnaire, determined that more than 80% of professional pilots think of workload in terms of effort. It is also an interpretation that agrees well with the individual nature of the piloting task and with such factors as natural ability, training, experience, age, and fitness. Bearing these points in mind Ellis and Roscoe proposed a modified version of the definition used by Cooper and Harper (2) in the introduction to their Handling Qualities Rating Scale: "Pilot workload is the integrated mental and physical effort required to satisfy the perceived demands of a specified flight task." There is evidence that the failure to perceive the demands correctly has been a causative factor in several accidents to passenger aircraft, therefore reference to this aspect of workload in the definition is highly relevant. For example, in 1974, a DC-9 crashed short of the runway at Charlotte North Carolina during an approach in marginal weather conditions; the cockpit conversation was "quite casual and completely unrelated to the flight task".

The most used technique for assessing workload in flight is some form of subjective reporting, and currently it is common practice to use a specially designed rating scale - like the Bedford scale (figure 1). However, as subjective opinions are vulnerable to bias and to pre-conceived ideas it is useful to be able to augment subjective data with a more objective measure, such as recording the pilot's heart rate (3). In the following examples, workload was assessed using this technique.

The Concept of Arousal

When flying an aeroplane, especially during the more demanding manoeuvres, a pilot's brain has to collect, filter, and process information quickly; he has to exercise judgement and make decisions, and then frequently he has to initiate appropriate and sometimes rapid actions. This neurological activity, which must have been important in helping primitive man to survive, is associated with a state of preparedness known as arousal.

Experimental evidence suggests that the relationship between performance and arousal takes the form of an inverted "U" shaped curve; there is an optimum level of arousal for best performance. Levels of arousal are probably determined by how an individual perceives the situation, and by how he responds to his environment. It can therefore be hypothesised that a pilot sets his level of arousal according to how he perceives the difficulty of the flight task. In most people, heart rate reflects the level of arousal.

Although the concept of arousal is an oversimplification of complex neuro-physiological mechanisms, it is functional and, provided that task-induced arousal is not confused with emotion-induced arousal (unlikely in the majority of experienced pilots), it serves to explain the relationship between a pilot's workload and his heart rate. Moreover, pilots seem readily to accept the idea of arousal with regard to their own experiences. The concept is also attractive when associated with flying as there is much evidence that underarousal has been present in the cockpits of public transport aircraft involved in accidents - for instance, the DC-9 accident refered to above. Importantly, there is increasing evidence that as the pilot moves further away from the "control loop" with increasing automation, underarousal is more likely to occur.

Pilot Workload as a Flight Safety Issue

Something like 65% of all accidents to air carriers occur during the approach and landing, and for many years high levels of workload were identified as important contributing factors. Approaches in conditions of reduced visibility were considered to be particularly demanding. The availability of improved autopilots and more accurate and reliable instrument landing systems led to the development of automatic landing techniques which reduced pilot workload significantly, as well as improving landing performance. Although the first fully automatic landing was made by an aircraft of the Blind Landing Experimental Unit in 1948, development continued afterwards for more than two decades.

Assessment of workload, using heart rate to complement subjective reporting, was first carried out at the Royal Aircraft Establishment at Bedford in 1969 during automatic landing trials using a Comet four-jet airliner. Heart rate levels supported pilot opinions that the workload during autolands was substantially less than during manual approaches and landings - as might be expected (fig 2). An unexpected finding was that heart rate responses for autolands in fog (RVRs of less than 300m) (fig

2-F) were generally lower than for autolands in clear weather (fig 2-C). The fewer visual cues to process in fog, and the resulting lower workload, being reflected by lower responses.

Of some concern at the time was emerging evidence that increasing familiarity with autolands in fog might be accompanied by underarousal and, perhaps, by an element of complacency. This observation was reinforced six years later during the flight evaluation of manual landings in fog using a 'fail passive' autopilot system instead of the more usual 'fail operational' autoland system (4). The technique consisted of coupled approaches to a decision height of 60ft (for a BAC 1-11) at which time if the runway lights were seen the decision was taken to disconnect the autopilot for a manual landing. At first, pilot's heart rates increased as decision height was neared in preparation for taking control (fig 3); but after experiencing several flights in fog some of the pilots displayed a tendency for their heat rates to remain relatively steady - increasing only for the hand-flown landing. This reduced response was interpreted as indicating an insufficient level of arousal and preparedness, where the failure to respond rapidly to the unexpected could be critical. Following discussions with the pilots they consciously increased their arousal, in preperation for possible malfunctions, by increasing their instrument scan. This increase in arousal was indicated by an appropriate increase in heart rate.

This example illustrates the importance of assessing workload during the evaluation of new techniques; and of the way in which pilots, on being made aware of possible deficiencies, can overcome them by modifying their attitudes to the task.

The issue of underload, underarousal, and complacency was highlighted some years later during an airline study to compare levels of workload experienced in the new technology Boeing 767 with those experienced in the older Boeing 737 (5). This study, which commenced in 1984, was designed to assess the effects on workload of increasing automation, and to demonstrate that levels of workload were quite compatible with two pilot operation. Volunteer line pilots were monitored on the B737 and then on the B767 following conversion and experience on type. Workload ratings by the pilot and by a flight observer seated in the flight deck (using the Bedford ten-point scale), together with the pilot's heart rate were recorded primarily during high workload phases of flight, like the take-off and initial climb, and the approach and landing; For example, in figure 4 the advantages of an improved autopilot that can be engaged shortly after take-off, and of an autothrottle system, can be seen in the reduced workload for the B767, compared with that for the B737, during instrument departures from the same airport by the same pilot. Observations and recordings at random during the cruise allowed comparison of workload levels at relatively undemanding times.

Personal observation, anecdotal evidence from pilots, and experimental data suggest that in the 767 - with its sophisticated flight management system - an element of underarousal, and possibly complacency, may occur in the cruise, especially at night; this is perhaps not surprising when the demands of the flight task are quite low. Several pilots have admitted that when in the monitoring role they are more easily distracted by relatively unimportant matters.

There is also some evidence that a degree of underarousal may occasionally be present during autolands. Figure 5 illustrates the different workload levels experienced during hand-flown flight director approach and landings and during autolands. (Note - heart rate responses are idiosyncratic and thus levels can only be compared for the same pilot - not between pilots). It is suggested that the heart rate response for the autoland flown by

Captain A is lower than expected possibly reflecting an inappropriately low level of arousal, whereas the response for Captain B is more usual. Such findings seem to be more likely when a pilot has carried out a large number of automatic landings and has become quite familiar with the technique.

It must be prudent for a pilot to be prepared for a rapid take - over from the autopilot during every autoland. This preparedness, analogous to a 'warm up' period, is important when changing from a passive monitor to an active controller.

Automatic complacency is not new, it has occurred in earlier generation aircraft with less advanced systems. In 1972, in a well publicised accident, a Lockheed 1011 Tristar descended into the Florida Everglades when the autopilot disengaged whilst the aircraft was orbiting. The crew were pre-occupied with a malfunction and failed to monitor the aircraft's flight path. And, in 1979, a DC-10 whilst climbing to cruise altitude stalled and lost 10,000 ft before recovery was effected. The flight crew had failed to notice that the autopilot was in the 'rate of climb' mode instead of the 'airspeed' mode.

The greater use of automation with the possibility of underload, underarousal, and complacency is of increasing concern. Although the possibility of this occurring in flight was identified during flight trials more than fifteen years ago, it is only within the past five years or so, since the introduction of aircraft with new technology flight decks, that operators have made any effort to address the problem.

Good flight deck discipline, well designed operating procedures, appropriate training, and a general awareness by pilots of the dangers associated with underarousal are important in minimising this problem. In this respect, the operator has an obvious role to play.

As mentioned above, an increasing number of people argue that workload, although different, may actually be increased by automation, with a consequent reduction in safety. It is pointed out that this increase is particularly likely during in-flight failures and emergencies - such as with the recent B737-400 accident at East Midlands. And again, it is being suggested that a third person is still needed in the cockpit. In view of these comments, it was decided in 1987 to extend the airline study to examine the effects of abnormal flight on workload in a B767 simulator(6).

The suitability of the simulator was first demonstrated by obtaining similar workload ratings and heart rate responses from pilots flying normal departures and arrivals in both aircraft and simulator. An example is shown in figure 6. The study is still in progress and levels of workload experienced during a wide range of failures and emergencies are being assessed in a number of pilots, both as 'pilot flying' (PF) and as pilot not flying (PNF). Figure 7 shows the heart rate responses and workload ratings for an engine failure with separation from the aircraft causing damage to the flaps, and for the subsequent single-engine approach and landing at a higher than normal reference speed. To date, workload ratings and heart rate responses have indicated that levels of workload are well within accepted limits.

Prior to certification the aircraft manufacturer has to demonstrate that levels of workload, during normal and abnormal flight, are reasonable. But, as is often pointed out, evaluation teams usually consist of test pilots and airline management pilots, and therefore may not be truly representative. This study, using line pilots, may add some support for the manufacturers certification programme - see below. Of course, a flight simulator is not a real aeroplane and, no matter how good, it cannot reproduce all the factors involved in flying. For instance, it has been suggested many times that heart rate responses in a simulator will not be as high because of the absence of danger. However, there is good evidence to show that in most professional pilots increased risk is not a factor in modulating heart rate in flight (7). The important factors in obtaining realistic responses and ratings in simulation are the fidelity of the simulator itself and the realism of the flight scenarios.

It should be possible for many operators to carry out their own critical evaluation of crew workload and co-ordination using a flight simulator and appropriate scenarios. This type of study, which would fit neatly into a Cockpit Resource Management programme using LOFT, could well lead to better operating procedures and to an improved training protocol.

Certification of Aircraft for Crew Complement

Following a long, and sometimes acrimonious, debate between pilot's unions on the one hand, and operators and manufacturers on the other, on whether passenger transport aircraft can be flown safely by two pilots, President Reagan established a Task Force to examine the question impartially. The President's Task Force on Aircraft Crew Complement reported in July 1981 (8), and identified flight deck workload as an important issue. It subsequently became necessary for manufacturers to assess workload during aircraft certification in order to satisfy the requirements of FAR 25.1523 and Appendix D, regarding crew complement.

British Aerospace elected to demonstrate compliance with the requirements during the certification of the two-pilot BAe 146 by means of a mini-airline exercise. In 1982 three teams of two pilots each flew consecutive three-day intensive flight schedules around a circuit of three major high intensity airports: London - Heathrow, Paris - Charles de Gaulle, and Amsterdam - Schiphol. Crew duty hours were substantially in excess of those allowed by the CAA for passenger flights. Pilot workload was assessed by means of subjective estimates from both pilots and from a flight observer seated in the flight deck (using the Bedford Scale and a post-flight questionnaire), and by recording the pilots heart rates. Flight deck activity and performance, including error counts, were monitored by video cameras sited in the flight deck.

The first day of each crew schedule consisted of normal - albeit intense - operations, on the second and third days various failures and emergencies were 'injected' into the operation. Heart rate was recorded continuously from before engine start-up to after engine shut-down; subjective ratings were requested according to a pre-determined plan, being more frequent during the predicted high workload phases of flight.

Subjective data and heart rates showed good agreement and demonstrated clearly that the BAe 146 can be operated safely with a complement of two pilots; figure 8 is an example of mean heart rates and workload ratings. Video recordings not only proved that performance was adequate but also confirmed that, in general, operating procedures and crew co-ordination were satisfactory.

Flight evaluation for the purpose of certification will often provide valuable practical data that can be used in the construction of manufacturers recommended operating procedures. However, these procedures are not necessarily appropriate for the individual operator because of differing operating philosophies and cultures. Local modifications or 'fine-tuning' may be of considerable benefit. In this respect, additional information based on the results from manufacturers flight trials, may be of use to operators.

Workload Distribution

Most research into pilot workload to-date has been directed towards the operating pilot or pilot flying (PF), rather than towards the non-operating pilot or pilot not flying (PNF). But it is important also to assess the levels of workload experienced by the PNF and, in particular, how the distribution of workload between two pilots can be influenced by different operating procedures and by abnormal situations. In the case of the PNF, who is most unlikely to have to take control of the aircraft, heart rate is of less value and one therefore has to rely more on subjective estimates of workload.

In the airline study referred to above, several pilots have been monitored as PF and as PNF during normal flight and during emergencies with some interesting results. For example, the workload of the PNF during some flight tasks may be increased by the level of automation that reduces the workload for the PF. A hand flown flight director standard departure in the B767 generates a lower workload for the PF than in the B737, but the workload for the PNF is increased by having to make frequent selections to the Flight Director System - resulting in ratings of 4 - $4^1/2$, compared with 3 - $3^1/2$ for the B737, figure 9. This change is particularly evident during emergencies such as an engine failure (figure 10) when automation reduces the workload of the PF significantly, while increasing that of the PNF because of the number of items to be addressed. In an emergency the captain may elect to take control so that, with a lower level of workload than that of the PNF, he would have more time for appropriate decision making.

Discussion

The examples presented above have been selected specifically to illustrate a number of flight safety issues that are associated with human factors. It is intended that they provide 'real world' points for discussion, not to form a comprehensive list. The research engineer, the manufacturer, and particularly the operator need to be aware of such issues and be prepared to take appropriate actions where necessary to maintain high levels of safety.

The assessment of workload during routine airline passenger flights in Britannia Airways Boeing 737 aircraft was started in 1977 as an extension of the Royal Aircraft Establishment Bedford flight trials. The study generated much interest within the airline and many pilots expressed a wish to participate. This level of interest, which has been maintained through to the current assessment of workload during abnormal flight, has been invaluable in generating a large number of conversations 'in confidence' with pilots about their own operational experiences. Much of this information, in a non-identifiable format, has been of considerable use in discussions with management pilots.

Obviously, most commercial operators cannot be involved in research. An airline study of the type described here must be quite unusual. Nevertheless, the results of 'real world' studies involving line pilots during routine operations can be communicated easily to non-participating pilots. The ability to associate their own experiences with data obtained from 'experimental subjects' would seem to add credibility to those data. In addition, operators can encourage regular discussion and 'feed back' from their own pilots which, with their own analysis of occurrences and incidents, might well lead to a re-evaluation of operating practices and training programmes.

A designated Flight Safety Officer (FSO) should have responsibility for co-ordinating activites within an operating company. As well as being a pilot he should have some training in safety, attend appropriate seminars (such as those organised by the Flight Safety Foundation) and publish a company journal on safety matters. Relevant information should be readily available for all flight crew.

Finally, it must be appropriate, from the point of view of flight safety, for operators to remind their flight crews periodically of the various medical and medically-related factors that can influence their performance. This can be accomplished most readily by articles in the company flight safety journal, and by the occasional presentation during refresher training.

The subject of pilot fatigue is always of concern and operators are responsible for ensuring that rosters comply with legal requirements. It is also good practice occasionally to remind rostering personnel of the factors involved in contributing to tiredness and fatigue, and to underline the benefits of a reasonably stable roster.

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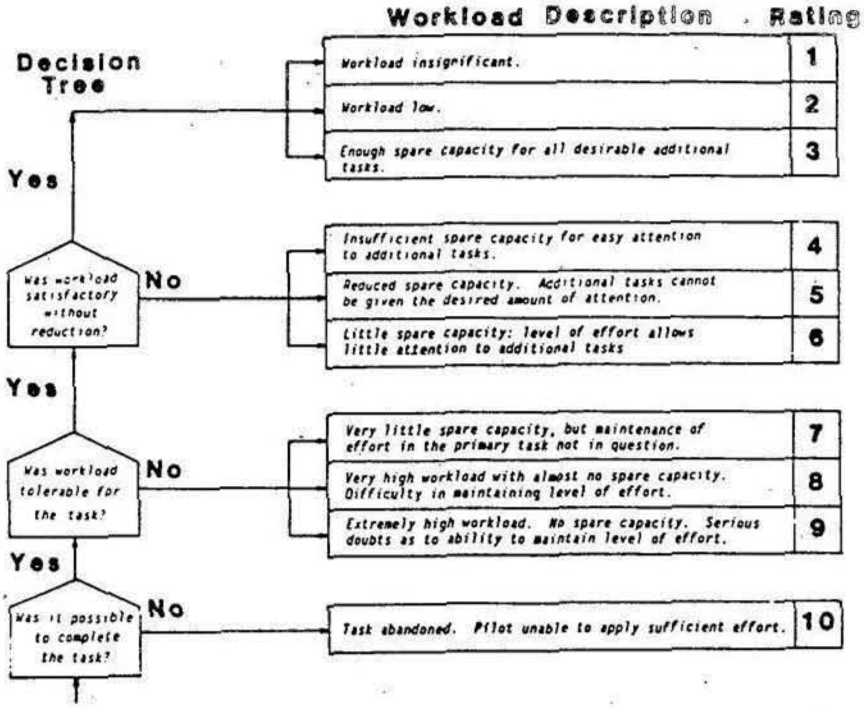

Figure 1 The 'Bedford' Pilot Workload Rating Scale. The pilot starts his decision-making process at the bottom left corner of the decision tree. The workload being assessed is that involved in the execution of the primary task, the effort expended on additional tasks must be included as part of his 'spare capacity.'

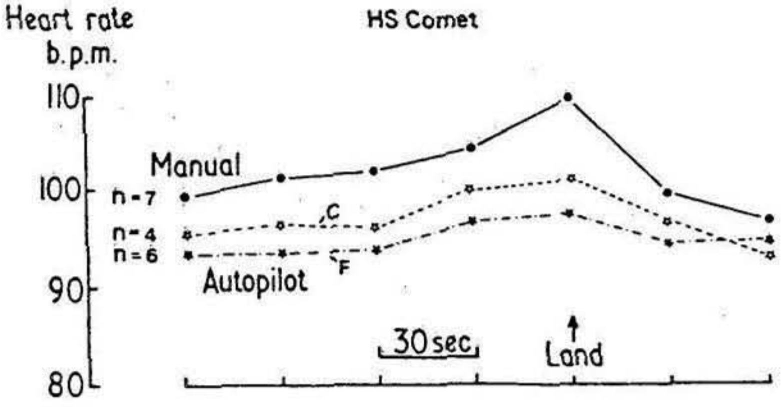

Figure 2 Mean heart rates (30s) for manual landings, and for autolands in fog and in clear weather. HS Comet.

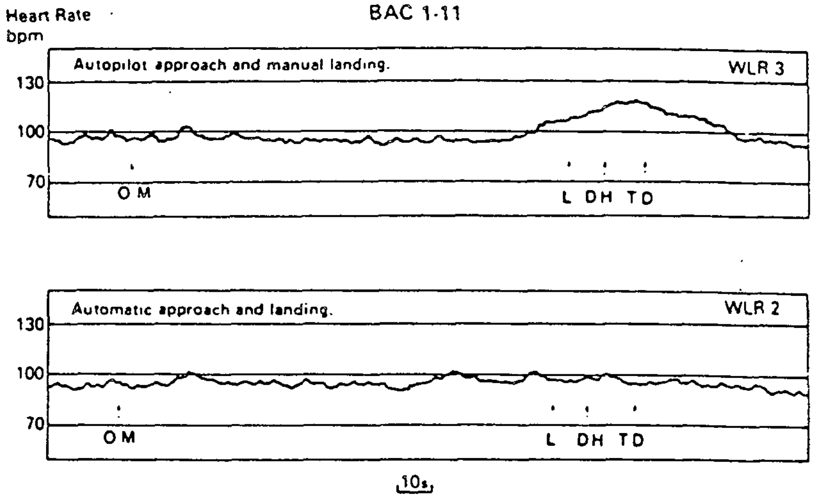

Figure 3 Beat-to-beat heart rates and workload ratings (WLR) for one pilot recorded during the same experimental flight in fog (RVR 190m). BAC 1-11. Upper trace autopilot approach and manual landing. Lower trace - autoland. L - Lights seen, DH - decision height, TD - touchdown.

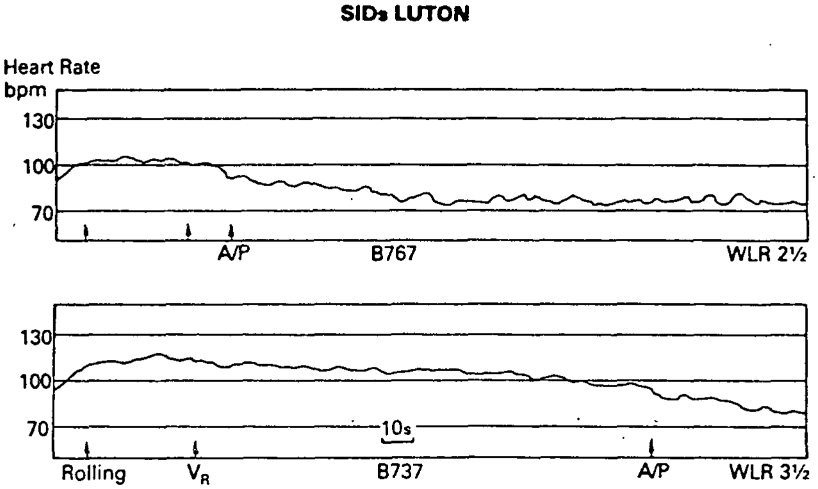

Figure 4 Comparison of heart rate responses (beat-to-beat) and workload ratings for standard instrument departures from the same airport B737 and B767.

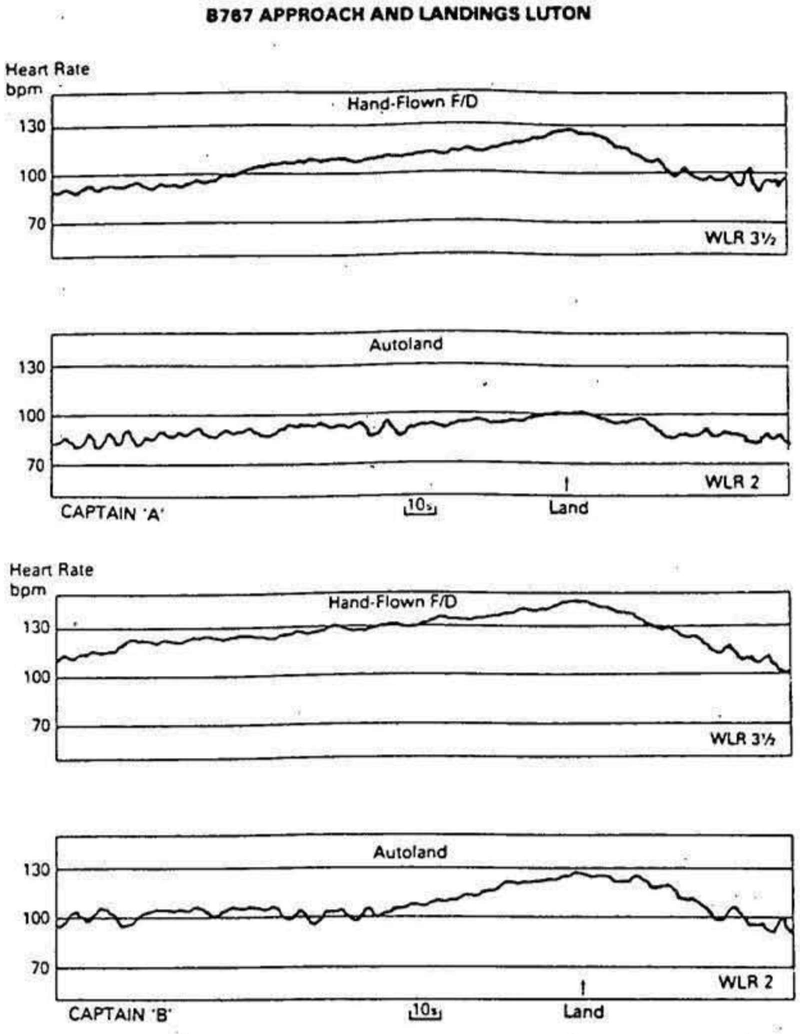

Figure 5 Heart rate responses and workload ratings for manual landings and autolands for two pilots.

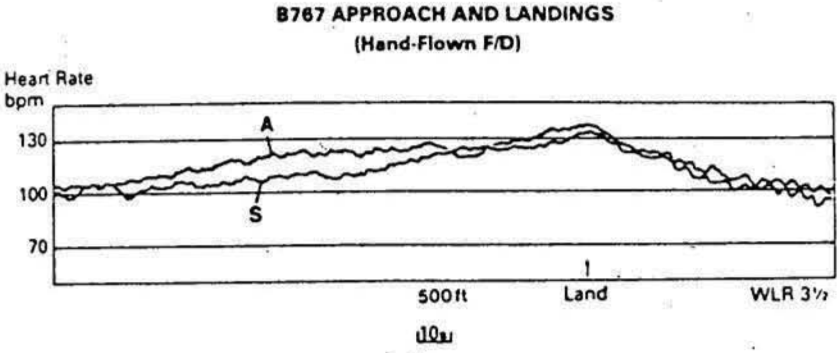

Figure 6 Heart rate responses and workload ratings for approach and landings in the aircraft (A) and in the simulator (S).

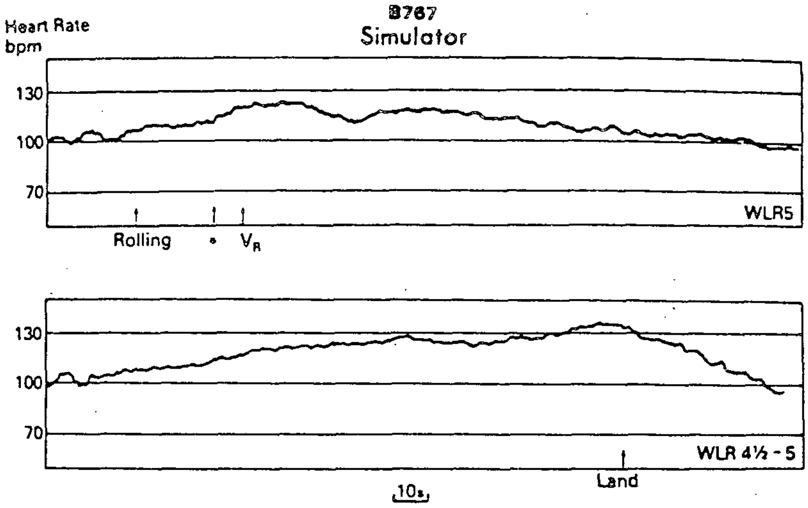

Figure 7 Engine failure on take-off (*) and single-engine approach and landing.

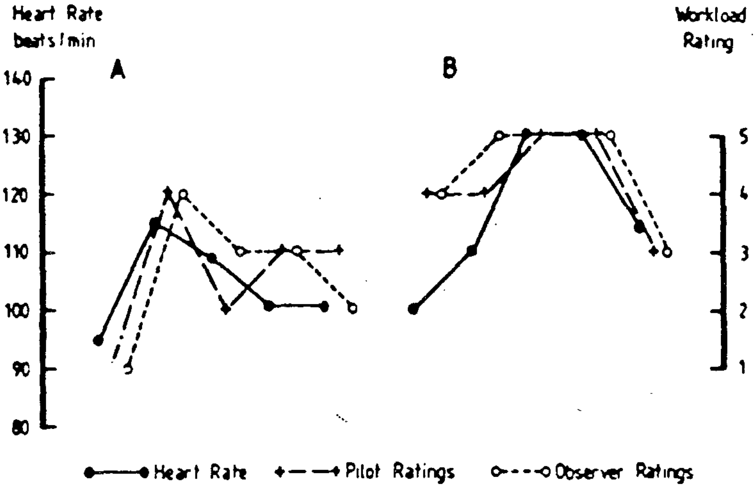

Figure 8 Plots of man heart rate responses (30 sec) and of workload ratings from the handling pilot and flight observer - BAE 146.

A - Take-off and departure from Hatfield.
B - Approach and landing at Amsterdam.

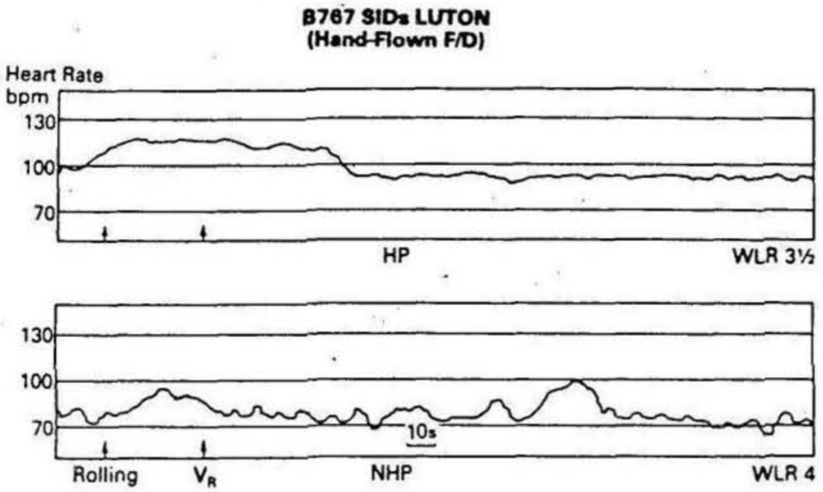

Figure 9 Standard departures - same pilot as PF (HP) and PNF (NHP).

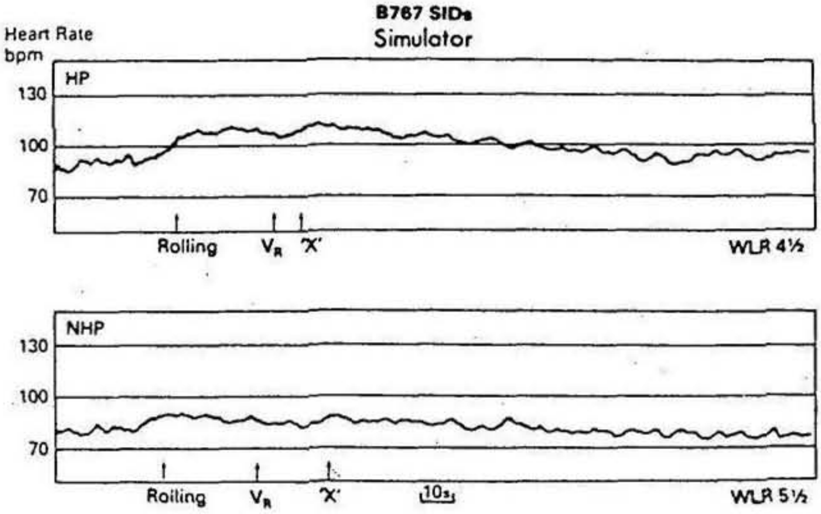

Figure 10 Engine failures after take-off 'x' - same pilot as PF (HP) and PNF (NHP).

HUMAN FACTORS OF THE HIGH TECHNOLOGY COCKPIT

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INTRODUCTION

The development of the microprocessors of the 1970 decade brought to transport aircraft a new era of cockpit automation, and the opportunity for safe, fuel-efficient, computer directed flight. It also brought a host of problems, not due to equipment failure, as the new devices proved to be highly reliable, but due to problems at the human-automation interface. The automation also offered the promise of conserving that one irreplaceable asset, air space, by permitting more precise maneuvering of the aircraft. However, the capabilities of the aircraft far outstripped those of the ground-based air traffic control (ATC) system, so many of the promised economies in fuel, crew time, and air space have not been realized.

The development of the advanced automation was coincidental with, and to some degree responsible for, the acceptance of the two-pilot crew, even for wide body aircraft, since much of the evaluation of the new cockpits has been based on a presumed workload reduction.

The introduction of the advanced technology cockpit was based on three major assumptions:

1. A reduction of workload, enabling the two-pilot crew even on wide-body jets and transoceanic operations.
2. A reduction in human error, by replacing human functioning with seemingly infallible machine functioning.
3. Uncritical acceptance of the equipment by the pilots.

These assumptions were first questioned in a paper by Wiener and Curry (1980), and later in their field studies (Curry, 1985; Wiener, 1985b, 1989b) of airline crews flying advanced aircraft. Chambers and Nagel (1985) have examined the role of the pilot (versus the computer) in the future cockpit.

The thrust today, on the part of researchers, manufacturers, regulatory personnel, and operators should be to solve the problems occurring at the human interface. It is no longer a question of whether cockpit automation is a good thing; it is here to stay, and every effort should be made to overcome the problems. The author is optimistic that this can be done, but only after a recognition that the current generation of automation has not lived up to its promises (Wiener, 1985a, 1988).

In this paper the author will outline some of the problems, both in the equipment and in the environment in which it operates, and then discuss training for automatic flight. A discussion of approaches to error reduction and management can be found in Wiener (1989a). General guidelines for automation by Wiener and Curry (1980) are listed in Appendix A. Obviously these are only a beginning, and development of more refined guidelines should be encouraged.

THE INTERFACE

As in the introduction of any new technology, the modern cockpit solves a great many problems, but creates some as well. These problems are documented in detail in the field studies by Curry and by Wiener listed above. Suffice it to say that the pilots have found the devices somewhat difficult to operate. They often require trial-and-error efforts to input the required solutions, and these impose heavy workload, often at the very point in a flight where workload is already high. It is also easy to input erroneous data and have the computer accept this and act on it. As in any auto-navigational system, it is also possible to enter an erroneous waypoint that will lie dormant for hours and not be a factor until it becomes active.

At the same time, the advanced capability of the map mode of the horizontal situation indicator (HSI) is an effective deterrent to errors. This feature is an example of what Wiener (1989a) has called an "error-evident" system, not preventing an error, but making it apparent to the pilot so that it can be corrected. Pilots are enthusiastic about this display, and recognize its value to safety. Those who have left the "glass cockpit" aircraft for more traditional models report that this is the feature they miss the most.

THE ENVIRONMENT

One should not view an airliner as if it operates in isolation from the rest of the world, but must recognize the extent to which it is affected by the environment in which it operates. This includes obviously the ATC environment, but also the economic, the regulatory, and the company environment. Research points toward an interaction of each of these with automation in the cockpit. For a further discussion of the influence on ATC on the operation of the "glass cockpit" aircraft, see Wiener, 1989b, Chapter V.

The ATC Environment

First and most obvious is the ATC environment. Note that the following comments apply only to ATC in the U.S. I do not know the extent to which they apply to ATC systems in other parts of the world, but I would guess that the situation is no better elsewhere. The problem very simply is that the current ATC system does not allow the exploitation of the remarkable capabilities of the modern aircraft, particularly LNAV, VNAV, and speed control. If a crew has programmed an LNAV and VNAV path and perhaps speeds and crossing restrictions, it is unlikely that they will be allowed to fly it to completion. Off-course vectoring, speed restrictions, and changes in preprogrammed altitudes can cause the program to "go out of the window", stripping the aircraft of its most valuable navigational assets, and possibly throwing the crew into a high workload in order to reprogram the changes.

It is unlikely that this lack of harmony between the capabilities of the aircraft and those of ATC will be remedied soon. Although work is continuing on modernizing the ATC system in the U.S. under the National Air Space Plan, we will probably be into the next century before we see the benefits. These problems are particularly critical in terminal areas, where ATC changes result in heavy programming workloads and "heads-down" time, often for both pilots at once, in contravention of airline procedures and good safety practices. As captains gain more experience in the glass cockpit, they seem to be more prone to "turn it off" and fly either manually or with autopilot/flight director support via the mode control panel (MCP).

This is a matter of some controversy. Captains typically regard the choice of equipment and flight modes as a matter of their discretion -- when to use or not use automatic features in the flight guidance systems. Some companies have maintained a policy which the pilots refer to as "we bought it, you use it." The Wiener-Curry guidelines (Appendix A) essentially support the view of the pilots, leaving the choice up to the crew. The Wiener-Curry approach essentially says that automation is on the aircraft to aid the pilot: the extent to which the pilots feel that it is doing so is the extent to which they should use it. At any given time if they feel otherwise, they should, within reason, feel free to deselect the various modes and features. We emphasize "within reason" as we recognize that certain maneuvers should be performed only with the support of automation. We are not recommending a raw data, hand-flown Cat IIIb approach!

The Company Environment

Little has been written about the impact of the policies and procedures of the individual company on the operation of the automatic aircraft. One may ask why single out the automatic aircraft? The answer is that the most modern aircraft seem to be the most sensitive to influences external to the cockpit, including company policies.

The "we bought it, you use it" policy has already been mentioned. Another basic policy question concerns checklists and procedures. For example, some companies have sought to minimize the differences in procedures and checklists between the traditional and the modern aircraft to aid in transition and minimize the likelihood of error. A discussion of the impact of company culture and philosophy on checklist design and implementation will be found in Degani and Wiener (in preparation).

An example is the use of airborne radar on the ground. With the advent of the MD-80 (formerly DC-9-80) series aircraft, a much lower power radar was installed, providing a safer environment for ground personnel. For this reason it was possible to change the procedures and checklists, allowing the radar to be turned on in the gate environment. However, some carriers, especially those allowing "mixed lines" of flying, continued to operate the MD-80 radar in the same manner as the DC-9 series, in order to eliminate the possibility of exposing ground personnel to risk, and in general to simplify procedures.

The policy of treating unlike aircraft alike has both advantages and disadvantages, and should be approached with caution. Obviously there are some advantages, as in the radar example just cited, but such a policy may also result in sub-optimal use of the more modern aircraft. With the rapid movement of pilots between seats and the mixed fleets in today's airlines, this matter requires considerable thought.

One of the most controversial matters in company policy is that of mixed fleets of traditional models and modern derivatives (e.g. the DC-9 and MD-80 series; the B-737-100/200 and -300/400/500; the A-300-600 and A-310). Although the FAA has ruled that some of these derivatives are essentially the same aircraft and can be operated with a common type rating, some airlines, encouraged by the pilots' unions in most cases, have chosen to "separate" the fleets, not allowing crews to fly both. Separation of the fleets may impose an economic burden to the airlines, which would like maximum flexibility in assigning crews to aircraft, but it is generally regarded as a plus for safety.

Finally the company environment includes the documentary support provided to the flight crew: flight plans, weight and balance computations, weather, load advisories etc. Again the author would state that this is not model independent, but is most critical in the automated aircraft. An example of a flight plan provided to the crew of a B-757 is given in Wiener (1989b, p. 180). In this case, a waypoint was written on the flight plan as simply "CLB" (Carolina Beach), making it appear to be a VOR. When the pilots typed it in on the Route Page, they continued to obtain "not in database" error messages. The problem was that Carolina Beach is a non-directional beacon, and to be consistent with the Flight Management Computer (FMC), the flight plan should have listed it as "CLBNB". In summary, we recommend that all operators reexamine their checklists, procedures, and all documentation to make certain that they are appropriate for the modern cockpit.

The Regulatory Environment

One cannot examine cockpit automation without confronting the regulatory environment and its effect on the conduct of training, flight, and quality control. The role of the regulators begins with certification of new aircraft and equipment. Unfortunately the human factors profession has not made a great impact in the world of certification. Under Part 25 of the FARs, human factors appears only in the demand that a workload study be made in order to evaluate the minimum crew size. The author feels strongly that human factors should be a central technology in the certification of new aircraft, far beyond workload, particularly in the determination of error-resistant designs and procedures. For a general discussion of human error in aviation operations, see Nagel, 1988.

The important question of a single type rating for derivatives of earlier models is complex and difficult. Following the DC-9/ MD-80 series, the trend was toward a liberal granting of common type ratings. In the last two or three years, the trend has reversed and the FAA has been less willing to treat a derivative as the same aircraft as its predecessor (e.g. B-747-100/200/300 versus the -400). In some cases there can be little argument about common type ratings (e.g. B-757/767 and A-300-600/A-310) where the cockpits are essentially identical. As mentioned previously, even in those cases where a common type rating satisfies the FAR requirements, it may not satisfy any particular airline, which can chose to treat derivatives as separate fleets.

Finally, the regulators also influence the use of the modern aircraft in their examination of crews, both in initial checkout and in biannual proficiency checks (PCs). Here the use/non-use controversy surfaces again. The question is whether the examiner should insist that a particular mode or automatic capability be used, or should leave that to the pilot. This has caused some consternation among the pilot group, who feel that it is up to the examiner to assign and grade the maneuver, not to tell the pilot what equipment to use. Wiener (1989b) quotes a B-757 captain who told him, "In the past the FAA examiners were always turning equipment off; now they make me turn everything on."

The Economic Environment

The rapidly changing economic environment in the world's airlines, brought by deregulation, rapid expansion, mergers, and internationalization, impacts the utilization of automatic equipment. The extremely rapid expansion of traffic in the U.S., without a corresponding increase in airport or ATC capacity, is a problem for all aircraft, but there may also be special effects o the modern aircraft. The effects involve high density traffic in an inadequate ATC system, extended operations over water with two-pilot crews, and the demand for expanded pilot training including inexperienced pilots (see below), and the incorporation of new equipment (TCAS, MLS, HUD, and Mode-S, for example). In short, the economic environment, which demands as never before that aircraft be operated efficiently and profitably, may amplify all of the other effects mentioned in this paper.

TRAINING

The question most often asked of the author is "What can you tell us about training for the high tech aircraft?" Unfortunately my answer would have to be "not much."The question expresses a concern about the quality of training, and the fact that training is quickly becoming a runaway cost for the airlines. The human factors profession has not examined the question, at least in the air transport environment. This is one place where military research is well ahead of the civilian world. My remarks will be confined to pilot training, but no doubt the same is true of training maintenance personnel for the high tech models.

The training problem can be summarized as follows:

1. The automated aircraft is not merely a traditional aircraft with some extra "boxes". It requires all of the old skills of airmanship and command, and many new ones as well. This has not been well documented.

2. The training courses for pilots transitioning to more highly automated models are considered arduous. Pilots complain about the amount of "book work" they must do at the end of an already stressful day, and overall the amount of information that is crammed into two weeks of ground school.

3. Training devices have not kept pace with training demands. The emphasis has been on the development of high-cost, high-fidelity simulators with elaborate motion and visual systems. These are extremely effective training devices,but their capabilities are often under-utilized when used

for training skills (e.g. elementary CDU operations) that could be assigned to less costly devices. At some airlines, cockpit procedures trainers (CPTs) (also called cockpit systems simulators) relieve the simulators of this load, but these devices are also extremely expensive, and the same comment may be made about them: many operations could be assigned to part-task simulators and less elaborate devices.

4. Traditional class room ("stand-up") instruction has been largely replaced by auto-instructional devices. Most of these employ audio tapes and color slides, which are fairly effective for routine material, but are essentially non-interactive, except for occasionally asking the trainee a question. More elaborate devices employ laser disks with the potential for movie-like dynamic displays. The examples the author has seen have been disappointing. They have been used merely to show what are essentially computer-produced static pictures, which are little better than color slides, rather than exploiting their potential for dynamic displays, possibly in conjunction with interactive display-control systems. Some touch screen devices are in use, and these offer the opportunity for a higher degree of trainee-system interaction (e.g. programming a CDU), but most are driven by extremely limited course ware, which is unresponsive to most of the inputs a trainee might make.

5. Current pilot contracts allow rapid movement from seat to seat. This, combined with the rapid expansion of airlines, with new equipment and new routes, as well as new hires, is now resulting in over-taxed training departments. The situation can only become more critical in the years to come. We can only hope that new training technology will be developed to help cope with the problem.

6. As traditional sources (e.g. the military services) of new hires continue to dry up, airlines will of necessity turn to non-traditional sources. Already there are problems arising from the depletion of the ranks of the regional carriers due to the hiring practices of the major airlines. Soon the airlines in the U.S. and elsewhere will face the greatest peace-time training challenge in history. One of the potential sources of new hire pilots will be the ab initio pilots, low-time, inexperienced pilots trained for airline seats. This system has worked quite successfully for years in Europe, but its training potential is only now being recognized in the U.S. The impact of automation is that in the years ahead highly automatic aircraft such as the MD-87/88, B-737-400, and A-320 will be the low seniority planes in many company's fleets, and very inexperienced pilots will be placed into the right seats of very sophisticated aircraft. This is a special challenge to training departments, and to the human factors profession.

CONCLUSIONS

Modern cockpit automation offers the airlines of the world the potential for safe, efficient flight, but there are a host of problems with the current models, as well as the environment in which they operate, which must be solved before their full potential can be realized. These problems will demand the ingenuity and cooperation of the designers and manufacturers, the government, the airlines, the pilot groups, and the world-wide human factors research community.

ACKNOWLEDGMENTS

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APPENDIX A

Automation Guidelines from Wiener and Curry (1980)

Control Tasks

1. System operation should be easily interpretable or understandable by the operator, to facilitate the detection of improper operation and to facilitate the diagnosis of malfunctions.

2. Design the automatic system to perform the task the way the user wants it done (consistent with other constraints such as safety); this may require user control of certain parameters, such as system gains (see Principle No. 5). Many users of automated systems find that the systems do not perform the function in the manner desired by the operator. For example, autopilots, especially older designs, have too much "wing waggle" for passenger comfort when tracking ground based navigation stations. Thus, many airline pilots do not use this feature, even when traveling coast-to-coast on non-stop flights.

3. Design the automation to prevent peak levels of task demand from becoming excessive (this may vary from operator to operator). System monitoring is not only a legitimate, but a necessary activity of the human operator; however, it generally takes second priority to other, event-driven tasks. Keeping task demand at reasonable levels will ensure available time for monitoring.

4. For most complex systems, it is very difficult for the computer to sense when the task demands on the operator are too high. Thus the operator must be trained and motivated to use automation as an additional resource (i.e. as a helper).

5. Desires and needs for automation will vary with operators, and with time for any one operator. Allow for different operator "styles" (choice of automation) when feasible.

6. Ensure that overall system performance will be insensitive to different options, or styles of operation. For example, the pilot may choose to have the autopilot either fly pilot-selected headings or track ground-based navigation stations.

7. Provide a means for checking the set-up and information input to automatic systems. Many automatic system failures have been and will continue to be due to set-up error, rather than hardware failures. The automatic system itself can check some of the set-up, but independent error-checking equipment/procedures should be provided when appropriate.

8. Extensive training is required for operators working with automated equipment, not only to ensure proper operation and set-up, but to impart a knowledge of correct operation (for anomaly detection) and malfunction procedures (for diagnosis and treatment).

Monitoring Tasks

9. Operators should be trained, motivated, and evaluated to monitor effectively.

10. If automation reduces task demands to low levels, provide meaningful duties to maintain operator involvement and resistance to distraction. Many others have recommended adding tasks, but it is extremely important that any additional duties be meaningful (not "make-work") and directed toward the primary task itself.

11. Keep false alarm rates within acceptable limits (recognize the behavioral impact of excessive false alarms).

12. Alarms with more than one mode, or more than one condition that can trigger the alarm for a mode, must clearly indicate which condition is responsible for the alarm display.

13. When response time is not critical, most operators will attempt to check the validity of the alarm. Provide information in a proper format for that this validity check can be made quickly and accurately and not become a source of distraction. Also provide the operator with information and controls to diagnose the automatic system and warning system operation. Some of these should be easy, quick checks of sensors and indicators (such as the familiar "press to test" for light bulbs); larger systems may require logic tests.

14. The format of the alarm should indicate the degree of emergency. Multiple levels of urgency of the same condition may be beneficial.

15. Devise training techniques and possible training hardware (including part- and whole-task simulators) to ensure that flight-crews are exposed to all forms of alerts and to many of the possible conditions of alerts, and that they understand how to deal with them.

HUMAN IMPACTS OF ADVANCED AIR TRAFFIC CONTROL SYSTEMS

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The Federal Aviation Administration (FAA) is carrying out numerous simultaneous activities guided by the National Airspace System Plan to design and acquire new air traffic control subsystems. More highly automated equipment is being introduced to increase capabilities for performing diverse functions, including:

- aircraft surveillance
- ground/ground and ground/air communications
- operational data processing, transmission, and display
- tactical traffic separation
- strategic traffic management

This paper is an overview of what FAA is doing to ensure that these advanced systems effectively support the air traffic controllers who will use them. In preparing for these system advances, the Air Traffic services are especially concerned with the following goals:

- to preclude significant human factors problems
- to ensure operational effectiveness and suitability
- to foster smooth transitions during implementation

Successive sections of this paper address the following topics:

1. the systems that are setting the pace
2. assessment of controller impacts.
3. projection of personnel requirements
4. controller training to augment system benefits

1. SYSTEMS THAT ARE SETTING THE PACE

Among the near term system developments that are driving our investment of resources, the following stand out. They are the most complex of the advanced systems, and will have substantial operational and human impacts. The innovations that the systems will introduce are briefly itemized here.

1.1 Initial Sector Suite System - first site by 1993

a. New computer consoles at Air Route Traffic Control Centers equipped with:

- Partitionable radar situation display screens, capable of displaying various kinds of data, including flight plans

- Electronic tabular display and manipulation of flight data

- Auxilliary electronic display for maps, charts, and other static information

- Message and data entry, as well as flight data notation, via keyboard and slew ball; no pencil entries

- Touch entry of voice communication channels and functions

1.2 Initial Data Link Services - systemwide by 1994

a. Digital communication of the following kinds of air traffic control information:

- transfer of communications frequency

- altitude assignment

- stored ATC messages

- typed ATC messages

1.3 Terminal Advanced Automation System - first site by 1995

a. Terminal Radar Approach Control facilities relocated to air route traffic control centers, where approach and departure control will be conducted using Initial Sector Suite System consoles; these consolidated centers will be called area control facilities

1.4 Tower Control Computer Complex - first site by 1995

a. Initial Sector Suite System consoles and software modified for use in the space-limited, brightly illuminated (by day) tower cab environment

1.5 Automated En Route Air Traffic Control - first site by 1998

a. Automatically predict flight conflicts at least 20 minutes into the future and generate ranked resolutions for:

- aircraft-to-aircraft conflicts
- aircraft-to-airspace conflicts
- aircraft-to-flow instructions conflicts

b. Accommodate pilot-preferred routes of flight and, even in heavy traffic, provide:

- conflict free direct routing
- timely response to re-route requests

c. Extensive digital transmission of controller-approved control information to pilots or other controllers

2. ASSESSMENT OF CONTROLLER IMPACTS

Various activities are under way to assess controller impacts -- more specifically, effects related to workload and performance. The activities involve collaboration among FAA offices that have different functions and different kinds of expertise. The work is truly multidisciplinary.

2.1 Identify Adverse Design Features Early

The earlier problems are detected and corrected during design of a subsystem, the better -- especially if the problems are identified by the operational personnel who will eventually use the equipment. Experienced air traffic controllers from different field facilities are thus serving on a number of teams that periodically evaluate equipment while it is being designed and developed. These teams are supported by technical professionals in other disciplines.

2.2 Strengthen Test and Evaluation Process

Despite the increased participation of operational personnel in subsystem design, opportunities still exist for developing features that have operational or human factor deficiencies. The FAA test and evaluation program addresses this possibility.

The Test and Evaluation Program Order (1810.4A) has been revised by persons from FAA's developmental and operational services, and is nearly ready for approval review. It specifically indicates, in addition to other matters, how the operational services shall participate actively in each step of the test and evaluation process for each major subsystem acquired into the National Airspace System.

Test and evaluation processes are also monitored and controlled by a recently strengthened Test Policy and Planning Review Board (TPRB) of service directors. These officials represent the services that develop the systems as well as the services that eventually use them.

2.3 Obtain Controller Feedback

After the advanced systems become operational, the psychologists of FAA's Civil Aeromedical Institute will apply interview and survey methods to identify problems and concerns of operational personnel, as well as overall employee satisfaction within the more automated environments. Assessments will also be applied routinely within the operational services themselves.

2.4 Simulate Alternative Equipment Configurations

The FAA Technical Center is expanding its cadre of human factors professionals in response to more numerous human factors initiatives. Also, the Center is expanding its laboratory capabilities to include a Human Factors Laboratory. This will be used for rapid prototyping of alternative automation configurations for evaluation via real time air traffic simulation.

2.5 Real Time Simulation of Automated Air Traffic Control

Hands-on access to a prototype of the Automated En Route Air Traffic Control (AERA) 2 subsystem has been provided controllers for several years during its design. Specifications from that effort will soon be used to build a realistic simulation of that system at the FAA Technical Center. This real time air traffic simulation will permit operational evaluation of the AERA 2 concept not only by controllers, but also by human factors engineers, psychologists, training experts, and computer scientists.

2.6 Expand Controller Memory Research

Diverse impacts on controller memory and cognitive functioning may be expected when the Automated En Route Air Traffic Control (AERA 2) subsystem is introduced. Due to the greatly increased automation assistance provided controllers in detecting and resolving aircraft conflicts, and in communicating with pilots and other controllers, the controller's mental picture of the traffic situation could change profoundly. The controller will, nonetheless, retain responsibility for operations under his or her jurisdiction, and automation must be compatible with retention of these responsibilities.

What does a controller have to know, and how will that knowledge be assured when it is needed? What automation aids will be needed to augment the controller's perception, comprehension, and memory in more highly automated sectors? These questions have been added to those already being studied by the FAA Technical

Center for the Air Surgeon, in research to avert errors due to controller memory lapses in today's sectors.

2.7 Expand Controller Workload Measurement and Analysis
Reduction of observable physical actions and voice communications by controllers, due to increased automation, could convey the impression that workload is reduced. Nonetheless, increased sector automation is also expected to permit increases in sector airspace volume, sector traffic flow complexity, and sector traffic load. There is a definite need to estimate actual controller workload, much of which may occur covertly as mental activities.

A new project is being formed by FAA to develop, validate, and apply workload measurement methods, starting with today's system as baseline, and evolving towards future Advanced Automation System contexts.

2.8 Expand Radar Display Scanning Research
The Initial Sector Suite System workstations will consist of one to three display consoles. Various kinds of information, dynamically changing or static, will be presented on these flexibly configured displays. Display contents will be in color, but information will also be highlighted using monochrome techniques. We should evaluate impacts of these capabilities on controllers' behavior in scanning displays to visually acquire information. Scanning of multiple displays will be added to existing research on radar scanning.

Present scanning research, at the FAA Technical Center, is adapting oculometry techniques to track, record, and analyze controller radar fixations. One goal is to better understand how controllers' radar scanning relates to near mid-air "collisions" and operational errors. Radar scanning research will, of course, be relevant even to advanced automation (i.e., AERA 2) sectors, because operational incidents will still be possible. But there, displayed information will be different than in today's sectors, and controllers' scan patterns are likely to change accordingly.

2.9 Develop Sector Design Analysis Tool
The Automated En Route Air Traffic Control (AERA) 2 subsystem is expected to permit more aircraft to fly pilot preferred routes. Increasing the number of aircraft on preferred routes could significantly complicate traffic flow patterns through a sector's airspace. Automation will, of course, enable the controller to handle higher complexity levels. However, recent analysis work by the Office of Air Traffic System Effectiveness has shown that operational errors are more likely in en route sectors that have more complex traffic patterns.

That work has led to a project, conducted by the FAA Office of Operations Research, to develop automated support for airspace designers -- a Sector Design Analysis Tool. The goal is to enable sector designers to perform fast-time simulation analyses of alternative configurations, to compare their effects on controller workload and the probability of traffic conflicts.

3.0 PROJECTION OF PERSONNEL REQUIREMENTS

Other anticipated impacts of the advanced air traffic control systems may be classified as human resource management concerns. They relate to how the work will change, how jobs should be structured, and what knowledge, skills, and abilities employees will need. Such human resource questions are, perhaps surprisingly, strongly linked to human factors considerations -- methods and variables relating to workload and performance. Here too, FAA's efforts are multidisciplinary, and involve a partnership among different organizational elements.

3.1 Estimate Facility Staffing Requirements

Implementation of the National Airspace System Plan at air traffic facilities is expected to bring with it increased productivity -- capacity for more efficient handling of more traffic. Thus, eventual staffing impacts, consisting of reductions in required hiring rates, are anticipated. The FAA's Office of Human Resource Development, working with other offices, is systematically estimating the controller workload implications of various future combinations of advanced systems. These are being translated into estimates of sector and facility staffing requirements.

Although automation may permit eventual decreases in staffing rates, transition to the new systems can impose needs for temporary increases in staffing. The increases would accommodate installation of the new equipment, simultaneous operation of old and new equipment, and training of operational personnel. Estimates are being made of the Air Traffic controllers and Airway Facilities maintenance personnel needed during transitions to different subsystems.

How does FAA gauge these requirements for systems that have not yet been experienced? We have been relying on the accumulated experience of persons who previously performed analogous installations. A major part of the analysis effort has been performed through workshops attended by persons from various organizations. Initiated by the Northwest Mountain Region, where many system installations will occur first, the analysis of transitional staffing requirements is continuing at FAA headquarters under the Office of Human Resource Development, the Transition Service, and Air Traffic.

3.2 Model Area Control Facility Variables

Future consolidation of terminal (TRACON) operations and en route operations within Area Control Facilities -- equipped with the Initial Sector Suite System and other automated subsystems --is expected to bring many benefits. To precisely define such large facilities, the FAA believes research is needed that estimates how large and complex they might be and still allow personnel to effectively perform required operational and administrative functions. A model development effort is being sponsored by Air Traffic to analyze the relationships between, and the limiting values of, variables that could significantly affect ACF structure and size.

3.3 Study Selection Procedures

Increasing air traffic system automation is expected to profoundly affect the controller's job and the definition of personal characteristics that are most favorable for the job. For nearly 30 years, the FAA Civil Aeromedical Institute has conducted research to identify the knowledges, skills, abilities, and other (KSAO) personal characteristics that are required to perform effectively as an air traffic controller. It will continue, now supporting the development of new controller KSAO profiles for future advanced automation contexts.

3.4 Develop New Controller Selection System

The FAA Office of Personnel plans to develop a new method for selecting terminal and en route air traffic controllers. This method must accommodate changes in controller jobs due to new subsystems, and be capable of generating quantitative predictions of on-the-job controller performance using that equipment.

4.0 CONTROLLER TRAINING TO AUGMENT SYSTEM BENEFITS

Maximizing the operational and productivity benefits of automation requires specialized, carefully designed training. Per subsystem, we need first to identify the functional capabilities of the automation. Second, we need to characterize the activities, both physical and mental, that controllers will perform using that equipment. Third, we need to apply that information in developing training that will affect controller performance within that context. These steps are being taken for each of the subsystems that will be delivered to the field via the National Airspace System Plan.

Advanced training techniques will be used consistent with the training requirements. Training adequacy for each new subsystem will be ensured by active participation of Air Traffic services in the associated requirements specification, design review, and follow-up evaluation processes. Additional assurance that training methods meet agency and workforce needs will come via formal assessments by the psychologists and analysts of the Civil Aeromedical Institute of training outcomes and later operational performance.

Highlights of our programmatic initiatives in controller training are briefly described in the following discussion.

4.1 Improve On-the-Job Training

The quality of operational controller training should be increased by recent revisions in the FAA order (3120.24) that concerns on-the-job (OJT) training. It requires standardized methods for selection and training of OJT instructors and examiners, separates instructor and examiner positions, and improves the OJT certification process. Incorporating results of review comments received from field personnel, the order is scheduled for publication this year.

4.2 Training for Automated En Route Air Traffic Control (AERA)

The Automated En Route Air Traffic Control (AERA) 2 system is expected to profoundly change controllers' activities, both physical and mental. We anticipate that controllers will rely on the automation not only to predict, detect, and resolve conflicts, but also to handle routine air/ground communications and ground/ground coordination. Extensive training will be provided to experienced and entry-level controllers to facilite their acquisition of the knowledge, skills, and attitudes needed to understand, accept, and use AERA 2.

4.3 Institutionalize a Systems Approach to Training

The Office of Training and Higher Education is using a systems approach to improve and accelerate training in general. Accordingly, different parts of the training program are being addressed at the same time. Redesigning curricula, increasing instructor effectiveness, and upgrading training equipment and facilities are among the simultaneous initiatives being taken to enhance the basic training milieu.

Redesigned curricula will specifically apply simulation throughout the training process using simulators of appropriate fidelities, and will incorporate improved computer based instruction. The FAA is developing at its Academy an Interactive Instructional Delivery System, which will combine the best features of lecture/laboratory training with computer based instruction, interactive video, graphic tutorials, automated testing and evaluation, and part-task training, all supported by advanced instructional design capabilities.

4.4 Procure Stand-Alone Radar Training System

The FAA plans to immediately initiate procurement of a Stand-Alone Radar Training System for Air Route Traffic Control Centers. This action responds to recently conducted studies showing that increased use of simulation in controller training should significantly accelerate on-the-job training and reduce the failure rate. As much as 50 percent of present on-the-job facility training will be shifted from the control room to the simulation training laboratory.

4.5 Develop Full Scale Tower Simulator

An exciting combination of recent technological innovations is reflected in recently developed specifications for a full scale Tower Simulator. This simulation is characterized as having a 210 degree panoramic screen for displaying computer generated targets, operating positions to be manned by trainees and instructors, computer driven equipment capable of generating real time traffic situations coupled to voice recognition processing.

4.6 Develop Air Traffic Training Management System

The Air Traffic Training Management System, a networked computer system linking headquarters, regional, and facility training offices, is being developed. It will support more timely record keeping on the training provided individual controllers and permit systematic quantitative analyses of training outcomes.

5.0 SUMMATION

In summary, we have presented an overview of FAA activities to ensure positive human impacts of advanced air traffic control systems to be installed in accordance with the National Airspace System Plan. The paper has, we believe, indicated why implementation of these systems is a tremendously exciting multidisciplinary challenge.

Controller and Pilot Decision Making in Transmitting and Receiving Microburst Wind Shear Alerts from an Advanced Terminal Wind Shear Detection System

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1. INTRODUCTION

Microburst[2] wind shear accidents have been responsible for over 35 air carrier accidents in the United States since 1964, resulting in over 650 fatalities (1). In the U.S., the most recent such accident was the crash of Delta Flight 191 at Dallas-Ft. Worth Airport in Texas on 2 August 1985, which resulted in the loss of 137 lives. On 3 September 1989, Cubana de Aviacion Flight 3046 crashed on takeoff from Havana, Cuba, with the loss of 115 passengers and crew and 24 persons on the ground. Evidence strongly suggested that the aircraft encountered a severe thunderstorm-induced microburst.

Since the mid-1980s, the FAA, in conjunction with several research organizations, including the National Center for Atmospheric Research (NCAR) and the Massachusetts Institute of Technology (MIT) Lincoln Laboratory, has developed a wind shear detection and warning system that consists of two separate wind sensor systems. First developed in 1976, the Low-Level Windshear Alert System (LLWAS) recently has been upgraded to detect microbursts. This new version of LLWAS, capable of detecting microbursts, employs 11 to 16 anemometer and wind vane wind- measuring sites situated in the runway proximity to detect diverging wind features near the ground.

More recently, the FAA developed the Terminal Doppler Weather Radar (TDWR), which utilizes the wind-measuring capabilities of Doppler radar to detect microbursts in the airport terminal vicinity. Complete technical details of these systems can be found in the references (2,3).

During the summers of 1987, 1988 and 1989, LLWAS and TDWR were tested operationally at the Stapleton International Airport, Denver, Colorado. In 1989, the microburst detection capability of both systems was integrated in a prototype development phase to provide air traffic controllers and pilots with simple, unambiguous hazard alert messages. The TDWR system can detect microbursts with a high degree of accuracy and with a low false-alarm rate. Specifically, for microbursts having headwind/tailwind differences greater than 40 knots, the probability of detection[3] is 98%, while the false alarm

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[1] NCAR is sponsored by the National Science Foundation.

[2] A microburst is an intense downdraft and associated outflow, located near the earth's surface, that produces strong headwind-to-tailwind changes for an aircraft which penetrates the phenomenon below 1,000 ft. AGL. It is typically situated within thunderstorms but can often occur in less intense convective storms, particularly in dry climates.

[3] The probability that a valid detection will be made by the system.

rate[4] is 4%. When a microburst detection is made, the system automatically generates a microburst alert and provides an alert message to a computer screen situated in front of the air traffic controller; the controller relays the alert to potentially affected flight crews in either the takeoff or landing mode. A typical approach-to-landing alert reads:

> UNITED 226, MICROBURST ALERT, EIGHT ZERO (80) KNOT LOSS ONE MILE FINAL THRESHOLD WIND TWO ONE ZERO AT TWO TWO KNOTS

A typical takeoff alert reads:

> AMERICAN 330, MICROBURST ALERT FOUR ZERO (40) KNOT LOSS ON THE RUNWAY DEPARTURE END WIND THREE THREE ZERO ONE TWO KNOTS

During the prototype operational tests of the system, air carriers developed company policy regarding flight crew use of these alerts. In most cases, flight crews were provided with flight safety bulletins that typically stated:

> FLIGHT CREWS SHALL NOT CONDUCT AN APPROACH TO LANDING OR A TAKEOFF WHILE A MICROBURST ALERT IS IN EFFECT.

In addition, air traffic controllers were instructed to provide all flight crews with the alert message whenever an aircraft might be affected by the microburst. However, since inbound flights normally contacted the air traffic controller at or near the final approach fix, the microburst alert was most often issued in association with the landing clearance. On takeoff, the alert was typically issued at the time of takeoff clearance.

These two demonstrations were prototypical, and while air traffic controllers and pilots generally were aware of the operational capability and associated procedures of the system, it was a new, unique system. Consequently, permanent conclusions about air traffic controller and pilot use of this system are somewhat speculative.

In this paper, three microburst events in which valid microburst alerts were issued by air traffic controllers are examined for the purpose of identifying human factor aspects of these alerts. Conclusions and recommendations for possible actions are addressed at the end of the paper.

2. EXAMINATION OF THREE MICROBURST ALERT INCIDENTS

Three microburst incidents are described briefly, followed by a description of pertinent human factors elements:

11 July 1988

At approximately 1600 hours (all times are local daylight time), a microburst developed at 1-mile final to runways 26 Left and 26 Right. TDWR was the only operating system; in 1988 the LLWAS and TDWR systems were not yet integrated. The event initially was detected as a 35-knot loss; it then drifted east and intensified to an 80-knot loss at a 3-mile final. The Geographic Situation Display (GSD) for this event is shown in Fig. 1. The

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[4] The probability that an alarm is false.

situation steadily intensified for approximately 8 minutes until it began to dissipate. Five air carrier jet transports were in various approach locations at the time, and they received a microburst alert outside the outer marker greater than 3 miles from the runway (4). Figure 2 shows the vertical profile of four of these flights during their go-around sequence. The following is a sequential summary of each flight:

> Flight 862 (B-737-200) made an immediate avoidance decision based on 40-knot loss microburst alert. The pilot stated that he did not want to make an approach when a microburst alert was in effect.
>
> Flight 395 (B-737-200) was given a 40-knot loss microburst alert at a 1-mile final. The aircraft continued the approach to a missed approach, reaching its lowest point at 50 ft AGL approximately three-quarters of a mile short of the runway. This aircraft encountered the most severe wind shear.
>
> Flight 236 (DC-8) was given a 50-knot microburst alert and continued the approach; it encountered severe headwind-tailwind fluctuations as seen in indicated airspeed. The flight crew executed a missed approach and descended to near 250 ft AGL.
>
> Flight 949 (B-727) continued the approach but made an early missed approach after receiving a microburst alert of a 70-knot loss 3-mile final. The aircraft did not descend below approximately 500 ft AGL.
>
> Flight 305 (B-727) received a microburst alert indicating an 80-knot loss 3-mile final. The crew elected to miss the approach just inside the outer marker.

The following are the pertinent facts associated with these air traffic controllers' microburst alert messages:

> The first two flights were handled by one air traffic controller. All alerts were given as appropriate, in the vicinity of the outer marker. In these two cases, the alerts were issued with a clearance to land.
>
> The last three flights were handled by a second air traffic controller who relieved the first controller due to a watch change. The third aircraft in sequence (Flight 236) was issued an alert along with a clearance to land.
>
> The fourth aircraft (Flight 949) was issued a microburst alert in the blind without a landing clearance. In this case, the automatic alert appeared on the controller's display, and the controller issued the alert to all aircraft monitoring the frequency, including Flight 949.
>
> The controller issued the most severe microburst alert (80-knot loss) to Flight 305, followed by "say request" rather than "cleared to land."

There were no additional approaches following these first five aircraft; due to the microburst event, the traffic was diverted from the airport for 30 minutes until the weather improved.

8 July 1989

TDWR was not operational on this day. The Enhanced LLWAS system, utilizing 16 wind-measuring sites, protected Stapleton Airport. This system included additional sensors sited to protect the final approach corridors out to 3 miles from the end of the runway. At approximately 1720 hours, a microburst occurred at the north end of the airport on the approach end of runways 17 Left and Right; this event is illustrated in Fig. 3. The following describes the experience of Flight 531:

> After being cleared for a visual approach, the captain heard three microburst alerts. The first one indicated a 60-knot loss on a 2-mile final. He continued the approach. Shortly thereafter, the captain heard a second alert, indicating a 95-knot loss 3-mile final. They initiated a missed approach at about a 3-mile final and did not actually experience the event until about a .5-mile final, when they lost 50 knots indicated airspeed and also lost 400 feet in altitude while experiencing moderate turbulence. The missed approach was initiated at approximately 600 ft AGL; the event was encountered at approximately 1,000 ft AGL with a subsequent loss of 400 ft.[5]

The air traffic controller/pilot interaction can be summarized as follows:

> The air traffic controller first had an indication of microburst activity: a 35-knot loss on a 2-mile final. When he delivered the alert to Flight 531, the captain asked for substantiating pilots' reports from other aircraft operating these runways. He queried an aircraft that had just landed on Runway 18 (located about 1 mile west); the pilot indicated a 30-knot loss on that approach. This report was heard by the captain of Flight 531 and apparently was used by Flight 531 to consider a missed approach. The controller continued to provide microburst reports to Flight 531 and following aircraft.

Approximately 15 aircraft did not land subsequent to the missed approach of Flight 531. Most aircraft landed at Denver following a hold of approximately 20 minutes; one aircraft diverted to another airport located approximately 60 miles to the south of Denver.

2 September 1989

On this day, a microburst was detected by the integrated TDWR/LLWAS system at 1-mile final to Runways 26 Left and Right. The integrated TDWR/LLWAS system issues consolidated alarms based on products from each independent system. The following describes the flight sequence for two flights, 914 and 2235:

> Flight 914, first in line for the approach, received a microburst alert, for 35- knot loss 1-mile final. The captain elected to continue the approach. The event reappeared on the controller's display as a 30-knot loss 1-mile final. The crew continued the

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[5] The captain stated in a post-incident debrief that the wind shear equipment was very good and felt that in this event it probably saved his aircraft.

approach after a direct question from the air traffic controller querying whether the flight wished to continue the approach. The flight landed with major difficulty, experiencing a 5 g landing that caused structural damage. The captain, upon exiting the active runway, confirmed the microburst and further recommended closing of the runway due to unsafe wind shear conditions.

Flight 2235 followed Flight 914, continued the approach but elected to execute a missed approach on short final.

The air traffic controller experience is summarized:

The identification of the microburst was clear, and all alerts were issued. The controller, in the case of the first aircraft, queried the flight crew regarding their landing intentions, confirming that they wished to land during a microburst alert.

3. ANALYSIS

Several analyses have been conducted for these three events, although only the first one (11 July 1988) has undergone extensive analysis (5). NCAR participated in crew debriefings on the 11 July 1988 and the 8 July 1989 events. The following general analytical comments apply:

11 July 1988

1. The microburst was accurately detected and alerts were issued by two air traffic controllers. However, there was a significant difference in the imperative tone between the first and second controller; the second controller used a more definitive tone of voice.

2. The second controller, upon recognizing the urgency of the alert information, used his controller's discretionary function not to issue a clearance to land for the fourth aircraft (Flight 949). He went further for Flight 305 and added "say request." In this case, we believe that the added query was instrumental in the flight crew's subsequent missed-approach decision.

3. The flight crews typically were unfamiliar with airline policy for microburst avoidance and with the airline flight bulletin describing the operational demonstration. In this regard, it must be recognized that this first-of-a-kind operational test cannot be expected to be well understood by most flight crews. However, the first aircraft (Flight 862) clearly was familiar with policy and made an early avoidance decision.

4. Several aircraft used microburst wind shear recovery techniques (6) during the missed approaches, indicating the value of these techniques; this might have saved Flight 395 from disaster.

8 July 1989

1. The Enhanced LLWAS performed flawlessly in this event, detecting a very dry environment microburst when there were no visual clues for either the flights involved or the air traffic tower controllers. It should be noted that the 95-knot loss measured by this system was the strongest microburst ever measured by any microburst detection system.

2. The controller exercised good judgment by querying adjacent flights for wind shear reports. His actions serve as a model for controller handling of wind shear events.

3. The crew of Flight 531 exercised outstanding judgement and used flight deck crew coordination (as determined in the crew debrief) to make a consensus avoidance decision upon hearing the 95-knot loss alert.

2 September 1989

1. This microburst event was just above the headwind/tailwind threshold for declaring a diverging shear microburst. The event was well detected just above the threshold that indicates a severe wind shear condition. This is confirmation that a 30-knot threshold is an appropriate one, given that the landing aircraft experienced structural damage.

2. The controller strongly suggested, by his queries, that Flight 914 should give serious consideration to an avoidance action (they did not take the suggestion). It should be noted that the controller did not state "say request" or "say intention" as did the controller on 11 July 1988.

3. The crew of Flight 914 made a clear choice to land the aircraft contrary to airline policy and after informal prompting from the controller. The aircraft easily could have been lost.

4. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

The LLWAS, TDWR and integrated TDWR/LLWAS microburst alert systems are a technical success. Once a divergent wind shear event reaches the microburst threshold of an expected 30-knot headwind-to-tailwind differential, the systems work extremely well and produce alarms which are accurate and timely.

The human factors aspects are less successful, and it is in this domain that considerable additional effort is needed. Flight crews continue to need extensive training regarding the impact of microbursts on aircraft and the inadvisability of penetrating them; standard procedures are needed to reinforce the training. In addition, improved air traffic controller training is needed to standardize controller response to microburst alerts. From the perspective of the scientists who have examined the basic science of microbursts and helped to develop detection capabilities, air traffic control rules and procedures that dictate avoidance are a required next step. Such rules should be consistent with onboard wind shear avoidance avionics equipment.

Controllers could help sensitize pilots to making time-critical decisions by using terminology that triggers the need for a pilot decision based on the presence of a hazardous weather event. The air traffic service should consider testing a cautionary message of "say request" or "say intentions" to encourage strongly a flight crew avoidance decision. This message will need to be examined to see if it adds to controller workload or has other deleterious impacts.

Finally, accurate and timely microburst wind shear alerting equipment is becoming operational in the U.S. Its international use at airports where microbursts are common would be critical to a major mitigation of this hazard worldwide.

5. ACKNOWLEDGMENTS

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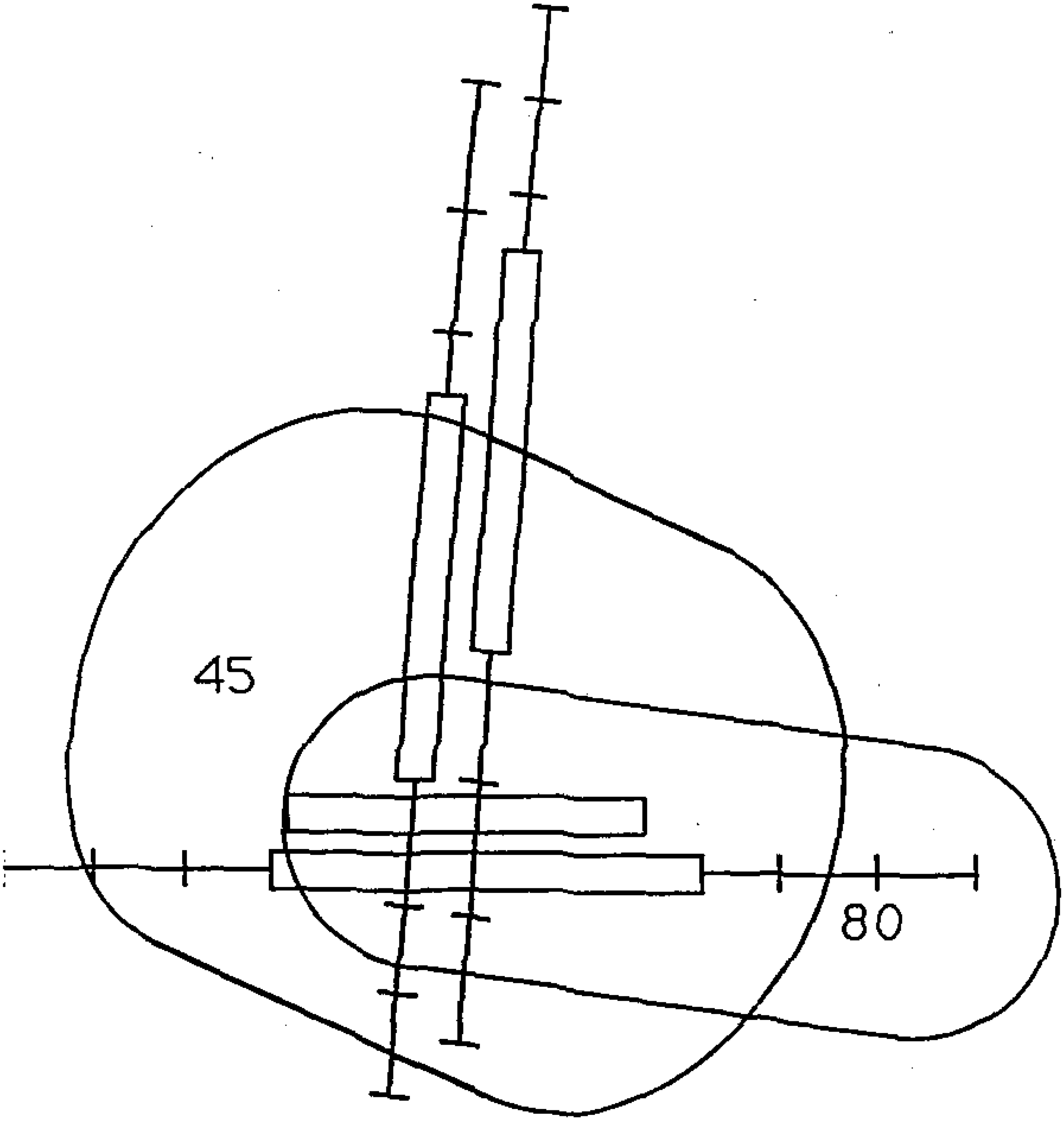

Fig. 1

11 July 1988, 1612 local time, geographic event display of the Stapleton Airport runways with 3 nm extensions off each runway end and microburst events areas shown by ellipses. The 80 knot microburst is shown at it's peak intensity located off the approach end of runway 26.

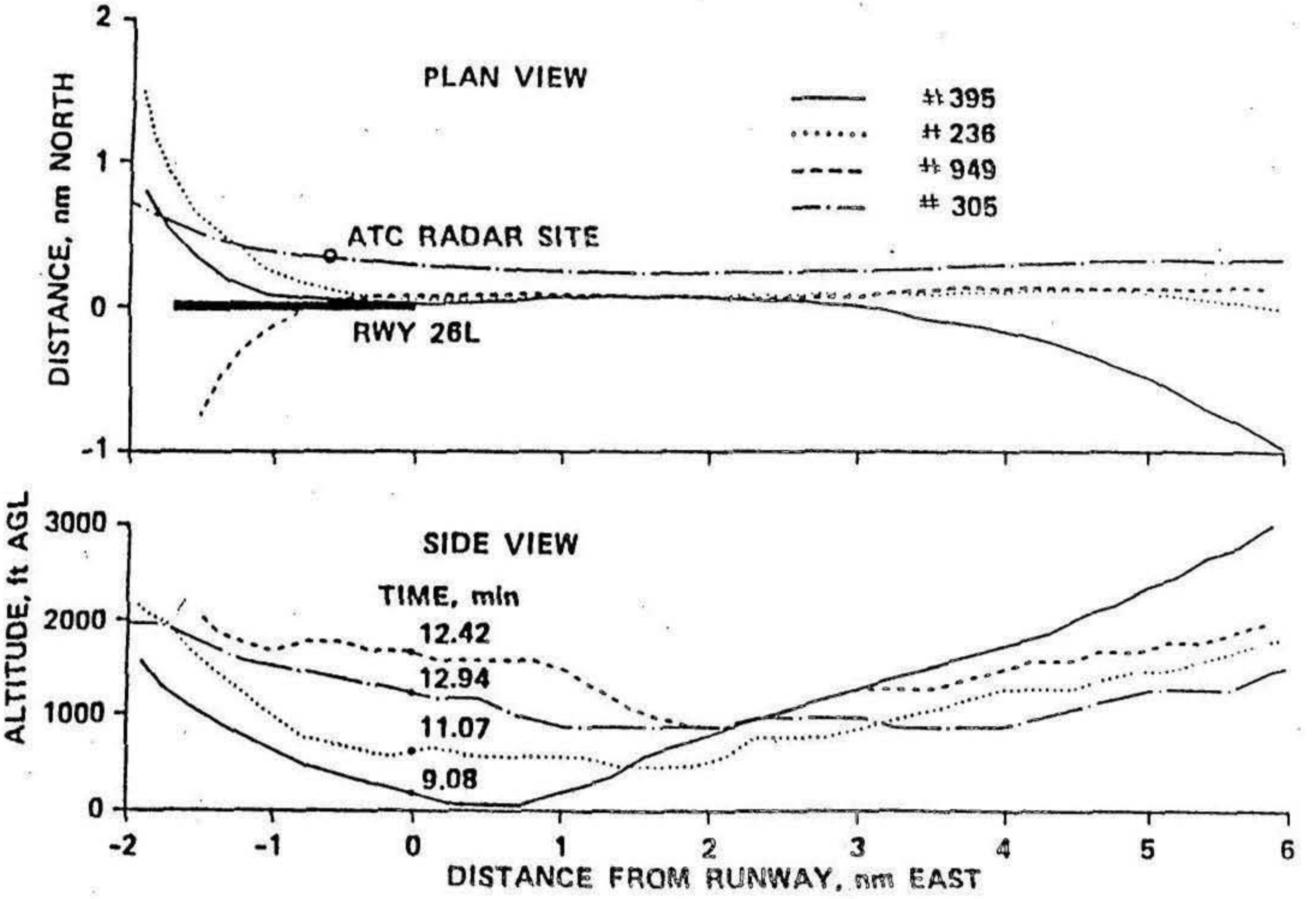

Fig. 2

Aircraft tracks of the four aircraft which penetrated the microburst event on 11 July 1988. The times at which they crossed the runway 26 threshold are shown in the side view with the time being minutes after 1600 local time.

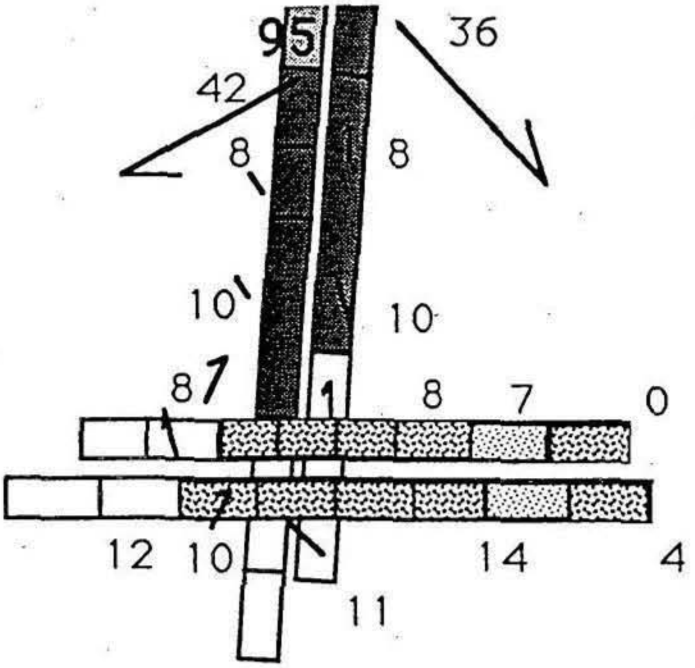

Fig. 3

8 July 1989, 1620 local time, plan view of the runways and three mile runway extensions off all runway ends. The origin of the wind vectors represent the location of the Enhanced LLWAS sensors, the arrows show the direction toward which the wind is blowing and the length and the numbers represent the wind velocity in knots. The 95 knot event on the approach to runway 17 is clearly shown to the north of the airport.

HUMAN FACTORS CONSIDERATIONS FOR LORAN-C RECEIVERS

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Introduction

This paper presents a brief description of the flexibility and use of the aeronautical navigation system Loran-C. It then introduces selected human factors issues experienced by general aviation pilots using this system, and describes some research activities currently underway at the Research and Special Programs Administration's Transportation Systems Center of the U.S. Department of Transportation in Cambridge Massachusetts.

Description of Loran

Loran-C is a low frequency, ground reference navigation system which uses time synchronized pulsed signals from ground transmitting stations spaced several hundred miles apart for identifying geographical locations. Loran-C position is derived by measuring the difference in arrival time of pulses from a master and secondary transmitters.

The transmitters are capable of providing accurate information at distances up to 1,000 nautical miles from the receiver. The geometric relation of transmitters to one another determines the accuracy of position location. In areas of good coverage some studies have shown that receivers can calculate their geographic location to within 600 feet. Consecutive calculations provide the data necessary to determine such information as ground speed and track. The latitude and longitude of waypoints stored in the receiver provide the references necessary for the calculation of distance and bearing to a selected waypoint. When waypoint location is combined with ground speed information, predicted times of arrival at the selected waypoints can also be calculated. When combined with altitude information from an outside source, some receivers can provide positive course guidance for vertical navigation.

Characteristics of Loran

Six characteristics of Loran system navigation systems contribute to their current popularity.

1. The low frequency Loran signal (90 to 110 kHz) follows the surface of the earth. Therefore the Loran signal has an advantage over higher frequency signal systems such as Very high frequency Omni-directional Range systems (VOR, 108 to 117.95 mHz) that are useful only for "line of sight" applications.

2. The Loran system does not require local navigational aids. Transmitters may be located as far as 1,000 nautical miles from the receiver and still be accurate.

(A VOR transmitter must be as close as 40 nautical miles to provide positional accuracy required for IFR flight at altitudes below 14,500 feet.)

3.The positional accuracy of Loran is independent of the distance of the receiver from the waypoint. (The sensitivity of a VOR receiver to lateral displacement off an airway decreases with distance from the transmitter. For example, at 30 nautical miles from the station one fifth of a full scale deflection of the course deviation indicator needle equals one mile. With time difference corrections, it's positional accuracy is accepted conservatively by the Government to be between 1/2 and 1/3 of a nautical mile.)

4. Loran systems are relatively inexpensive. Portable general purpose units that may be used in aircraft can be purchased for less than $350. Systems designed for installation in aircraft with user provided data bases may be purchased for as little as $1,000. Systems with an internal and updatable database of as many as 20,000 waypoints may be purchased for less than $4,000. (Comparable area navigation systems using VOR transmitters cost over three times that amount and have the accuracy and distance limits of VOR systems.)

5. The availability and decreasing cost of microprocessors provides our newest receivers with enormous computational power. There are several Loran receivers now available to the general aviation pilot that:

- Store and track flight plans with automatic sequencing from leg to leg
- Alert pilots to the presence of special use airspace
- Provide minimum safe altitude information throughout the National Airspace System (NAS)
- Provide graphic displays that show the aircraft's position relative to selected waypoints
- Contain Loran approach procedures at airports approved for their use
- Provide information on nearest airport upon request
- Provide integral calculators for trip planning while underway

6. Some Loran receivers are now being designed to integrate data from Loran and Global Positioning Systems (GPS). These systems have the potential for the vertical and horizontal accuracy required for precision approaches.

Loran Receiver Packaging

Today's aviation receivers have evolved from equipment originally designed for marine applications; an evolution that has produced a wide variety of control, display and logic configurations. This variety makes it unwise to generalize too specifically about the difficulty or ease of use of the equipment of different manufacturers from experiences gained from the use of only a few systems. However the sophistication of the aviation user and the demand for more and better features in a package that will fit in the limited space of personal aircraft have tended to result in receiver designs of increasing similarity. The design of today's receivers reflect a compromise between ease of use and compactness. In many cases controls, alerts and alphanumeric displays are squeezed onto a display panel that covers a surface area of no more than 12 to 18 square inches (77.4 to 116.1 sq.cm). The results are desirable and imaginative, but they do present challenges to the human operator who will always make errors, forget rules and procedures through disuse, and become disorganized under stress.

From the pilot's viewpoint, the Loran receiver is a computer with four major components. Each of these components is subject to variations in design, with respect to appearance, physical location, and function.

The digital electronic display may be made up of light emitting diodes (LED) or liquid crystal display (LCD) units . These displays present alphanumeric and sometimes graphic information to the pilot.

Most Loran receiver sets have between 5 and 30 push buttons. Sets with extensive databases may have as few as five buttons. However, receivers that depend on pilot data entry for their data bases include a key pack, therefore have more buttons.

Some sets, particularly those provided with databases, have at least two pairs of multi-function knobs. The outer ring of the knob may be turned to any one of a set of functions, e.g., "calculate" or "flight plan", or data categories such as "VOR" or "airports"; and the inner knob may be used to scroll through the contents of these categories.

All Loran receivers contain a microcomputer where speed calculations, bearing determinations and flight planning is accomplished. The functional power of the microcomputer is deployed through the use of control knobs and buttons, according to a set of procedures determined by the structure and logic of the computer. The pilot must memorize these procedures in order to utilize these capabilities efficiently in flight. It was observed in the laboratory that some of our operators tried to develop models of this structure to help them use the system, rather than relying on rote memory of the procedures. For example, one operator said that he saw the computer as a book and its various functions as individual chapters. Research is being conducted at NASA Langley to determine the influence of the operator's model on the types of errors that he makes.

Current Applications

VFR

Over 70,000 Loran sets are estimated to be in use today. These sets are used in search and rescue, by helicopter and fixed wing air taxis, in emergency medical services, by regional airlines, by corporate pilots, small charter operators companies, and in enormous numbers by private pilots. Loran is popular in these applications because it is an inexpensive area navigation system that allows pilots to fly direct to pilot defined waypoints as well as most facilities and intersections included in the national airspace system. With its distance measuring and other computational powers, it contributes greatly to flight planning, situational awareness, and therefore to flight safety.

IFR

A few manufacturers are making receivers that have been certified by the FAA for use in enroute and terminal use under IFR conditions. To date, none have been certified for use in instrument approaches. Perhaps the greatest driving force for Loran-C instrument approaches are state governments through the National Association of State Aviation Officials (NASAO). Many states have small cities that could benefit economically from regular air transportation to and from their small municipal airports. These municipalities cannot afford the cost of installing and maintaining expensive local navigational aids or they may be located in terrain that would interfere with the operation of such facilities. Loran, which is independent of local navigational aids and is usable in mountainous terrain could be used for instrument approaches into such areas.

The use of Loran for instrument approaches is being looked at cautiously. Current approaches are primarily designed and operated for purposes of evaluation and only exist at about 12 to 14 airports across the country. Loran signal monitors at each airport track the synchronized signals from the transmitters designated for each approach to determine if the signals meet accuracy requirements specified by the FAA. If an error is detected an alarm is sounded in the appropriate air traffic control facility and subsequent requests for Loran approaches will not be approved. Charts for the use of these approaches are not available to the general flying public and only specially certified aircraft may make the approaches under IFR conditions. The receiver and its installation must be certified. And, another certified instrument navigation system must exist in the airplane as a backup to the Loran. At the present time, Loran-C has not been approved for use as the sole means of navigation under IFR conditions.

Prominent human factors concerns in the use of Loran for instrument approaches include: crew workload, pilot error, and pilot awareness of system status. To reduce crew workload and the potential for pilot error during Loran approaches, time distance calibration data (from transmitter stations used in navigational computations for the approach), and the waypoints will have to be entered in the system prior to going into the approach mode. In addition, all Loran approaches must be flown with a crew of two. The earliest approved Loran approaches had to overlay another instrument approach, such as an ILS. This overlay redundancy is no longer required for approaches currently being approved, but other instrument approaches do have to be available to the runway. System status is monitored during the approach by the receiver and warning annunciations are presented to the pilot whenever system discrepancies occur.

The flexibility of Loran makes it possible to put instrument approaches into airports that otherwise might not support them. In some mountain locations a single microwave landing system (MLS) can be economically installed to provide a precision approach, but because of the mountainous terrain no VOR dependent systems can be used to bring the aircraft to the final approach fix or to provide guidance to the pilot for a missed approach. In some cases, obstacles may require the initial approach segment and departure courses to be curved. Research is underway to examine the utility of combining Loran with MLS for use at remote airports.

Human Factors Activities and Issues

As inexpensive Loran receivers become increasingly available, new applications for Loran are developed, and the use of Loran for navigation by a single pilot under instrument conditions becomes a reality, the need for information regarding pilot performance with Loran systems gains new importance. The Research and Special Programs Administration's Transportation Systems Center is initiating a series of research activities on human factors related to the use of Loran systems by private pilots. The research results will be available for use in developing realistic applications of Loran; criteria for Loran approaches, requirements for instrument training for Loran, and educational material regarding the use of Loran by private pilots.

Our exploratory research included the following activities:

- Comparison of Loran and VOR display and control panels
- Laboratory studies of operator's learning, programming, and exercising the various features of different Loran receivers
- Personal use of Loran during VFR conditions
- Flight tests of pilot tracking performance during non precision approaches
- Discussions and observation of the use of Loran by private pilots in personal aircraft

Comparison

Today Loran is the navigation system of choice among general aviation private pilots. Loran is fast replacing the VOR as an enroute navigation system. Our comparison of Loran and VOR controls and displays indicates that Loran, although a more powerful navigation system, has characteristics that may make it more difficult to use, more prone to operator error, and less error tolerant than the VOR. Recognition of these characteristics and their contribution to pilot workload and error will facilitate the identification, description and solution of human factors design problems that could contribute to a new family of errors among general aviation pilots if left unattended.

The frequency of a VOR is selected using knobs or thumbwheels dedicated to that function. These controls are located next to the windows that display the selected frequencies, and are used for no other purpose, and therefore they are rarely inappropriately used. Further, the controls are "detented" so frequencies may be selected without continuously monitoring the digit windows. This is big advantage to the single pilot who must watch for other traffic and maintain his heading and altitude while he tunes the VOR receiver. If an error in frequency designation is made, it can usually be corrected by one or two twists of the appropriate control.

A common method of selecting a waypoint with Loran is to turn the outer ring of a multi function knob to the detent marked VOR (VORs are commonly used as waypoints, particularly if the Loran is being used to fly published airways). The operator spells out the waypoint name using the inner knob as a cursor that presents letters consecutively on the display, and the outer knob to determine the location of the letter in the waypoint name. This process may take 20 or more discrete control actions, requires considerable head-down time, and is subject to a number of errors that are hard to detect. One common error is setting the function switch on APT (airport), rather than VOR. Since the APT and VOR are located at adjacent detents on a number of current receivers, VORs often have the same letter designations as airports that are located nearby. The adjacent location increases the likelihood of this kind of mistake and is a good example of DESIGN INDUCED ERROR.

Another example of design induced error is the adjacent location of the "waypoint" and "enter" buttons on some Loran sets. These two buttons are used when entering flight plans into the set. In the flight plan entry mode "wpt" is pressed after each waypoint is entered into the flight plan, and "ent" is pressed after the final one is entered. If "ent" is pressed prematurely the flight plan will be closed out too early. As a result the plan will have to be edited. Inattention on the part of operator, or turbulence can easily cause the wrong button to be pressed and cause unnecessary workload to correct the resulting error. The design solutions to both problems are obvious and simple, increase the separation between the detents or buttons by inserting space, or other functions between them.

Verification of the correct selection of frequencies with a VOR is accomplished by looking at the digit windows that are dedicated to that purpose. If one digit in the frequency designation is incorrect, the solution is intuitive. The control beneath that window can be rotated through the correct number of detents to get to the correct digit. The operational status of the VOR is determined by pressing the button provided specifically for this purpose and listening for the morse code corresponding to the letter designation of the VOR.

Verification of the selection of the correct VOR waypoint with Loran usually is not done quite so easily. The distance to the waypoint may be checked for reasonableness. This distance, along with the bearing to the station, will probably be automatically shown on the Loran's electronic display. What is not always shown is whether a VOR or an airport has been selected. To make this determination an information page may have to be called up to see if the information is appropriate for the desired waypoint. Runway length data would indicate that an airport and not a VOR had been selected!

Standard verification procedures do not yet exist for Loran and should be developed as part of the training support provided for Loran users. The design solution to this problem would be to label the waypoint as it appears on the display as either a VOR or an airport. To correct the error the operator must delete the erroneous waypoint and completely reenter the correct one.

Selection of a waypoint by its three or four letter identifier assumes that this waypoint is stored in the data base of the receiver. This may be done manually by the owner or it may be provided as part of the receiver's data base. Only the most expensive receivers have this capability. The less expensive sets, and therefore those very often purchased by private pilots, have accommodations only for data bases that are manually entered by the user. Manual data entry requires time and the knowledge of what waypoints will be required in the upcoming flight, and has its own human factors problems.

Laboratory

This past year, we had several highly trained operators enter an eight waypoint flight plan into receivers provided by three different manufacturers. We also had the operators program a diversion by deleting two waypoints and adding three new ones. On average it took between six and seven minutes to enter the flight plan on the systems without a data base and about 2 1/2 minutes to do the same thing on receivers with a data base. When the operators were required to do the same thing while maintaining a desk top simulator in "straight and level" flight, it took approximately twice as long in each condition. If we had introduced "turbulence" into the simulator undoubtedly it would have taken longer. An aircraft flying at 120 kts will fly 24 miles in 12 minutes or make 4 turns around a holding pattern!

It took between two and three minutes to enter the diversion when not flying the simulator. The requirement to fly the simulator concurrently more than doubled this time. The time consuming nature of these activities was verified in our observations of a general aviation pilot's preparations for a Loran approach into a rather active airport in Massachusetts. These examples illustrate the potential dangers of data entry in the terminal area and the fact that doing the data entry on the ground is no guarantee that it will be done without error. In preparation for this demonstration flight, the pilot programmed the waypoints required for the approach while on the ground. While flying the initial segment of the approach, he discovered that the waypoints had been entered in the wrong order. Sitting behind the pilot, my associate noted that changing the sequence of the waypoints required considerable knob twisting and button pushing and would have required more than one turn outside the initial approach fix to accomplish it safely. The loss of pilot vigilance outside cockpit and the spare attention necessary to effectively manage the aircraft during this process has clear safety implications.

The designers of man/machine systems recognize that the human operator will make errors. The more actions the operator must make the higher the likelihood of an error. Manual data entry is an activity that is particularly error prone. Research at Douglas aircraft has shown error rates as high as 10% to be quite common even in the relative quiet of the laboratory. We too have demonstrated high error rates when manually entering latitude and longitude information into Loran systems. One approach to reducing the effects of operator error is to make the system ERROR TOLERANT. Systems may be considered error tolerant to the extent that they make it easy for the operator to identify errors that are made, make it easy for errors to be corrected, and reduce the influence of uncorrected errors on system operations. The VOR system is error tolerant to the extent that the frequency and radial selected for navigation is continuously displayed and so may be examined at any time for errors, and corrections can be made with the twist of a single knob. Once data are entered in a Loran system, they are no longer available for review unless specifically recalled. The only information continuously available on the electronic display may be the name that the pilot has assigned to the waypoint, and the distance and bearing to latitude and longitude coordinates that are now concealed in the system data base.

The analytic capabilities of current Loran systems indicate their considerable potential as error tolerant systems. One system that we examined would not accept latitude and longitude coordinates that were impossible. For example, any longitude or latitude designation in which more than 59 minutes were specified were rejected. Conceivably logic could also be developed that would reject VFR flight plans through prohibited airspace or alert the pilot to illogical waypoint sequences. For example, a waypoint that put an extreme course change in a route to the final destination could be flagged. Systems with map displays that graphically present the flight plan as it is programmed have been shown in advanced technology aircraft to provide a very effective means of detecting large programming errors. Such displays are now available for Loran systems.

The ease of correcting errors varies considerably from system to system. One system that we examined had an extensive data base and required less than four discrete actions to replace a waypoint. Systems requiring new latitude/longitude insertions for waypoint corrections required about 25 discrete actions for such replacement. Given that pilots will make errors in data entry procedures, system features should be developed for detecting such errors, and once detected, errors should be correctable with a minimum of effort.

Clearly the smaller the system's data base is, the greater the data entry requirements will be while in flight. This will increase the workload of the flight, increase the probabilities of error and increase head-down time; all of which reduce flight safety. User entered data bases are also less likely to be current. The more sophisticated Loran systems are provided with data base updates at least every 56 days. Historically these periodic updates may contain as many as 1,000 changes. Pilots who use Loran without the advantage of these scheduled changes may neglect to update their own data entries and be using data bases with errors in them.

Today's receivers have great functional power. But, their functionality is embedded, or hidden from view. We call it EMBEDDED FUNCTIONALITY. If we can remember the correct procedures, we can get it to display our flight plan, tell us where the nearest airport is, tell us the frequency of approach control, and probably accomplish a variety of other functions depending on the particular receiver that we are fortunate enough have. Unfortunately, unlike the case with our simple VOR, whose functions are self evident, we can't tell how to access the functions in current aviation Lorans just by looking at them. We have to apply a set of rules and procedures that we memorize or that we can understand quickly from reference to a handbook. Either stress or just time away from the system reduces our ability to recall procedures or understand written material. Conversations with a number of private pilots who use Loran for VFR navigation indicate that through infrequent use they often forget how to access the capabilities of the Loran equipment in their airplanes. They use the systems to fly direct from one point to another but they have forgotten how to create new waypoints, to obtain frequency information for a particular airport, or to call up an airport, whose identifier they have forgotten, from their system's data base. This difficulty is particularly acute for pilots who rent and fly a variety of aircraft with different Loran equipment. Pilots who fly for small charter companies that obtain their equipment from a variety of sources may encounter the same problems. Important problem areas include: different procedures for accessing information required for certain emergencies, different sequences with which to enter latitude/longitude coordinates, and variation in terminology used for labeling controls and for prompting. These effects are made worse by the variations in format and information content of the quick reference handbooks that manufacturers supply with their systems.

Three potential solutions to this problem should be considered:

1. Certain safety critical functions should have dedicated controls. For example, perhaps there should be a button dedicated to obtaining information on the nearest airport. Quick access to this critical function should be guaranteed

2. Prompting should be used more often We found in the laboratory that as short a break from training as one week caused operators to forget how to accomplish certain tasks with the Loran. Often it was only the first step of a procedure that had to be provided for them to remember the procedures necessary to access the function that they wanted. Function selection controls could be used to select and activate the step-by-step prompting necessary to "walk" the pilot through the procedures necessary to implement the Loran functions required. Eventually, the growth in the importance, popularity and applications of Loran will result in the dedication of more cockpit space to Loran functions. This will permit the use of larger displays that can provide the pilot with the instructional detail necessary to identify and use the capabilities of Loran efficiently.

3. Limited standardization should be considered. Standardization is not always well received by American manufacturers. They often feel that the unique characteristics of their products make them more desirable to pilots and are a marketing advantage. Furthermore, poorly conceived standards could discourage innovation and serve to restrict the development of Loran technology. These are important points but need not preclude all efforts to standardization. Implementation of the following recommendations should not stifle innovation or interfere with marketing advantages, but should increase the usefulness of Loran systems and contribute to their popularity:

- The most safety-critical and error prone functions should be identified, and standard and simplified procedures for implementing those functions should be developed.
- A standard terminology for use in labeling and prompting should be developed.
- A standard format for quick reference handbooks should be developed.

Flight Test

All aeronautical Lorans have a course deviation indicator (CDI) to provide the pilot with a graphic indication of the lateral displacement of the aircraft with respect to the desired course to the next waypoint. This indicator may be a bar graph defined by light emitting diodes (LEDs) on the receiver's display or a round dial with a single needle like that used with a VOR that may be located remotely from the receiver. The sensitivity of this indicator is selectable on some receivers and may range from 2 1/2 miles (4 km) to the most sensitive setting of about 950 feet (289.5 m.) for a full scale deflection. A sensitivity of 1 and 1/4 mile (2 km) displacement off course for a full scale deflection is recommended by the Radio Technical Commission for Aeronautics (RTCA) for instrument approaches. The ideal sensitivity for instrument approaches is a matter of some controversy and is influenced by a number of variables, including whether the approach is to be manual or coupled. Since pilot tracking error (called flight technical error by procedure design specialists) accounts for over 80% of the .6 mile (with time difference updates) system error budget used by procedure specialists for designing instrument approaches, we examined the influence of CDI sensitivity on tracking error. A reduction in the flight technical error associated with Loran instrument approaches might make the system more useful for getting in and out of some of those remote airports.

We established a non-precision approach into a small uncontrolled airport and had 12 instrument rated private pilots make instrument approaches into the field using an instrumented single engine fixed gear aircraft equipped with Loran-C. The 12 pilots made a total of 144 approaches with the following six CDI sensitivities (displacements required for full scale deflections):

Crosstrack error and pilot workload for six CDI sensitivity levels

	RMS Error (Naut. miles)			
sensitivity	**first 1/3**	**second 1/3**	**third 1/3**	**workload 1 to 7**
2 1/2 miles(4 km.)	.26	.23	.17	2.4
1 1/4 miles(2 km.)	.15	.11	.08	3.2
3797 ft (1157 m.)	.15	.10	.09	3.1
1898 ft.(578.5 m.)	.10	.05	.05	4.0
949 ft.(289 m.)	.06	.04	.05	4.3
475 ft.(144.8 m.)	.06	.03	.0	5.6

The 475 foot sensitivity level is about the same as that of an ILS at the middle marker.

Each pilot was asked at three different points during the approach to rate (on a scale of 1 to 7) how hard he was working, with 7 indicating that the pilot had barely enough time to attend to all aspects of the flying task. As the sensitivity of the needle increased, cross track error decreased consistently. In fact increasing the sensitivity of the needle by four times over the 1 1/4 mile recommended by RTCA decreased the cross track error by over 30 percent during the first third of the approach, and nearly 40 percent during the last third of the approach. If 1,898 feet rather than 1 1/4 mile were used as the standard for CDI sensitivity, it could substantially reduce the system error value used in developing instrument approaches, and lead to a significant reduction in the width of the path required to be cleared of obstructions for Loran approaches.

This fourfold change also increased the pilot's estimate of workload by less than 1 point. The average workload rating of 5.6 that was given the highest sensitivity condition would not seem to be too unacceptable, but the 475 foot sensitivity level was rated as "unflyable" on 4 of the 24 approaches made with it. The second highest level produced a lower workload estimate, but was also judged uncomfortably difficult to fly on a couple of the approaches and might be too hard to fly under marginal flying conditions,for example, such as those that could be produced by icing.

Our next flight study will examine the flight technical error associated with using positive course guidance provided by Loran-C for straight and curved missed approaches.

Discussions

One of the most thorough and efficient methods of determining the human factors problems associated with a particular avionics system is to ask the users about the features of the system that they use and don't use, and the problems that they have with them. Prof. Wiener of the University of Miami has been very successful in using this approach, in conjunction with exhaustive cockpit observations, to identify human factors issues in the application of automation to air carrier flight decks. We have just initiated discussions with the Aircraft Owners and Pilots Association's (AOPA) Air Safety Foundation to conduct a survey of Loran-C use by private pilots. Our preliminary work in this regard has already revealed a few human factors issues beyond those already discussed.

The cockpit environment of the most common private aircraft may require special design considerations. There is often no room on the cockpit instrument panel within the pilot's area of primary view for a Loran receiver. The primary flight displays are directly in front of the left seat and the nav/com receivers are mounted in the center of the panel. Often the Loran receiver is mounted way far to the left side of the panel nearly 45 degrees from the pilots primary line of sight. The pilot has to stretch and lean to the left to use the controls and read the display. Annunciations of warnings and alerts cannot be detected without looking directly at the display. Some pilots equip their aircraft with remote CDIs and warning annunciators located within their area of primary view, a requirement for IFR approved systems, but few VFR systems are so equipped. Deductibility of visual warnings is also reduced by high ambient illumination. Small GA aircraft often are designed for high outside visibility and may admit more light than is the case with larger aircraft. RTCA guidelines recommend that "...the brilliance of any display shall be adjustable to levels suitable for data interpretation under all cockpit ambient light conditions...," and many sets have either manual controls for this adjustment or sensors that automatically increase display brightness as ambient illumination increases. Unfortunately, the range of conditions seem to go beyond the limits of the display capabilities. Solutions to these problems include tilting the display/control panel toward the pilot, shielding the displays, and the use of auditory alarms.

Another RTCA operational standard is "minimum risk of inadvertent turn-off." Many of the small Piper aircraft have the switch for the electric fuel pump located next to the electronics master switch. The pump functions as a backup for the engine driven pump and is turned on for takeoff and approach and turned off when at a safe altitude. Occasionally when busy climbing out and heading toward the first departure fix the pilot will reach down, intending to turn off the electric fuel pump and inadvertently turn off the electronics master switch. The pilot almost instantaneously turns it back on. His VORs and communications are on line immediately, but his Loran is not. Loran guidance will be lost until the set reacquires the signal, the set is reinitialized, and the flight plan is called up again. It depends upon signal strength and some other variables. This could take over a couple of minutes to do and would create an uncomfortable situation if the aircraft were exiting a congested terminal area. The design of the Loran or requirements for its installation must preclude such inadvertent turn off.

Just as Loran must interface well with the aircraft that it is installed in, so must it be compatible with the practices of air traffic control. When flying under instrument conditions pilots must expect to receive unanticipated changes in routes of flight. When flying an area navigation system the changes may be given in terms of waypoints that are define in latitude and longitude coordinates. This information is given the pilot by the air traffic controller in the following format:

42.22.8 **N** and 71.29.4 **E**

In three of the sets that we examined in the laboratory, the hemispheric designator must be entered before the degree, minute and second information, for example:

N 42.22.8 and **E** 71.29.4

The difference between the order in which the alphanumerics are presented by ATC and the order in which they must be entered into the Loran sets may be expected to cause some errors in data entry, or rejected data entries that can be disruptive and time consuming.

Complacency is a term that aviation human factors professionals have come to associate with aircraft automation over the last decade. It describes a relaxed attitude associated with the confidence that flight crews develop in the reliability and correct functioning of the automated systems currently used to help fly commercial air carriers. In a sense it is a compliment to the designers, maintainers, and manufacturers of those systems, because complacency develops as an inverse function of the negative experiences accumulated by the system user and a lack of appreciation of the automated system's limits. The manifestations of complacency include relaxation in monitoring the performance of the systems and a willingness to let the skills replaced by automation decline. We now have good reason for adding LORAN COMPLACENCY to the lexicon of aviation terminology. Several examples of admitted pilot behavior justify this addition.

It is common today for pilots to connect their Lorans to the aircraft autopilot for VFR flights. This should free their attention for monitoring other traffic and for flight planning. Unfortunately, in some cases it also relieves the pilot of the necessity for monitoring his charts closely and gives him enough spare attention to engage in activities that reduce situational awareness and otherwise detract from flight safety. A recent discussion with the owner of a Loran-equipped Beachcraft Bonanza revealed that he accomplished considerable preparation for a presentation he had to make at his destination while under a Loran-automation controlled flight to a business meeting. The pilot did not know when he passed near restricted airspace or crossed a rather significant mountain range during the flight. He only returned to his flight duties when the Loran calculated ETA and distance information alerted him to the time when he had to prepare for the approach.

Private pilots also use their VFR Lorans for instrument approaches. They create instrument approaches into airports and "shoot" difficult instrument approaches with their Loran rather than the approved equipment, e.g. the ADF, and descend below minimums "for a better look" at home base airports. They do this because their experience with the apparent rifle-barrel accuracy of Loran gives them the confidence that they can perform these activities safely. They do not understand the limits of the Loran systems. For example, FVR Lorans are not designed to accommodate some of the waypoint configurations that may be created for a home made instrument approach. Closely spaced waypoints that require sharp turns may cause the sequencing mechanism to skip a leg of the programmed approach and will produce inaccurate time and distance estimations. Also, steeply banked turns, planned or inadvertent, may cause the receiver to momentarily lose the Loran signal and skip a pulse cycle. Such cycle slips can indicate a lateral displacement of the aircraft by as much as a mile. The human factors problem of system misuse probably cannot be completely solved. However, I'm sure that if more pilots were aware of the limits of Loran, fewer pilots would be misusing it. User education would seem to be at least a partial solution here.

Conclusions

The issues concerning human factors of Loran-C are many. Those identified in this paper illustrate that, as with other area navigation systems, human factors problems with Loran include but are not limited to displays and controls. These problems extend to the interfaces with other aircraft systems that are necessary to support the operation of the Loran and to the flight environment within which the Loran is to be used.

Concerns that were identified in this paper include:

Receiver

- Control locations that increase the probability of errors
- System logic that makes recovery from data input errors difficult
- System designs that make it difficult to verify data entry accuracy
- Data entry procedures that are time consuming and susceptible to error
- Lack of convenient in-flight guidance on how to access and exercise Loran functions
- CDI sensitivity that is not be optimal for certain Loran applications

Environmental compatibility

- Inadequate protection against inadvertent turn off
- Inadequate display capability for full range of viewing conditions in the cockpit
- Miss-match of data entry logic to air traffic control operations

Training/handbook

- Users not alerted to the limits of Loran systems in aviation operations

In order to identify human factors issues before they become safety issues, designers must review errors made in the design of similar systems, determine user requirements and anticipated equipment applications, and simulate the use of prototype designs in representative flight scenarios. Potential solutions to identified human factors problems include interface redesign, changes in procedures required to use the equipment, and user education.

DEVELOPMENT OF A NATIONAL PLAN FOR ADDRESSING FUTURE AVIATION HUMAN FACTORS NEEDS

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My purpose here today is to provide you with an overview of the human factors research and development efforts that we are undertaking. Specifically, I will describe the major priorities, or research areas, that are the components a new, comprehensive national plan for human factors research. This national plan will include research aimed at the alleviation of human performance problems in all types of aircraft, in the air traffic control environment, and in the interaction of the two environments. Moreover, this work is intended to encompass both the operational and maintenance spheres of each environment. My job with the Federal Aviation Administration (FAA) is to coordinate the development of the comprehensive plan, but it will be the product of a joint partnership between the FAA, the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), the operational and industry community, and the academic community.

There is, of course, no need for me to remind this distinguished group of aviation authorities of the magnitude and breadth of the human performance problem. We all are painfully aware of the statistics, but even so, we have still not taken the necessary steps, or committed adequate resources, to attack the problem on more than a superficial level. Our governments, industries, and academic institutions expend enormous resources on engineering and technology-oriented research and development, but in comparison, we spend very little on vital research areas in the social and behavioral sciences.

This situation has only recently shown signs of changing in the U. S. after a number of well-publicized and entirely preventable aircraft accidents. Ironically, some of these accidents occurred in "new technology" aircraft that were highly automated as a means of reducing operator workload and human error. These aviation accidents, as well as those in other non-aviation environments (e.g. the nuclear reactor accident at Chernobyl, USSR; the accidental destruction of an Iranian airliner by the USS Vincennes; and the "Herald of Free Enterprise" ferry capsizing at Zeebrugge, Belgium) have shocked us all and stimulated new discussions of the human performance problem.

Fortunately, there has also been some significant action. Last year, the Congress of the U.S. enacted new legislation, "The Aviation Safety Research Act" which provided for the increased funding of human factors research. In addition, the Air Transport Association of America (ATA) organized a Human Factors Task Force made up of representatives of government, the manufacturers, operators, and the scientific community to address the problem. This group has just released its recommendations, and they represent a broad consensus as to the critical dimensions of the problem.

At this point, I am sure some of you are wondering perhaps what is so different about the current effort? Our interest in seriously addressing critical human performance issues has been high in the past, but has faded without significant action. Moreover, very productive human factors efforts have been on-going at NASA, DOD, FAA and in academia for many years, even though they have not been coordinated on a systematic basis. However, there does seem to be something fundamentally different about the current high level of interest in human factors. Many of today's managers and decision-makers seem to perceive that our society may be nearing a point of diminishing returns on investments in technology, making investments aimed at the human element far more attractive.

But, perhaps more significantly, the difference now may be that the key elements necessary for a fundamentally greater commitment to human factors research and development appear to be in place. These four conditions include: 1) A very high level of government and management support currently provided by the active participation of the senior management of the FAA the current Administrator, and the Secretary of Transportation; 2) A general agreement among the key government agencies that the problem should be addressed as a coordinated national effort to avoid duplication and inefficient utilization of scarce resources; 3) A widespread belief in various parts of government in the necessity of more resources for research, and the Congress and various agencies have begun to plan for substantial funding augmentations; and 4) Agreement among researchers and the operational community as to what the human factors research priorities are and how to go about addressing them, which is rapidly being accomplished through activities such as the ATA-sponsored Human Factors Task Force. Thus, to a substantial degree all four of these conditions have been met, providing the human factors community with a substantial opportunity to rectify past neglect.

I will now describe the major categories of our national plan. They represent those problem areas that we consider to be the most serious, as well as many questions for which there are no reliable answers. This paper does not in any way represent an exhaustive list of research projects. Rather, it is an attempt to provide an overview of the types of problems that must be effectively addressed if we are to make significant progress into the 21st century.

AUTOMATION AND ADVANCED TECHNOLOGY

One of the biggest temptations facing the designers and engineers struggling to reduce human error in the aviation system is to address the problem by automating many of the tasks traditionally performed by humans. Under this design philosophy, the human operator has begun to assume the predominant role of "systems monitor," or serving as a backup to the automated systems. Few would question that this is the direction in which the aerospace industry has been headed and, indeed, appears to be going in the future. This approach has resulted in an impressive array of aircraft and air traffic control technology that is highly reliable and which contains vastly superior capability from a pure performance standpoint. No one questions that the technology is better. However, questions are beginning to emerge about the respective roles of humans and the new technology.

One of the things that we are beginning to learn is that it is simply not true that automation is an easy way to remove human error from the system. While automation can and does eliminate certain classes of error, we have begun to realize that it can also create whole new classes of error. It has been observed by some researchers in this area (e.g. Wiener), that in some cases new errors created through automation can be worse than the types of errors alleviated by automating. Thus, it is becoming increasingly common to hear suggestions that we critically examine our automation philosophy and consider new approaches to automation that are more "human-centered." Our prime concern is not so much the current levels of automation seen in aircraft such as the B-747-400, MD-11, and A-320 and in air traffic control concepts such as AERA III, but how far down the same road can we afford to go with future systems? Do we continue to automate more and more functions leaving humans with less and less to do? Anecdotal reports are abundant, but there is little research pertinent to either current or planned generations of aerospace systems that either supports or relieves our increasing concern.

The primary experimental priorities revolve around issues such as: 1) too little workload in some phases of flight and too much workload associated with programming when flight plans or clearances are changed; 2) the potential for substantially increased head down time; 3) an inadequate "cognitive map" of what the system is doing making recovery from automation failures sometimes problematic; 4) hesitancy of humans to question or take over from an automated system even when there is compelling evidence of a problem; 5) degradation of basic skills; 6) job dissatisfaction associated with the lack of a challenge; and 7) complacency, lack of vigilance, and boredom.

Our national research program will include a number of empirical investigations utilizing high-fidelity simulation techniques to explore some of these issues. This is a particularly critical period of time for such research to take place because we are in a very interesting transition period. Currently, we are seeing the introduction of very advanced technology operating alongside predominantly manual systems, and at the same time, pilots and controllers are often moving back and forth between automated and manual environments. Thus, the current environment provides many opportunities for controlled comparisons of two very different types of operating environments.

We feel strongly that this area of research should be the top priority for human factors research and development. The impact of automation technology will not only be felt in all sectors of the aviation community, but will extend well beyond to virtually all human performance issues in many environments.

AVIATION SYSTEM MONITORING CAPABILITY

A key element of our human factors research and development effort depends on our ability to keep abreast of trends, both positive and negative, in the operational environment. Historically we have done a reasonably good job of compiling, integrating, and utilizing databases in the hardware arena. These databases have been invaluable in problem identification and in specifying where further research efforts (usually engineering efforts) are necessary. However, we have not been as successful in utilizing or adapting these databases for use in human factors research.

One bright spot has been the Aviation Safety Reporting System (ASRS), a joint effort of NASA and the FAA, where pilots, controllers, or anyone connected with the aviation system can submit confidential reports about safety problems of which they have direct knowledge. ASRS has received well over 100,000 reports since its creation in the mid-1970's, but has not been utilized to its fullest potential by human factors researchers. We will seek to expand the application and promote usage of the ASRS.

In addition, other types of databases, such as those kept by many organizations on incidents and operational anomalies, would be useful in many types of human factors studies. We need better standardization and awareness of human factors variables among individuals in a position to collect these data so that it is entered and classified correctly and reliably across databases. There is very little variability with respect to how various technical parameters such as engine malfunctions are classified across databases, but no such commonality exists for human factors variables. This problem clearly compromises our ability to search for statistically significant trends.

BASIC SCIENTIFIC KNOWLEDGE OF HUMAN PERFORMANCE FACTORS

Many of the products of our national plan for aviation human factors research will be focused upon very specific applications, such as workstation design or the training of aviation personnel. Nonetheless, it is important to recognize the vital link between basic scientific knowledge and specific applications such as new technology or training and selection techniques. Thus, we must invest in the pursuit of this basic knowledge in certain vital areas if we are to expect answers to our human behavior and performance problems in the future. Unfortunately, science rarely provides quick answers to complicated problems.

The issue of fatigue and circadian dysrhythmia is one example of an area where the state of basic scientific knowledge is currently not sufficient to allow us to design effective countermeasures to problems associated with shift work and long-haul operations. In the early 1980's, Curt Graeber and his colleagues at the NASA-Ames Research Center began an ambitious research program into the factors affecting flightcrew fatigue, and this program is just now beginning to suggest useful applications.

Another area where more basic knowledge is needed is the influence of organizational and management "culture" on human performance. We tend to focus almost all of our attention on the pilot or crew, the air traffic controller, or the maintenance technician. At the same time, we spend very little time examining how the organization itself affects the performance of these individuals. It does not matter how well you select and train an individual, or how well-designed the technology is, if the "culture" or climate of an organization is unhealthy or does not allow an individual to perform at his or her peak. Richard Hackman and his colleagues at Harvard University have begun an innovative program to look at these factors across various U. S. airlines. We intend to promote more research of this type so that the knowledge base will be there for future applications.

HUMAN PERFORMANCE MEASUREMENT

The development of better research methodology and techniques for measuring human performance will be of vital importance to our ability to accomplish the national plan. The aviation human factors community has made significant strides in this arena within the last 10 years. Thanks to the rapid advancement of microprocessor technology, high fidelity, real-time simulation is widely available in most areas of the aviation environment. This technology has revolutionized the researcher's ability to design and conduct controlled scientific studies of human performance in the aviation system. Computers coupled with video and audio systems allow precise measurement of all aspects of human behavior. Moreover, the realism associated with many types of simulation enhances the accuracy of our results and allows us to apply these results to the operational environment with greater confidence. We intend to expand the usage of these techniques and to promote the development of ever more sophisticated methodologies.

Another area where better methods for human performance measurement are necessary concerns the assessment of crew performance. Virtually all of our emphasis has been upon the assessment of individual technical performance. However, we have recently become acutely aware that most aviation incidents and accidents are due to breakdowns in the process of crew coordination and communication, not because of a lack of individual technical skill or knowledge. As a result, many U. S. airlines are now conducting training commonly referred to as "Cockpit Resource Management" (CRM) programs, and the FAA expects to issue new regulations governing pilot training known as the "Advanced Qualification Program" in which CRM will be required. In order for CRM programs to be effective, we will need to able to do a better job of evaluating how crews are performing as a unit--something we have not had very much experience with. Robert Helmreich and his colleagues at the University of Texas have pioneered work in this area, but much remains to be done.

INFORMATION TRANSFER

Approximately 70 percent of all the ASRS reports (over 100,000) involve some sort of information transfer problem, suggesting that information transfer may be the single most difficult problem facing the aviation system. Many of these difficulties involve communications between air traffic controllers and pilots. As system complexity increases and traffic grows, we can only expect the frequency of information transfer difficulties to increase. The priority research questions in this area revolve around the most efficient and reliable ways to exchange information, what information should be available to each, and when.

Eliminating or reducing the system's reliance on verbal communication is often mentioned as a promising solution, and a considerable amount of research is underway aimed at designing and evaluating the best uses of data-link technology. Few will question the need for improving upon the current system, but, as with other "automation solutions," data-link may not be the panacea engineers and designers sometimes claim. Its potential application raises a number of human factors questions. One such question revolves around whether data-link can or should provide the same "richness" of information currently available verbally. For example, listening to information pertaining to other aircraft on the air traffic control "party-line" provides sometimes valuable information on what to expect that allows crews to prepare for various types of contingencies. The urgency of a clearance sometimes conveyed via a controller's tone of voice is another example of "extra" information available on the verbal channel. In short, not enough is known about the system-wide implications of the widespread usage of data-link technology.

CONTROLS, DISPLAYS, AND WORKSTATION DESIGN

The design of controls and displays is the area most commonly associated with human factors research, but while the focus of the field has widened, it will remain an integral part of the national plan. Significant progress has been made in applying human factors techniques to the design and evaluation of controls and displays. A simple comparison of the cockpit displays on new derivative aircraft, such as the 747-400 or the soon to be rolled out MD-11, with their predecessors (B-747-100/200 and DC-10) illustrates this progress nicely.

However most of the advances have occurred by applying human factors design principles on a sub-system by sub-system basis. As a result, we have not been as successful as we should have been in predicting interactions between systems that may have negative consequences from the human performance standpoint. This is an important consideration, since design changes on one system that may have been scientifically validated as enhancing operator performance on that one system may well have workload implications for a seemingly unrelated system. The widely cited examples of pilots in congested terminal areas with their heads down attempting to keypunch in a new clearance instead of looking outside is an example of one of these unforseen interactions. Our research must do a better job of identifying these interactions by taking into account the performance of the entire system.

TRAINING AND SELECTION

This is an area of obvious need, but also one where significant progress has been made within the last decade. The progress made in high fidelity, real-time simulation technology has also revolutionized the training world. Line-Oriented Flight Training (LOFT) and CRM programs are now widely utilized to provide realistic training in crew coordination, judgement, and decision-making. We have begun to realize that training on technical skills dimensions will not guarantee that a crew can function with a high degree of reliability and efficiency. FAA policy-making now recognizes the necessity of CRM training for multi-pilot aircraft operations, but there may well be applications for air traffic controllers as well. In addition, CRM training programs are relatively new and little is yet known about the long-term effectiveness of such programs.

In order for training programs to produce the best possible personnel, the right people must be selected, and this is an area where much work remains. Our selection criteria for pilots, controllers, and maintenance inspectors have focused primarily on technical aptitude. This rather narrow focus ignores the influence of many other dimensions, such as personality characteristics, that may significantly influence performance. For example, in commercial aviation, selection criteria have been weighted heavily toward individuals who are highly skilled technically, but also tend to be less communicative, and more aggressive than average. Tom Wolfe described this profile colorfully in his book, The Right Stuff. What is interesting about this population is that they are working in an environment where team performance is vitally important (as the accident statistics testify), but they tend to possess social and personality characteristics less often associated with team performance. In this case most selection criteria may have been incongruent with operationally significant performance factors.

Another factor that will no doubt present challenges for our selection and training efforts will be the continuous application of ever more sophisticated automation in our cockpits and air traffic control suites. Pilots and controllers have traditionally come from a segment of the population that is highly achievement-oriented and motivated to perform in difficult and challenging environments. We are beginning to see signs that automation is removing many of the job-related characteristics that originally attracted these individuals to the aviation environment. Some researchers have further speculated that we may need to begin think about selecting on radically different psychological and behavioral dimensions as the environment moves from an emphasis on "active controlling" to one of more passive "system monitoring." One thing is sure: there exists a significant need for extensive research into these questions.

CERTIFICATION AND VALIDATION STANDARDS

This last area is perhaps one of the most focused applications and is concerned with how we go about translating the products of this program into concrete certification and validation guidelines. Currently there is precious little in the way of human factors certification criteria. Part of the problem is related to the way a new aircraft or air traffic control system is developed.

As discussed previously, these systems are evaluated on a sub-system by sub-system basis. Usually, as in the case of aircraft, the entire system is not available for evaluation until very late (sometimes not until the first aircraft is rolled out). At this point, the discovery of human factors problems as a result of unforeseen sub-system interactions is very costly.

Unfortunately, there are no simple answers to this problem, but there is some hope that advances in simulation science and in the power of computer modeling techniques can help us address this difficult issue.

Summary

The human factors community is now in the midst of a unique opportunity to begin addressing the broad array of human performance issues that have traditionally been neglected. In light of aviation's general lack of success in reducing the large proportion of human error incidents and accidents, there appears to be a growing perception in government and industry that we may be entering a stage of diminishing returns on our investments in the pursuit of purely technological solutions to human performance problems. This perception has contributed to recent efforts to expand human factors research and development efforts.

In the U.S., the FAA has recently begun managing the development of a comprehensive national plan for aviation human factors research. This effort will be a partnership of the FAA, NASA, DOD, industry, and academic communities. Major efforts are being planned in the following areas: automation and advanced technology; aviation system monitoring capability; basic scientific understanding of human performance factors; human performance measurement; information transfer; controls, displays, and workstation design; training and selection; and certification and validation standards.

Human error on the flight deck

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Despite terrorist bombs and structural failures, human error on the flight deck continues to account for the majority of aircraft accidents. The Royal Air Force (RAF) Institute of Aviation Medicine (IAM) has investigated the psychology of such error since the early 1970s, and to this end has used two principal techniques. The first has involved assisting in the official inquiries into both RAF and civil flying accidents, and the second has involved setting up a reporting system that permits any commercial pilot to report his own everyday errors, in complete confidence, to the RAF IAM. The latter system possesses the clear benefit of gathering error data untainted by considerations of culpability, and sometimes permits system rectification before the occurrence of accidents. This paper examines selected examples of errors associated with the design of equipment and with the social psychology of crews, and suggests that some consideration of the psychology of organizations may be necessary to ensure that the problems of human error are given the degree of consideration they require.

INTRODUCTION

It has become cliched for those writing about aircraft accidents to point out that flying is, compared with other forms of transport, safe. Commercial jet transport aircraft are lost at a rate of about one per million flying hours, so there is some degree of contradiction in including the consideration of such events in a symposium on hazardous situations. The individual perception of 'risk' is determined, however, not just by the probability of a certain outcome, but by the subjective utility of that outcome. The negative utility of being involved in an aircraft accident is enormous, and this naturally affects the importance of the subject to the passenger. It is also true that when an aircraft accident occurs, it is such a large and public event that it cannot be ignored, and this may help to generate the measure of perhaps irrational anxiety about flying that undoubtedly exists in a significant proportion of the population.

The attention consequently focused on flying accidents has meant that errors in aviation have been investigated more thoroughly than errors in any other sort of endeavour, and the solutions that have been put in hand may well have lessons for those in less well-researched disciplines. What then, makes flying safe? A common belief is that the commercial pilot is a singular individual, carefully selected for his or her high degree of astuteness and particular aptitude for the job. In fact, the average holder of a commercial flying licence in the U.K. has a performance on a test of adult intelligence about equal to that of the average student at a teacher training college, and rather lower than the average undergraduate's. The range of intelligence scores achieved by pilots is very wide, yet even the poor performers have been able to demonstrate sufficient competence at flying to gain a commercial licence. If safety does not appear to stem from the intrinsic quality of the pilots, what is its source?

There are probably two main factors safeguarding flying from human error. The first, and probably most important, is that commercial flying has become extremely regulated and 'proceduralized'. In flying there is a 'procedure' for every predicted eventuality. In leaving any airport the pilot will be provided with a set of standard departure patterns that define the routes and heights that he musch achieve during that departure, and the same goes for arriving at an airport. If an engine catches fire, the pilot will not need to invent or think through the best course of action: it will be written down in his flight reference cards. In starting or shutting down the aircraft, the safest procedure will have been worked out and embodied in a drill. This process has meant that everything possible in flying has been reduced (in terms of one set of jargon) to a 'rule-based' activity (Sanderson & Harwood 1988). High-level decisions are made as infrequently as possible on the flight deck as every contemplable set of circumstances will have been discussed, and the best solution and procedure decided upon in advance. This has not always been so in flying, however, since there was natural resistance among pilots to see every aspect of their job reduced to the exercise of some predetermined set of responses, leaving much less within their immediate locus of control. The pressure for standardization has come from safety considerations, and O'Connor (1987) has pointed out that in 1933, when flying in the U.S.A. was regulated in a way that did not happen in the U.K. until the 1950s, U.S. airlines flew 21 686 515 passenger miles per fatality, whereas the British figure was 1 080 000.

The second major reason why the system is safe is the emphasis that is placed on the training and competency checking of airline pilots. The pilot must not only demonstrate his general competence at flying before gaining a commercial licence, but he must hold specific endorsements on his licence for each aircraft type that he flies. Even then, he must pass regular checks in the simulator and when flying on the line so as to remain legal, and he must be retested if his level of flying activity (or skill maintenance) drops below certain prescribed minima. It is probably true to say that in no other profession in which errors can threaten life, such as medicine or air traffic control, is the maintenance and checking of competence so thoroughly addressed.

The two factors considered above address exclusively human factors considerations: minimizing the scope for error in flight-deck decision making through proceduralization, and ensuring that pilots are competent at exercising the procedures for their aircraft. Neither of these factors ~~have~~ has required the application of any particular psychological expertise as the requirements and solutions have been largely obvious. Unfortunately, serviceable aircraft continue to crash, and the remainder of this paper is concerned with the human factors that remain relatively unaddressed in flying. The data for the conclusions that are drawn come from two main sources. The first is the attendance of psychologists from the Royal Air Force (RAF) Institute of Aviation Medicine (IAM) at the inquiries into (and interviews with the crews involved in) both military and civil flying accidents. The second data source is a scheme known as the Confidential Human Factors Incident Reporting Programme (CHIRP)†. This enables all civil airmen and air traffic controllers to report their errors, not anonymously, but in complete confidence, to the RAF IAM. Each year about 200 pilots and air traffic controllers take the opportunity to use this scheme to tell us about the mistakes they have made in the air and why they believe they made them. No attempt is made here to give a comprehensive account of the human factors that cause incidents and accidents but only to provide a set of examples that typify certain problem areas.

† The Confidential Human Incident Reporting Programme was initiated and is sponsored by the Civil Aviation Authority and is operated by the RAF Institute of Aviation Medicine, Farnborough, Hants, U.K. Information on the scheme and its publication, *Feedback*, may be obtained from this Institute.

HARDWARE

The first area that is always assumed to attract a great deal of attention in aircraft development is that of the design of the controls and displays used by the pilot, and this is, at least to some extent, true. Unfortunately cockpit designs are constrained by cost, space, and the number of operators that have been decided upon. There are also many problems that can arise through the life of an aircraft as it is modified to meet new requirements that may render an initially adequate arrangement less acceptable. The following report was submitted to the CHIRP system by a helicopter pilot, and concerns the way in which pressure settings were demanded and displayed on his helicopter's altimeters. 'At 2000 ft my co-pilot said, "You've gone below 2000 ft!". I replied that I had not, but then saw that my altimeter was set on 1030 mb and not the correct QFE (airfield ground level pressure setting) of 1020 mb'. Consider the altimeters shown in figure 1. The altimeters are viewed from a distance of some 50 cm, while the instrument panel is acknowledged to suffer from shake. In the AS332 fleet of aircraft, the individual helicopters are fitted with altimeters of types (*a*) and (*c*) or (*b*) and (*c*). As the pilots fly from either seat, according to crewing requirements and convenience, a pilot may find himself using an instrument of type (*a*), (*b*), or (*c*).

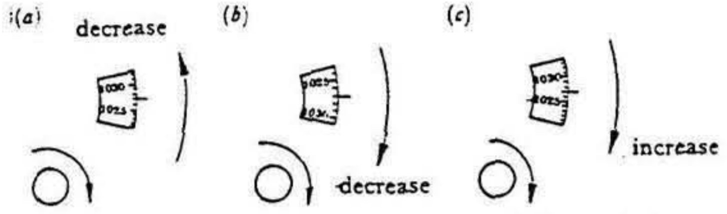

FIGURE 1. Arrangements of barometric setting controls and displays on helicopter altimeters.

These altimeters are superficially similar, but the sub-scales and the mode of changing the datum pressure setting are all different. It seems that most of my colleagues have difficulty in seeing and setting the correct pressures. Whatever happened to the altimeters with veeder counters for the pressure setting that we used to have 20 years ago?'

It requires no knowledge of ergonomics of man–machine interface design to see what is wrong with the altimeters described above, or to imagine the nature of the accident that they could bring about since a wrongly set altimeter can easily cause ground impact. The practical decision that has to be made, however, is whether these altimeters are so unsatisfactory that the regulatory authority should compel the operating companies to go to the expense and trouble of replacing or standardizing them. The altimeters clearly function, and who is to assign a probability to their causing an accident during their operational life? Had the altimeters actually caused an accident, however, they would obviously be changed since we would know that the above probability is 1, and it is this fact which determines that flight safety is a process driven far more powerfully by failures that result in accidents than by identified system shortcomings. An airline operator has justified this situation as follows:

> Aircrew should be expected to be reasonably intelligent alert human beings who are able to assimilate that they are liable to normal human error. Consequently, they should be prepared to accept these errors are their own responsibility and not palm everything off on some designer or management who expect a fair day's work for a fairly generous salary. A crew member who by his own admission is previously aware that the switch positions are reversed on two similar aircraft is surely capable of considering mis-selection as soon as a problem appears.

It has been implied that although ergonomic problems may be powerful progenitors of human error, they do not demand intellectual solution but simply an appropriate appreciation of the balance between risk and cost on the part of operators and regulators. It is clearly part of the task of the applied psychologist to evaluate the risk that may be inherent in a piece of design. but broader interests will inevitably need to be taken into account, and the role of the psychologist may be less clear, in evaluating the balance between the probability of hazardous failure and the economic cost of rectification.

Unfortunately, not all ergonomic problems on flight decks are as amenable to solution as that described above. A problem of current interest concerns engine instrumentation. Such instruments may be divided into those required for setting engine parameters and those providing status information such as oil temperature. The 'setting' instruments have traditionally been located on the front panel of the cockpit, arranged in columns aligned with the appropriate throttles and in rows of identical instruments (see figure 2*a*). The 'status' instruments may, on a three-man flight deck, be displayed on a panel behind the pilots as it will be the third pilot or engineer whose task it is to monitor them.

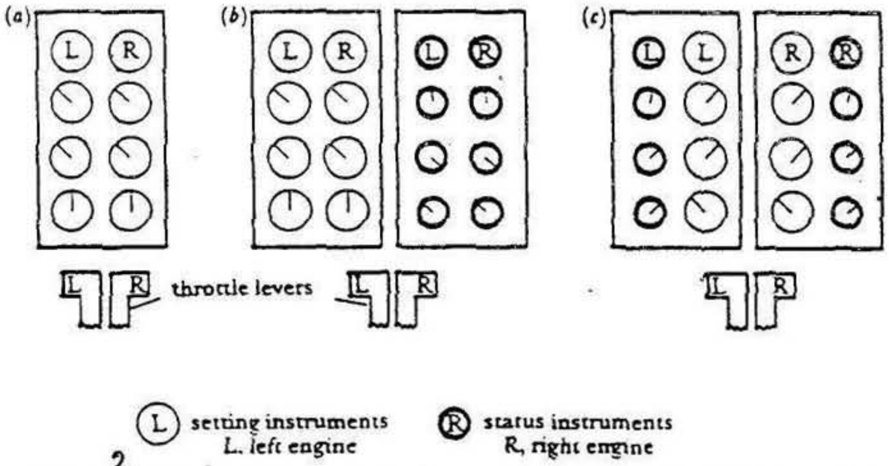

FIGURE ~~1~~ 2. Possible arrangements of engine instruments on twin-engine aircraft.

On a two-man flight deck, however, all of the engine instruments must be accommodated in view of the two pilots. Since the front panel is limited in height, is it better to have arrangement (*b*) shown in figure 2, in which the status instruments have displaced the setting instruments to the left, or is it better to leave the setting instruments aligned with their respective throttle levers and split the status instruments so that they are placed on either side of the setting instruments (arrangement (*c*)? (*c*) Has the advantage that the instruments for each engine are kept together and in line with the landmarks provided by the throttles, but B has the advantage of keeping similar instruments together and making deviant readings easier to identify. In fact, most two-pilot aircraft have arrangement (*b*), but a recent accident in which the crew shut down the serviceable rather than the faulty engine will doubtless cause some attention to be given to the wisdom of the practice.

Aircraft equipment today is far more flexible and capable of being more closely tailored to the human's requirements than ever before, and this means that the onus has moved from training the pilot to cope with what is practically achievable to designing a system that matches the human's abilities. A specific example of this process is provided by the display of attitude (pitch and roll) information to pilots. Traditional attitude indicators (AIS) appear as they do because the original devices consisted of a vertical gyro with a horizon card and aircraft symbol attached to its front. Although the attitude indicator in a modern aircraft is likely to derive its data not from a gyro but from a laser inertial platform, the image on its electronic display would be familiar to the users of the very earliest gyro instruments.

Such consistency is obviously advantageous in minimizing the likelihood of negative transfer of pilot skill between one aircraft and another, but pilot disorientation continues to be a lethal problem in flying, and conventional AIS may have a lot to answer for. They provide information to the central or focal part of the visual system that provides the dominant visual input to conscious attention, but do not drive the peripheral retina that is so important in detecting the movements of the world, vection cues, which are probably essential for providing a normal perception of orientation. Traditional AIS therefore compel instrument flying to be a conscious and rather complex skill rather than an exploitation of natural human abilities. Attempts are now being made by life scientists (Green & Farmer 1985) to develop wide field of view attitude indicators to match the machine to the man instead of vice versa.

The balance between the work that is done by man and that which is done by machines on the flight deck has progressively shifted since the first jet airliners were developed. On these it was common for there to be two pilots, a navigator, a flight engineer, and a radio operator. Automated engine management and navigation have caused all but the two pilots to be dispensed with, and automation in military aircraft has reached the stage at which the term 'electronic crew member' has become part of the accepted jargon (Taylor 1988). How to integrate this electronic individual with the other crew members is more than a simple design problem, as the manner in which the pilot models his environment may be changing in a fundamental way.

On older aircraft the pilot knew that the airspeed indicator was driven by the pitot head sensor in a way that he could comprehend. By integrating information from various simple displays like this, the pilot was able to generate his model of what the aircraft was doing in space. Today, however, information is sensed in highly sophisticated ways and combined by the aircraft's computers to be presented on an integrated electronic display. Such displays are generally reliable, well engineered, easy to interpret, and a pleasure to use. The potential problem is that as they are so seductive, and since the pilot cannot possibly understand the technology involved in the generation of the display, he is compelled to use the display itself as his world model rather than creating his own internal model from the raw data. Although this shift in modelling mechanisms is likely, overall, to reduce error, it may generate a different class of problem in which the pilot, used to trusting his technology, actually trusts it too much and fails to utilize cues that should suggest to him that an error has crept in. The most spectacular example of his form of error that has so far occurred concerned the Air New Zealand DC10 that collided with Mount Erebus in Antarctica. The aircraft's inertial navigation system's computers had been programmed with an incorrect position, but the crew trusted them and were probably seduced into interpreting external visual information in a way that conformed with the world model generated for them by the aircraft.

Although equipment design, or traditional ergonomics, is not a topic that is presently in vogue among those who theorise on human error, the purpose of the foregoing has been to emphasize that these micro-factors in the aviation system are still matters of critical importance that must constantly and individually be addressed by those human factors specialists who are engaged in bringing about practical improvements to safety.

SOCIAL FACTORS

Equipment deficiencies have their effects, by and large, on the individual operator, and there are many perceptual and skill problems of flying not addressed here of which the same could be said. The individuals on a flight deck are required, however, to operate as a team or social group and it is only relatively recently that this flight deck team has been studied to identify the ways in which their interactions may affect operational safety. Such a study suggests that many of the concepts, such as conformity and compliance, already existent within social psychology are adequate to describe the events observed in reported breakdowns of team behaviour. The idea of 'risky shift' in group decision making (that a group is likely to make a more risky decision than the average member) is clearly illustrated in the following CHIRP report from the first officer of an aircraft that had already been forced to overshoot from two approaches in poor weather.

> A suggestion was made that we should fly down 50 feet lower (than the decision height – the height at which the runway must be visible for the approach to continue) but as this was not legal, it was ruled out. We then managed to delude ourselves that flying level at the decision height of 220 feet was a legal and reasonable way to achieve our landing ... From my position I studied the information on the flight instruments with a growing feeling of unease ... We touched heavily on the centre line. Heavy braking followed what can only be considered a 'max performance' stop ... The pregnant silence which followed served to reinforce our feelings that we'd been party to an act of supreme folly and bravado and were lucky to escape with a few grey hairs and severely battered pride.

Perhaps a more common problem in the flight deck team is that associated with the way in which leadership is exercised by the captain and the influence that this has on the propensity of the junior members of the crew to question his or her decisions. Examples of such problems are quoted by both Wheale (1983) and Foushee (1984), and the two which follow are from the transatlantic analogue of CHIRP. The first concerns a captain who was ignoring a speed restriction from air traffic control. After the co-pilot had attempted a number of times to bring the captain's attention to the restriction, the captain's response was 'I'll do what I want'. Air traffic control issued further requests which the copilot attempted (unsuccessfully) to persuade the captain to comply with, until eventually the captain told the co-pilot 'just to look out the damn window'. Breakdowns in coordinated behaviour are not always associated with such obvious dominance on the part of one crew member, however, as the second example makes clear.

> The captain said he had misread his altimeter and thought he was 100 ft lower than he was. I believe the main factor involved here was my reluctance to correct the captain. This captain is very 'approachable' and I had no real reason to hold back. It is just a bad habit that I think a lot of co-pilots have of double-checking everything before we say anything to the captain.

Even when danger is clearly imminent there can still be reluctance to take assertive action. In a recent helicopter accident in the North Sea, the aircraft was manned by two captains, but the handling pilot suffered a temporary incapacitation as he came to the hover before landing on an oil rig. The aircraft descended rapidly, and the cockpit voice recorder shows that although the non-handling pilot appreciated that matters were extremely abnormal, he initially tried to gain the other pilot's attention by asking him what the matter was, and actually took control too late to prevent the aircraft from hitting the sea.

The complexities of the relationship between the pilots on the flight deck are well illustrated by the incident which occurred to a BAe 1-11 aircraft landing at Gatwick on 12 April 1988 (AAIB 1989). The main runway was out of commission and aircraft were landing on runway 08L. This was known as the emergency runway and normally acted as the parallel taxiway for the main runway. When in use as a runway, 08L was lit with good quality edge lighting, but when used as a taxiway it was lit by a set of green centreline lights. There is a further parallel taxiway to the left of 08L and this was also illuminated with green centreline lights. The result of this rather complex description is that when the main runway was in use the pilot was presented with a visual picture of an obvious runway with a taxiway to its left, and when the emergency runway was in use the visual picture was very similar. As many pilots were aware that the emergency runway was 'the taxiway to the left of the main runway', there was a danger that, during main runway closure, a crew might believe the emergency runway to be the main runway and consequently land on the most northerly taxiway believing it to be the emergency runway.

The aircraft that actually landed on this taxiway contained a two-man crew. In the left seat (normally the captain's) was a very steady and unhurried individual who was actually the legal first officer, but who was acting as the captain on his last check trip before being made a full captain. He had given the handling of the aircraft to the man in the right seat who was a rather more assertive sort of individual, was a training captain, was the legal commander of the aircraft, was checking the aspiring captain, but was behaving (for the purposes of the check) as though he were the first officer or co-pilot. The latter individual had aligned the aircraft with the correct, emergency, runway and the approach was progressing normally. The first officer was unhappy with the visual scene, however, and wanted to confirm with the captain that both of them were clear what they were doing. He consequently said to the captain words to the effect of 'You are going for the emergency runway aren't you?'. The effect of this remark on the senior, handling pilot was instantly to make him believe, inaccurately, that he was flying towards the main runway and that he should be flying towards the taxiway to the left of the main runway. Since he did not wish the first officer to think that he had made such an error he replied 'Yes, of course I am', and then surreptitiously changed course for the taxiway while the first officer's attention was directed inside the cockpit. The first officer did not look up until too late to prevent the aircraft from landing on the taxiway and narrowly avoiding another aircraft that was taxiing towards it.

The crew members of this aircraft were mature and competent individuals who were not tired, and who had a friendly and natural relationship with one another, but who nevertheless did not wish to be as frank with one another as system safety dictated. Study of incidents such as these suggests that the four main factors that determine how crew members will interact are their personalities, their statuses, their roles, and their relative abilities. It is obvious that if personality and status act in the same direction (that is, a dominant captain is paired with a submissive first officer), then there is a considerable likelihood that events will have to be serious before the first officer will choose to challenge the captain. Slightly more surprising perhaps, are the examples that show how hazardous the situation has to become before the pilot with the non-handling role will intervene in the behaviour of the handling pilot, especially if he believes the handling pilot to be competent. The Gatwick landing incident involved the interaction of all these factors, but it also required the potential for failure provided by the ambiguous runway lighting.

To prevent the recurrence of such an incident it is clear that modification was required to the runway lighting, but incidents such as this also call for a programme of behaviour modification on the flight deck. How can first officers be made to intervene in a timely and firm way that will not exacerbate the situation? How may captains be encouraged to act so as to encourage co-pilots to air their uncertainties? Many airline are now tackling these problems with programmes of simulator training that attack not only the rule-based elements of flying (shutting down an engine after a fire alarm), but that are aimed to encourage crews to solve unexpected and sometimes vaguely defined problems on a group basis. Such simulation exercises are frequently video-taped to enable, for example, the captain who believes himself to be exercising an appropriate level of authority to see that he is actually presenting himself as something of a martinet. These exercises also enable the naturally submissive first officer to discover, in a benign role-playing environment, that it is possible to air his views and anxieties in ways that contribute to the effectiveness of the team operation without appearing to challenge the authority of the aircraft-commander.

The benefits of improving crew coordination training, and enabling crews to practise solving the types of ill-defined problems that are known to have caused accidents, are difficult to quantify as it is extremely difficult to identify the accident that fails to occur. Nevertheless, such training is becoming widespread and generally accepted in airlines, and is likely to become a legal requirement in airline operations in the foreseeable future.

SYSTEM FACTORS

The issue of teamwork training described above represents another example of the type of factor that confronts the operator with a decision that requires cost to be balanced against safety benefit. It is relatively easy for the profitable airline to decide that such training is beneficial, but the airline operating in a more competitive area of the aviation system, where economic margins are extremely constrained, may simply be unable to undertake all of the desirable training and standardization of equipment without going out of business. The regulatory authority may have considerable difficulties in compelling such airlines to undertake costly procedures as the airlines may accurately point out that by doing so they will be made less cost efficient vis à vis foreign operators (possibly operating in a less regulated environment) with whom they compete directly.

The temptation for operator and regulator alike, when faced with an acknowledged but intractable problem, is to undertake some unconscious dissonance resolution by regarding the problem as less serious than they might if it were readily soluble. The example of this provided by the operator quoted above shows that this dissonance resolution can extend to the stage of what might even be termed denial. Although CHIRP was not originally designed to counter such behaviour, it has an important role in doing so.

By enabling pilots to report their anxieties to an agency outside the system within which they operate, constraints on candour are removed, and issues that were previously discussed only in crew rooms and bars become available to be fed back into the system in an overt way. However widespread covert knowledge of a problem may be, it is unlikely to generate remedial action since an operator can scarcely be expected to solve a problem with which he has not been overtly acquainted. A good example of this process is provided by the fatique reports submitted to CHIRP. A number of these reports are of incidents in which complete airline crews found themselves asleep while, for example, crossing the Atlantic. Although flying mythology acknowledged such incidents, it has required the CHIRP system to force the problem of the sleeping crew to be confronted and tackled.

Operation of the CHIRP system suggests that the dominant organizational factor of importance to system safety is attitudinal. Management must be forgiven if, when publicly confronted with a safety problem, they seek to minimize its magnitude, but they must not let themselves believe their own publicity. It should be the responsibility of all managements to ensure that when deficiencies in design or operational procedures are reported, they do not seek to discipline, belittle, or even dismiss individuals so as to maintain the status quo, but attempt instead to come to an understanding of the problem and its likely consequences to ensure that any possible modifications and improvements may be made.

CONCLUSIONS

This paper has attempted to show that human error on the flight deck requires solution at all levels of the aviation system. The examples provided of failures in equipment design, failures in crew coordination, and failures of safety consciousness in system managers suggest that we should not be considering whether there is a particular psychology of human error, but that we should be attempting to marshal all of the psychological knowledge available to solve the perceptual, skill, design, selection, training, social and organizational problems with which the aviation psychologist is presented.

An important tool for the psychologist involved in studying failures in any complex system must be some form of confidential reporting system for human error. To be effective, such a programme must be operated by an agency external to the system but, if successful, such schemes can not only yield information that enables individual system shortcomings to be tackled, but can compel the whole level of safety consciousness in the system to increase. Industry is now so complex that only by involving psychologists closely in the investigation and analysis of incidents and accidents will they achieve the level of applied knowledge that enables a real and practical contribution to system safety to be made. Aviation has fully adopted this philosophy, and, fortunately, other industries are rapidly following suit.

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Discussion

P. NIXON (*Charing Cross Hospital, London, U.K.*). In our work we find that many people respond to anxiety and anger by hyperventilating, and the hypocapnia can be severe enough to cause cerebral and coronary arterial vaso constriction. Have Dr Nixon's studies shown whether hyperventilation contributes to errors of response to signals in emergencies?

HUMAN FACTORS REQUIREMENTS AS A BASIS FOR AVIATION OCCUPATIONAL SELECTION AND TRAINING SYSTEMS

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The United States airspace system of the future is described in the National Airspace System Plan (NAS Plan; Department of Transportation, 1984). This plan, continually updated, presently extends through 1990 with the follow-on Capital Investment Plan (Department of Transportation, 1989) extending indefinitely. These plans are comprehensive, involving new concepts of aerial navigation, terminal approach and departure procedures, and air traffic control.

The shape of the future air traffic control (ATC) system is reflected in the new flight service station of today. A very few years ago there were flight service stations at most airports that were associated with VOR navigational facilities. Now, under the Flight Service Station Consolidation Plan (1978), one facility serves an area previously served by many flight service stations. Consolidation was possible because of technological advances in automation, telecommunications, and remote radio outlets. The pilot now can file a flight plan by telephone without ever talking to a Flight Service Station Specialist in person. Thus, procedures have been simplified and speeded up, and specialists, now relieved of many time-consuming duties, can concentrate on providing preflight briefings instead of performing clerical duties. The future ATC system calls for similar consolidation of Air Route Traffic Control Centers and will engender many changes in the role of the Air Traffic Control Specialist.

Automation is a common thread that runs through the NAS Plan, and that thread raises many important questions about the role of the human operator in the system. An adequately selected and trained staff of human operators to run the evolving airspace system is fundamental to the success of the NAS plan. To accomplish that staffing, human factors analyses of equipment design, operational procedures, and selection and training programs must be conducted.

What might be considered traditional human factors analyses will have to address technical, procedural, and ergonomic factors. Technical questions may focus on appropriate equipment design. This technical evaluation includes such factors as the placement of keys on the control panel in a manner which does not confuse the operator, and placement of important information on a screen in a position where it can be easily observed.

Procedural issues include how the controller will interact with the new automated systems. For example, research must be conducted that will result in the development of procedures that ensure that the controller's need to attend to requirements such as scanning the scope or communicating with pilots or other controllers will not be negatively affected by the increased requirement to attend to how information is typed into the computer.

Ergonomic analysis will address such issues as design of work stations and optimal arrangement of important air traffic control data on cockpit display screens. However, ergonomic analysis may well be more complex than in the past due to the need to consider the handicapped as well as women in the workforce. Thus, a wider range of anthropomorphic types will have to be accommodated in the design of future work stations so that a more extensive array of workers will have full and comfortable access to switches, controls, and panels as well as to the facility itself.

As airborne control of aircraft and as ground-based guidance systems becomes increasingly automated (computer-to-computer), the roles of the air traffic controller and the pilot may shift from one of direct control to one characterized more by system monitoring and emergency backup (Gisch and Zimmerman, 1986; U.S. Department of Transportation, 1985). Characteristics sought in today's controller may not be those looked for in future controllers and the selection criteria may have to be changed accordingly. For example, high tolerance for low levels of activity while maintaining vigilance may become a more desirable characteristic than, say, quickness in reaction time and decision-making.

In this regard, work at the FAA's Civil Aeromedical Institute (CAMI) has addressed issues regarding performance of humans on systems that simulate the automated air traffic control systems of the future. That research may shed some light on questions surrounding the type of person who might be appropriate for the future job of the air traffic control specialist and the type of training required for that person. In general, CAMI findings indicate that the ability to detect conflict situations shows significant impairment under high visual taskload (Thackray and Touchstone, 1989; Thackray and Touchstone, 1988; Thackray and Touchstone, 1986.) Another finding showed no evidence that computer aiding contributed to either reduced alertness or reduced detection efficiency during relatively short monitoring sessions (Thackray and Touchstone, 1989). Additional research is currently being conducted which addresses performance on complex monitoring tasks under conditions of sudden workload changes and differing methods of displaying VFR beacons.

Other areas will also require attention. Curricula will have to be developed or modified to train specialists to operate the evolving system. That evolution will require that the workforce in place at the time of transition be kept up-to-date on the operation of existing equipment by recurrent training and also undergo sufficient initial training to be able to interact effectively with the new system. While training on one system must not interfere with performance on the other, curricula for newly selected controllers, will have to be designed to encompass the new system. This development will be aided by the implementation of new simulators and other advanced training technologies.

Identification of procedures to select the air traffic controllers to operate the new systems and selection of curricula to be developed or modified will be based on a comparison of the job tasks performed using the current system with the job tasks performed using the new system. Such a comparison will point to the differences in knowledges, skills, and abilities required of the operators of the two types of systems.

Just as the airspace system of the future will affect air traffic controllers, so too will it affect pilots who will be operating advanced design aircraft in it. Federal Aviation Regulations and airmen's flight test criteria may have to be altered to accommodate new piloting requirements. Outcomes of human factors research studies in these areas may lead to new training and certification criteria for pilots. Complicating these developments is the reduced proportion of military-trained pilots in the resource pool available to the airlines. The effectiveness of ab-initio training programs currently under development to train new airline pilots "from the beginning" (Nooy, 1987), must be evaluated to ensure that the graduates of these programs are safe pilots.

Evaluation of the pilot/ATC interface in the NAS system will be extremely important as such interaction critically affects air safety. Human factors analyses may result in improved communication procedures. Analysis of pilot error rates and their causation will likewise be important, especially after the introduction of automated equipment. The results of studies such as these will provide feedback to be incorporated in plans for aircraft design and modification as well as for future automation of the ATC and air navigation systems.

The evolving airspace system will further require a new generation of maintenance personnel with new skills and insights. Downtime of automated systems will be a critical factor with reliance on automated data processing increasing. With maintenance personnel, as with air traffic controllers, human factors analysis of the job tasks must undergird successful selection and training programs.

The Civil Aeromedical Institute

We have developed, at the Civil Aeromedical Institute, a research-based model, incorporating the various areas of work done at CAMI, to support analyses of some of the human needs of the evolving airspace system. The original model was based on air traffic control requirements, but with modest modifications, the model can be applied to other elements of the FAA workforce and to cockpit human factors.

Essentially, the research model defines one interactive approach to understanding and improving the human-system interface by a continuous appraisal of task needs, job design, and characteristics and performance of the human operators. That appraisal process is rooted in a "living" research data base from which analytic and predictive information can be drawn for application to developing needs and to address questions that arise during the evaluation of new systems. Because of its aeromedical base, our model does not include the human engineering components of advanced systems design; that work is conducted under other auspices but must, of course, be interactively coordinated with aeromedical findings.

In the air traffic control model currently in use at CAMI, an initial foundation is laid with the development of a job task analysis. Data are then added from initial selection test results and a biographic questionnaire administered when air traffic control trainees enter the FAA Academy for basic training and further screening (selection). All academic and laboratory grades earned at the FAA Academy are also stored as part of the data base. Performance at the Academy (measured by both a pass/fail dichotomy and by numeric grades) can be quantitatively linked to selection test scores and to biographic characteristics as well as qualitatively compared (traced back) to the job task analysis. Such analyses have extensive practical applications. For example, biographical and demographic factors which predict success at the Academy (such as age, high school grades earned in mathematics courses, and expectations of future success in air traffic control) have been used to target air traffic controller recruitment efforts (Collins, Manning, and Taylor, 1984; Collins, Nye, and Manning, 1990). Results of other analyses became the basis for implementing a single Academy screen (selection) program in 1985 (Manning, Kegg, and Collins, 1988) to replace the dual screen (en route and terminal) that had been the traditional Academy approach. In those analyses, expected success rates and validities of final grades in predicting success in field training were modeled using alternative weightings for the components of the (then) current Academy programs. The new screen that resulted from that work has generated cost benefits and has improved the selection process.

For those who pass the Academy screen, data related to field training progress (or failure) comprise another data base developed and maintained at CAMI. The data base can be used to target potential training problems for FAA management officials. For example, analysis of the data base revealed that pass rates in en route training programs and the amount of time required to complete training varied considerably as a function of the facility assignment. This information stimulated management officials to look more closely at training administration practices and to modify them.

The data base can also be used to assess relationships between measures of field training performance and Academy grades, selection test scores, biographic factors, and the job analysis. For example, one study assessed the relative contributions of the Office of Personnel Management (OPM) written selection test battery and the Academy score in predicting ATC field training performance (Manning, Della Rocco, and Bryant, 1989). That study found that the OPM rating did not contribute to the predictability of supervisor ratings in either nonradar or radar en route field training when the Academy score was included as a predictor, but both were predictive of the amount of time required to reach full performance level (FPL) status (see Table 1).

Table 1
Relative contribution of OPM rating
and Academy score in predicting performance
in en route field training

Criterion	Partial correlation OPM rating	 Academy score
Supervisor rating in radar associate training	-.01	.38
Supervisor rating in radar training	-.01	.39
Time to reach full performance level	-.23	-.19

That study (Manning, et al, 1989) also indicated that, of the tests included in the OPM battery, the Multiplex Controller Aptitude Test (MCAT) is the best predictor of field training performance at en route facilities, but is not as predictive of field training performance at terminal facilities as is the Occupational Knowledge Test (OKT). These findings suggest ways to improve the selection and placement of air traffic controller trainees.

Other CAMI research data bases that have been, or are being, developed contain job performance measures, supervisory/managerial training and development ratings, and individual instances of operational errors. Matching records across data bases and analyzing the resulting data is a method that can be used to identify elements of training programs that need enhancement, point to a lack of standardization in training, and distinguish facilities or work groups which are more effective than others.

As shown in Figure 1, related research findings that are more generic but also impact selection and training programs are in the areas of workload, scanning and monitoring behaviors, ATC-pilot interactions, human factors determinations for the Advanced Automation System (AAS), Automated En Route Air Traffic Control (AERA) capabilities, and workplace job attitudes. Information from all of these areas will also influence job design. As the systems for air traffic control evolve, the job design will change. The changes will be reflected as new or modified tasks in the job task analysis. Identification of changes in job tasks will be dependent on other interactions, not noted in our aeromedical model, between human factors researchers and human engineers, those who design and evaluate the automated equipment. Analysis of task changes will lead to the redefinition of requirements for selection and training procedures.

The ATC model described above is a dynamic model that presupposes continuing assessments and modifications. It also does not presuppose that ATC job tasks need be operational to yield useful information. For example, as shown in Figure 1, before future automated work environments become operational, a job task analysis, human factors analyses, assessments of work load and resultant behaviors, and procedures for ATC-pilot interactions must be developed. A preliminary task analysis has already been developed for the Initial Sector Suite System (ISSS; Alexander, Alley, Ammerman, Hosetler, and Jones, 1988) which will be implemented about 1993, and a document identifying job tasks that will change upon implementation of ISSS has been produced

(Ammerman and Jones, 1988). Elements of that task analysis, in turn, will be used to identify required changes to selection criteria and training curricula prior to the time that the system is made operational.

Highly similar human factors models can be constructed for members of the FAA workforce other than ATCSs (see Figure 2) and for pilots (see Figure 3). Some elements of the ATC model are deleted for these purposes (or may be unavailable), and other elements may be added. But all of the models share the characteristics of being dynamic, data-based, evolutionary, and multi-determined. They provide a way of systematically approaching the resolution of performance/safety issues for professionals and specialists throughout the airspace system.

Conclusion

Human factors expertise is crucial to the proper development and implementation of the new concepts of flight and air traffic control that characterize the FAA's National Airspace System Plan. That expertise will also be needed to ensure the safety and assess the efficiency of the airspace system during the planned evolutionary changes in aviation technology. Such assessments will provide continuous feedback on the appropriateness of specific selection and training methods for specialists operating new, automated equipment. If the present levels of aviation safety and productivity are to be exceeded by the future airspace system, highly focused work must begin now to anticipate the impact of that system on human operator capabilities.

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PERFORMANCE MEASURES

WORK ATTITUDES

SUPV/MGMT TRAING & DEV

ATC-PILOT INTERFACE

FIELD TRAINING

WORKLOAD

ACADEMY SCREEN

SCANNING & MONITORING BEHAV

BIODATA

OPERATIONAL ERRORS

SELECTION

HUM FACTORS IN AAS/AERA

JOB TASK ANALYSIS

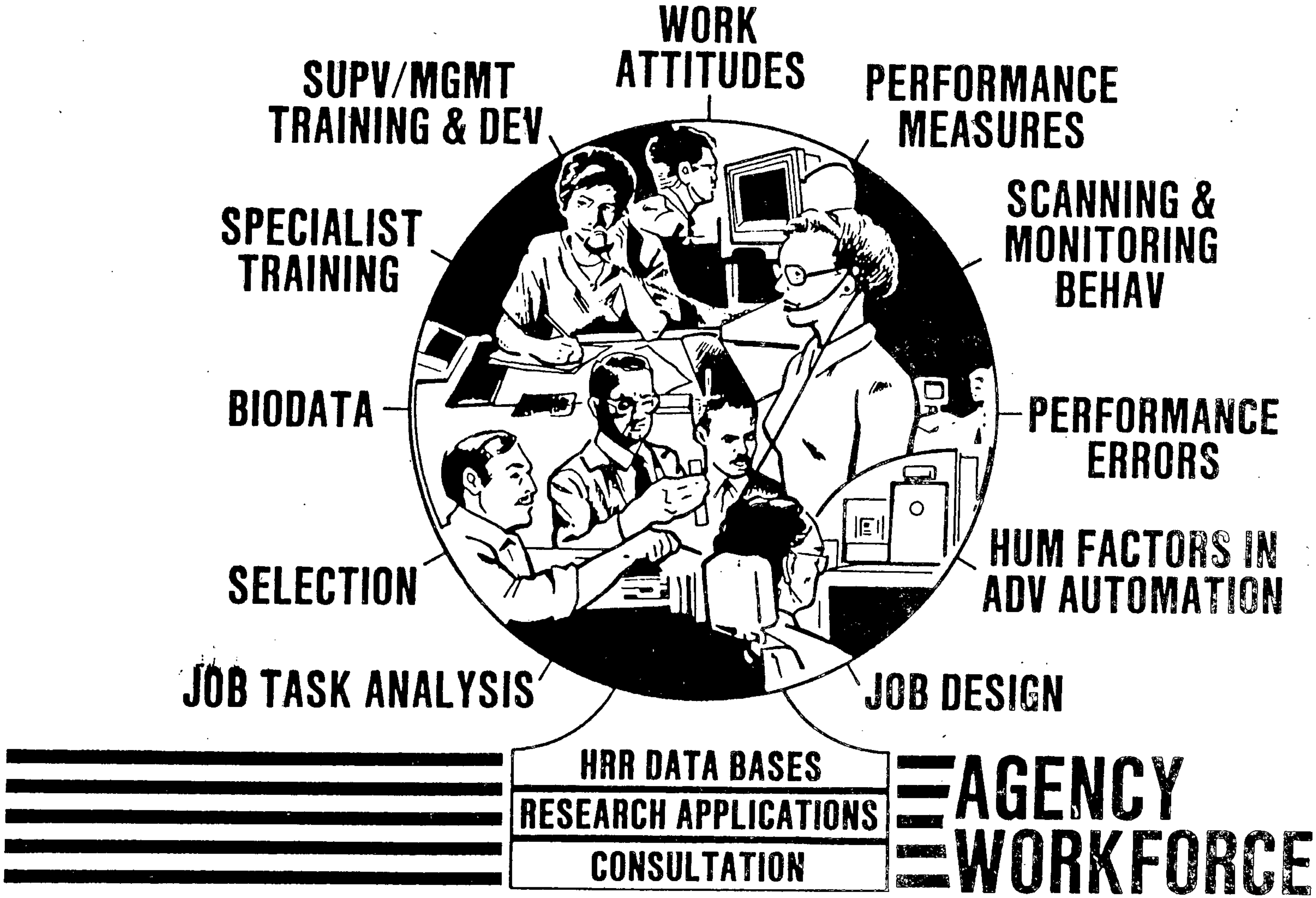
JOB DESIGN

HRR DATA BASES

RESEARCH APPLICATIONS

CONSULTATION

ATC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HRR DATA BASES
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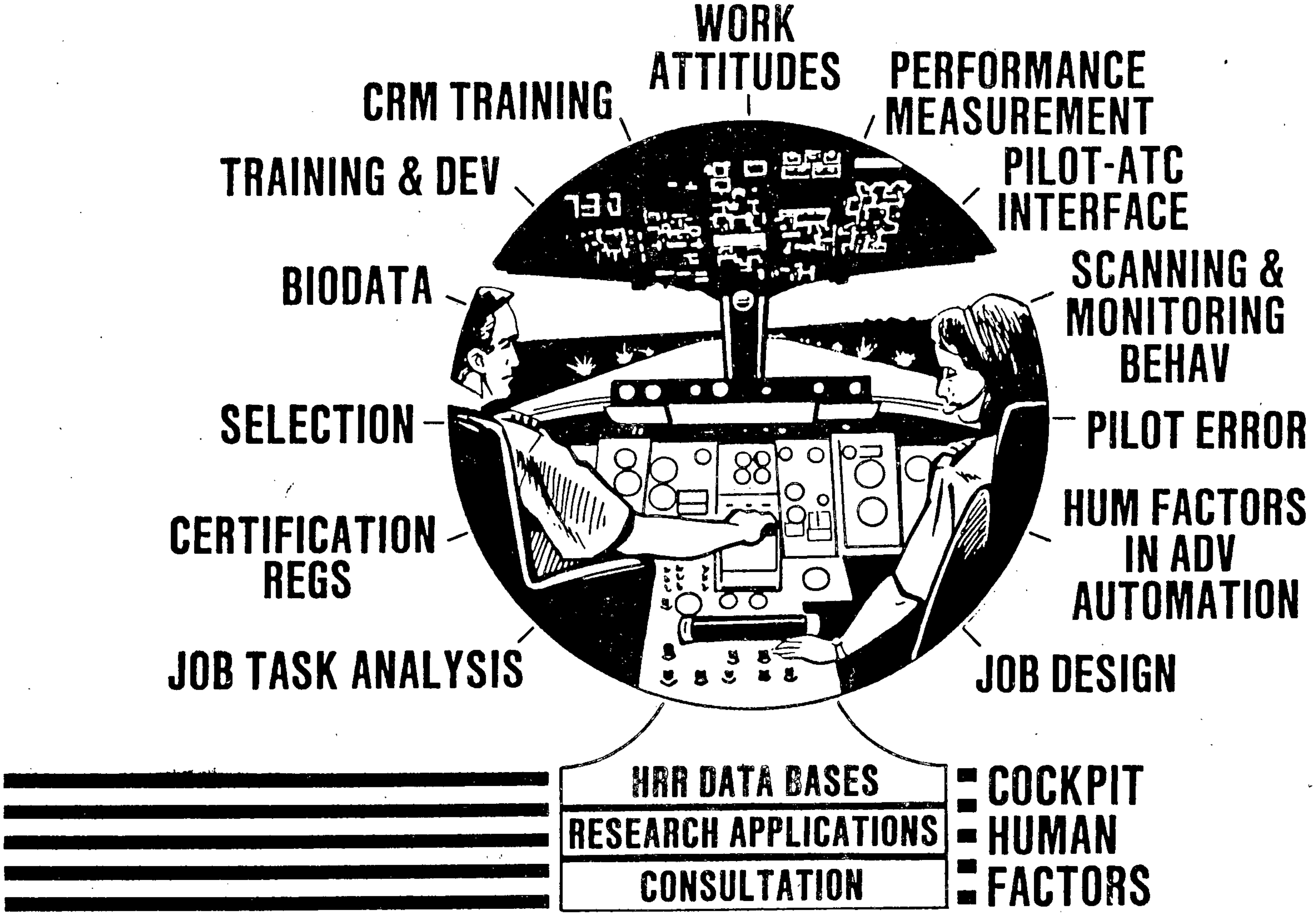
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PILOT-ATC INTERFACE
BIODATA
SCANNING & MONITORING BEHAV
SELECTION
PILOT ERROR
CERTIFICATION REGS
HUM FACTORS IN ADV AUTOMATION
JOB TASK ANALYSIS
JOB DESIGN
HRR DATA BASES
RESEARCH APPLICATIONS
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COCKPIT
HUMAN
FACTORS

АВИАЦИОННЫЕ ТРЕНАЖЕРЫ И СНИЖЕНИЕ ОТРИЦАТЕЛЬНОГО ВЛИЯНИЯ ЧЕЛОВЕЧЕСКОГО ФАКТОРА

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Тренажеростроение и соответственно тренажерная подготовка принадлежат сегодня во всех технически передовых странах к интенсивно развивающимся отраслям. Причина очевидна: с помощью хорошо организованного тренажерного обучения можно существенно повысить уровень профессионального мастерства и тем самым значительно снизить отрицательное влияние человеческого фактора (ЧФ). Здесь наметилось несколько направлений. Одно из них ставит целью практически непрерывное повышение технических характеристик тренажеров и их компонентов, - систем визуализации, подвижности вычислительных сетей и др. Добиваются при этом все более высокой адекватности полета.

Ограничением служит возрастающий рост стоимости и сложности в то же время у авиакомпаний наметилась тенденция установления предельных цен на комплексные, процедурные, специализированные тренажеры. Отсюда возникает задача достижения не максимальных, а минимально-необходимых характеристик тренажеров, в том числе и адекватности.

Весьма перспективным следует считать систему подготовки LOFT. За счет строгого ориентирования обучения и расширения используемых технических средств удалось достичь высоких результатов - углубить и интенсифицировать процесс приобретания не только навыков, но и знаний и умений.

В настоящем докладе излагаются результаты многолетних исследований Летно-исследовательского института, реализующие еще одно направление. Основными его особенностями являются (рис.I):

- тесная увязка тренажерной техники и способов обучения с методами и результатами сертификации самолетов;
- интенсификация обучения за счет использования т.н. "эталона пилотирования";
- использования глубоко автоматизированной системы контроля обучения, включающей советующие (экспертные) блоки;
- расширение тренажных средств за счет электронных классов;
- тестирование средств обучения, подтверждающее возможность успешного решения поставленных задач.

Реализация данного направления должна позволить существенно повысить обучающие качества тренажера при умеренных характеристиках его компонентов. При этом все перечисленные элементы должны рассматриваться и осуществляться в едином пакете, что обеспечит общую эффективность направления.

Факторы, определяющие обучающие качества тренажера, можно условно свести в три группы (рис.2). В первую входят параметры, определяемые структурой и совершенством конструкции. В конечном счете они формируют составляющие адекватности - *информационную* адекватность, динамическую, эргономическую и др. Вторая группа охватывает те факторы, которые практически обеспечивают содержательно-методическую базу процесса обучения. С одной стороны они являются сердцевиной Знаний, Навыков и Умений, подлежащих освоению, с другой - позволяют успешно организовывать этот процесс.

Третью группу образуют элементы, определяющие эффективность систем "тренажер - обучаемые - инструктор". Важнейшую роль в этой группе играет оборудование пульта инструктора, наличие средств автоматизации обучения и управления тренажером. Включение в состав пульта элементов подсказывающей или экспертной системы с выдачей информации на графический дисплей может существенно повысить обучающие качества. Наконец, использование статистического задатчика режимов, действующего по схеме Монте-Карло помимо воли инструктора, может заметно улучшить качество контроля навыков и умений.

До последнего времени вторая и третья группа элементов развивались недостаточно. Существенно и то, что с их совершенствованием появилась необходимость учета взаимного влияния всех факторов, а следовательно проводить их комплексную оптимизацию. Так адекватность, даже высокая, рассматриваемая изолированно, может не обеспечить требуемые обучающие качества, тогда как комплексный подход к тренажеру позволяет достичь высокий технический уровень.

Использование результатов сертификации и эталонов пилотирования, а главное, представление этих данных в легко обозримом и понятном виде на пульте не только позволяет инструктору быстро и безошибочно контролировать действия обучаемых. Исследования показали, что в этом случае возникает, как бы обратная связь - возрастает психологическая адекватность полету, увеличивается дисцип*лина и отдача курсанта*.

Задача определения уровня летной годности при всевозможных отказах функциональных систем, а также на штатных режимах, выполняемых вблизи границ ожидаемых условий эксплуатации (ОУЭ), принадлежит к числу центральных, решаемых в процессе сертификации воздушных судов. В отечественной практике им посвящена известная глава 2 Норм. В методах оценки соответствия указаны эксплуатационные и предельные ограничения важнейших характеристик (рис.3), позволяющие классифицировать последствия Особых ситуаций. На этой основе классифицируются последствия совокупности возможных отказов. В демонстрационных полетах эти последствия должны быть подтверждены, а безопасность штатных режимов полностью доказана, в том числе вблизи границ ОУЭ. При этом демонстрируются и соответствующие способы пилотирования, при которых либо обеспечивается безопасность, либо возникают ситуации, последствия которых по своей тяжести не превосходят сложную.

В результате обучения, направленного в конечном счете на снижение отрицательного влияния человеческого фактора, должны быть выполнены два важнейших взаимосвязанных требования:

- исключена, или точнее, снижена до очень малой вероятности возможность создания пилотом аварийных или катастрофических ситуаций в условиях, в которых, согласно сертификационным испытаниям либо вообще отсутствовала потенциальная угроза безопасности (штатные режимы), либо имели место ситуации, оцененные как усложнение условий полета или сложные;
- доказана близость пилотирования к характеристикам, признаным при сертификации эталонными.

Под эталоном пилотирования понимается полученная из летных испытаний, выполненных высококвалифицированными пилотами, область допустимого управления (включающая характеристики движения и параметры решений), обеспечивающая достижение последствий и результатов, адекватных полученным при сертификации. Пилотирование должно выполняться в точном соответствии с указаниями Руководства по летной эксплуатации (РЛЭ) .

Если линейные летчики полностью овладеют эталонами пилотирования, уровень реальной безопасности окажется близким к сертификационному уровню летной годности. Сегодня, как известно, здесь наблюдается большое расхождение.

Очевидно, во всех случаях обучения необходимо подробно анализировать детали деятельности пилотов в "полете" на тренажере. Сравнение полученных данных с эталоном в реальном масштабе времени, а затем представление этих данных курсанту существенно помогает решению главной задачи.

Для того, чтобы пояснить, как формируется эталон, вспомним что задается пилоту в РЛЭ. Как правило, в части непрерывного пилотирования по продольному и боковому каналу задаются лишь ограничения и узловые точки (рис.4), что допускает определенную свободу.

Для воплощения этих указаний в полную программу приходиться проводить интерполяцию, учитывающую множество особенностей самолета. Традиционно при обучении программу курсанту "передает" инструктор. Однако здесь возможны большой разброс и субъективизм и даже ошибки. Таким образом проявляется еще одно отрицательное влияние человеческого фактора. Ошибки усугубляются дефицитом времени, недостатками квалификации и пр. Эталон пилотирования позволяет устранить эти недостатки.

Для примера на рис.5 показана эталонная программа продольного пилотирования при взлете и наборе высоты самолета Ту-154Б. Там же указаны дискретные процедуры: подъем передней стойки, уборка шасси, уборка механизации крыла. Для полного формирования эталона эту программу необходимо дополнить, указав:

- эталонные зависимости отклонений управляющих и контролируемых параметров;
- допустимую область разброса каждого параметра.

Частично указанные данные иллюстрируют графики на рис. 6 (привести все управления не представляется возможным). Границы допусков определялись в летных испытаниях исходя из заданных эксплуатационных и предельных ограничений.

Весьма плодотворным оказался перенос в практику тренажеростроения и процесс обучения хорошо зарекомендовавшего себя при сертификации по главе 2 принципа "Расчетных случаев". Суть его заключается в том, чтобы вместо исключительно большого "размытого" множества возможных режимов, отказов, параметров эксплуатационных условий использовать относительно небольшой - 100 - 120 - набор типовых сюжетов или "расчетных случаев", формируемых по специальной методике. Эти сюжеты являются статистически значимыми для всей области ОУЭ, которую они полностью покрывают.

Система расчетных случаев позволяет существенно сократить число моделируемых в тренажере отказов и режимов без снижения представительности. Кроме того она позволяет упорядочить число ситуаций, в которых должны отрабатываться навыки и умения на тренажере. Поскольку практически невозможно отработать все эти случаи на тренажере во время ограниченного цикла переподготовки пилотов, целесообразно детально изучать их в электронных классах. Контрольные же проверки и отработку навыков целесообразно проводить с помощью статистического датчика.

Так же, как реальная полная программа полета, эталон пилотирования не является жестким. Оба они содержат постоянную и переменную составляющие. Отдельные параметры штатной программы могут изменяться в пределах постоянной составляющей из-за варьирования эксплуатационных условий. При возникновении же отказа или при действии сильных возмущений программа должна быть изменена. Алгоритм такой перестройки показан на рис.7. Летчик должен на основании сигнализации и естественных признаков отказа распознать возникшую ситуацию, точно идентифицировать ее, принять решение по выбору новой программы, осуществить безошибочно и быстро переход на эту программу и далее четко реализовывать ее для безопасного завершения полета. Все эти компоненты, включая принятие решения составляют переменную составляющую. Задача обучения, в частности, научить курсантов этой гибкости, не допускать грубых ошибок.

На рис.8 перечислены типовые ошибки пилотов, приведшие к летным происшествиям в практике многолетней эксплуатации гражданских самолетов. Если в штатных режимах критические ошибки сводятся к значительным отклонениям от эталонных параметров или перепутыванию процедур, то в условиях ОС дополнительно имели мест ошибки в решениях, неверный выбор программы, неверная идентификация отказов. Из-за дефицита времени, недостатка обученности или других причин пилоты допускали очень грубые ошибки или психологические отказы.

Рассматриваемое нами направление обучения направлено на максимальное снижение вероятности таких ошибок, главным образом за счет выявления их с помощью системы автоматизированного контроля (САК) и демонстрации курсантам в электронных классах.

Поясним структуру САК. На цветных дисплеях графстанций или персональных ЭВМ фактические параметры движения и управления, реализуемые в процессе полета на тренажере, сопоставляются с эталонными значениями. Здесь индицируются как непрерывные, так и дискретные процедуры. При возникновении ОС - а отказы вводятся инструктором или автоматически - эталон мгновенно перестраивается Все это позволяет инструктору быстро и безошибочно контролировать действия курсанта, устанавливать соответствие этих действий алгоритму, показанному на рис.7. Таким образом САК позволяет также оценивать точность и качество принимаемых решений. Документирование обеспечивает возможность разбора пилотирования непосредственно после полета. Благодаря этому реализуется адаптивное обучение.

Курсант может использовать систему и для самообучения, – освоение программ. В электронном классе ему должны быть продемонстрированы последствия неверных действий.

В результате многолетних исследований были отработаны облик и структура САК, разработано программно-методическое обеспечение, выбраны оптимальные форматы машинной графики, созданы макетные и экспериментальные образцы. В настоящее время САК внедряется на отечественных тренажерах нового поколения.

Типовые форматы САК показаны на рис.9-I2. Рассмотрим для примера формат предстартовой подготовки самолета Ту-I54Б (рис.9). Указаны операции, подлежащие согласно РЛЭ выполнению конкретными членами экипажа. Вначале зеленым цветом высвечивается заданный набор процедур (рис.9а). Выполнение каждой процедуры изменяет ее цвет на желтый. Одновременно на дисплее выдается время, отсчитываемое от начального момента; по телефону инструктор слышит радиообмен. Таким образом легко установить правильность, полноту и последовательность выполняемых операций.

На последующих рис. показаны форматы для нормального и прерванного взлетов, а также для нормальной посадки. Все они показывают фактические и эталонные значения траекторных параметров, положение органов управления, а также выполнение дискретных процедур. Различия графики объясняются особенностями режимов и служат для облегчения восприятия. На подобных графиках четко заметны допущенные курсантом отклонения параметров от эталонных значений или указаний РЛЭ. Формат прерванного взлета обеспечивает контроль бокового движения самолета на ВПП; здесь указан фактический момент отказа (красным цветом), после чего желтым цветом индицируются выполненные дискретные процедуры парирования отказа. Такая структура формата типична для отказных СС.

Экспериментальная проверка, в которой участвовали летчики, инструкторы, психологи и эргономисты, подтвердила высокую эффективность САК; показано значительное повышение обучающих качеств тренажера, оборудованного этими системами. Для испытаний была разработана специальная методика. Была составлена серия сценариев в части которых вводились определенные ошибки отработки программ пилотирования. В качестве "курсантов" использовались высококвалифицированные летчики-испытатели, способные точно выполнить заданные сценарии. К испытаниям была привлечена группа штатных инструкторов гражданской авиации, имевших большой опыт работы. Инструкторы не знали, с каким сценарием – точным или имеющим ошибки – они работают в каждом конкретном случае.

Испытания проводились на экспериментальном пульте, оборудованном САК и на традиционном пульте тренажера КТС – Ту-I54Б, снабженном приборами-повторителями. Было выполнено две серии испытаний. В первой (рис.I3) фиксировались только невыявленные инструктором ошибки. В процессе экспериментов было установлено, что наряду с пропуском действительных ошибок курсанта инструктор сам допускает промахи, указывая курсанту на ошибки, которых тот не совершал. Для оценки этого явления была проведена вторая серия испытаний, результаты которых показаны на рис.I4. Как видно, с помощью экспериментального пульта все 5 инструкторов смогли точно оценить действия обучающихся, выявив полностью допущенные ошибки. Ложных ошибок инструкторы не обнаружили. На традиционном пульте только два инструктора выявили все ошибки; у трех остальных остались незамеченными от I0 до 50% действительных ошибок. Вместе с тем все инструкторы на традиционном пульте допустили промахи, обнаружив в I0 – 25% случаев ложные ошибки.

Параллельно проводились психофизиологические исследования деятельности инструктора по методике "Резервы внимания". Среднее время сенсомоторной реакции при работе с САК составило 0,54с, а с традиционным пультом 0,92с. Таким образом время реакции уменьшилось на 70%. Число ошибочных реакций на световой сигнал при работе инструктора за традиционным пультом в 4 раза больше, чем при использовании САК. Все это указывает на значительное снижение напряженности работы инструктора.

Для того, чтобы завершить рассмотрение предлагаемого направления, следует осветить вопрос тестирования. Здесь задача достаточно ясна: необходимо доказать, что созданный тренажер действительно способен обеспечить эффективное обучение и переучивание пилотов на новые самолеты. При этом характеристики пилотирования должны соответствовать эталонным, ошибки, приводящие к летным происшествиям или к их предпосылкам должны быть исключены, а привитие неверных навыков исключено. Основой тестирования является упоминавшийся тезис: тренажер должен обладать не столько максимальной адекватностью характеристик, сколько, обеспечивать с высокой надежностью формирование навыков полностью адекватных тем, которые соответствуют эталонному пилотированию и вырабатываются в реальном полете.

Признано, что экспертные оценки тренажера, формируемые летчиком-испытателем, совершенно недостаточны, хотя безусловно необходимы. Поэтому нами автоматизирован этот процесс. Во-первых, для получения объективных оценок использовалась система автоматизированной регистрации, обработки и выдачи данных (САРОИВД). И здесь были применены унифицированные форматы выдачи графической информации. Материалы летных сертификационных испытаний самолета и испытаний тренажера выдавались в виде унифицированных графиков или дисплейных данных.

Во-вторых, использовалась система автоматического пилотирования тренажера, аппроксимирующая действия "эталонного летчика'

Испытания тренажеров проводятся в три этапа. На первом испытываются основные компоненты. На втором испытывается тренажер в режиме автоматического пилотирования. Пример характеристик, полученных на этом этапе и сопоставленных с результатами сертификационных испытаний самолета, показан на рис.I5.

На третьем этапе тренажер оценивают высококвалифицированные летчики-испытатели. Летчик, ранее не работавший на тренажере, но летавший на самолете, должен со второй-третьей попытки подтвердить возможность реализации эталонных характеристик пилотирования и движения. Эти данные должны быть зафиксированы с помощью САРОИВД

Таким образом проведенный комплекс работ показал, что направление, интегрирующее все представленные на рис.I элементы, является весьма перспективным и может внести существенный вклад в решение проблемы снижения отрицательного влияния человеческого фактора.

ОСОБЕННОСТИ НАПРАВЛЕНИЯ

I. УВЯЗКА С МЕТОДАМИ И РЕЗУЛЬТАТАМИ СЕРТИФИКАЦИИ

2. ЭТАЛОН ПИЛОТИРОВАНИЯ

3. СОВЕТУЮЩАЯ СИСТЕМА АВТОМАТИЗИРОВАННОГО КОНТРОЛЯ

4. ЭЛЕКТРОННЫЕ КЛАССЫ

5. ТЕСТИРОВАНИЕ СРЕДСТВ ОБУЧЕНИЯ

Рис. I

ФАКТОРЫ, ОПРЕДЕЛЯЮЩИЕ ОБУЧАЮЩИЕ КАЧЕСТВА

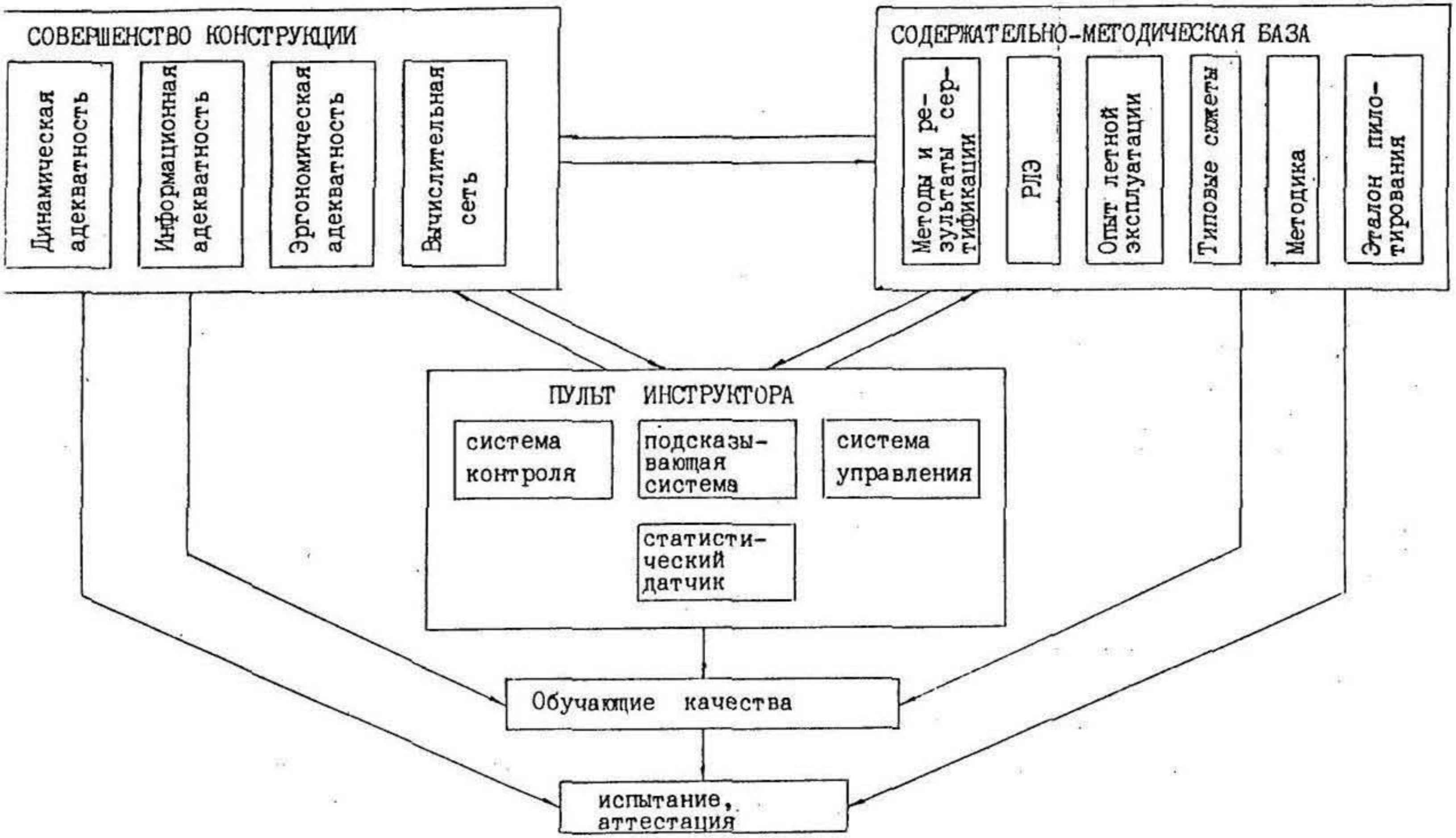


РИС.2 .

ЭКСПЛУАТАЦИОННЫЕ И ПРЕДЕЛЬНЫЕ ОГРАНИЧЕНИЯ.

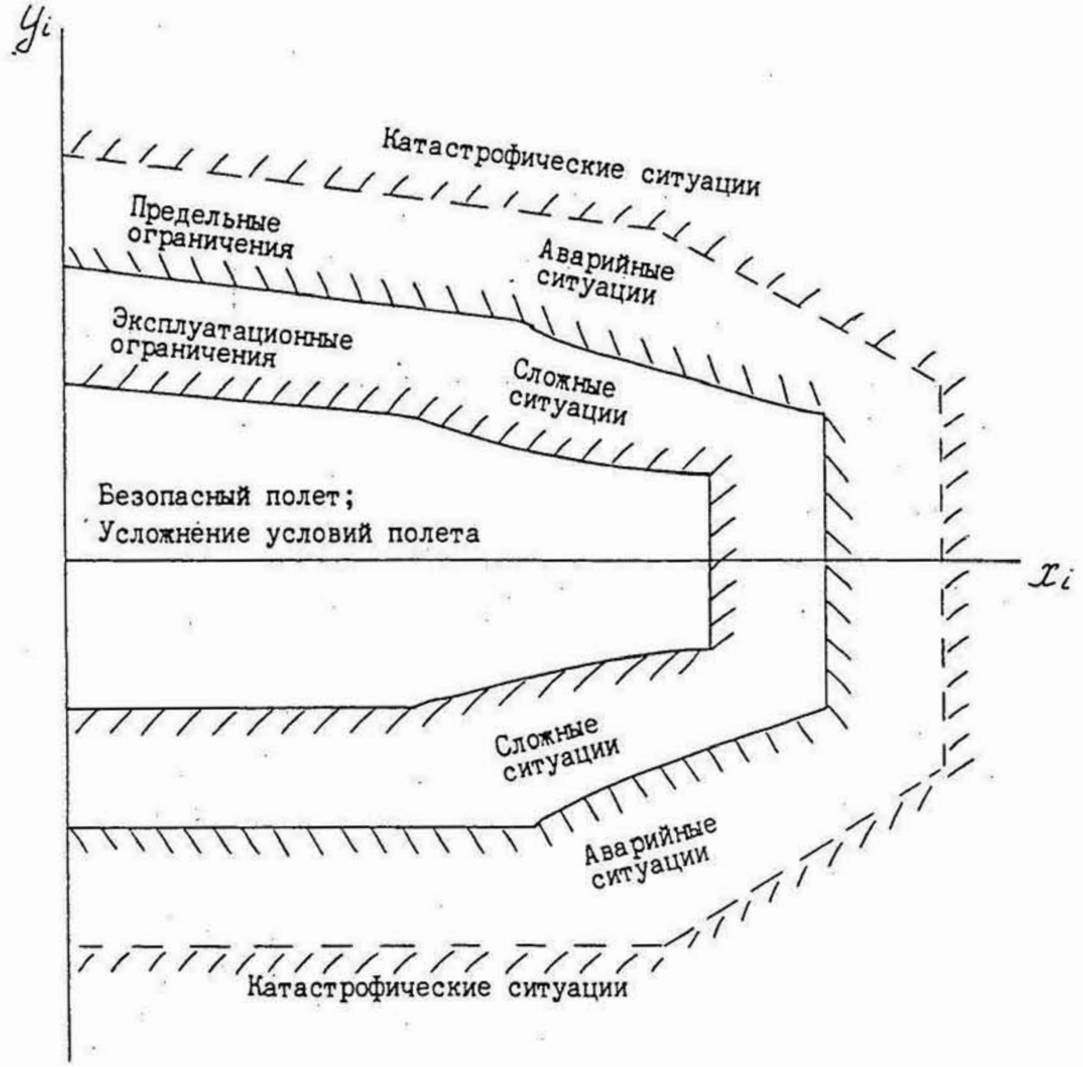


РИС. 3 .

ТИПОВОЕ ЗАДАНИЕ ПРОГРАММЫ ПИЛОТИРОВАНИЯ С ПОМОЩЬЮ УЗЛОВЫХ ТОЧЕК И ОГРАНИЧЕНИЙ

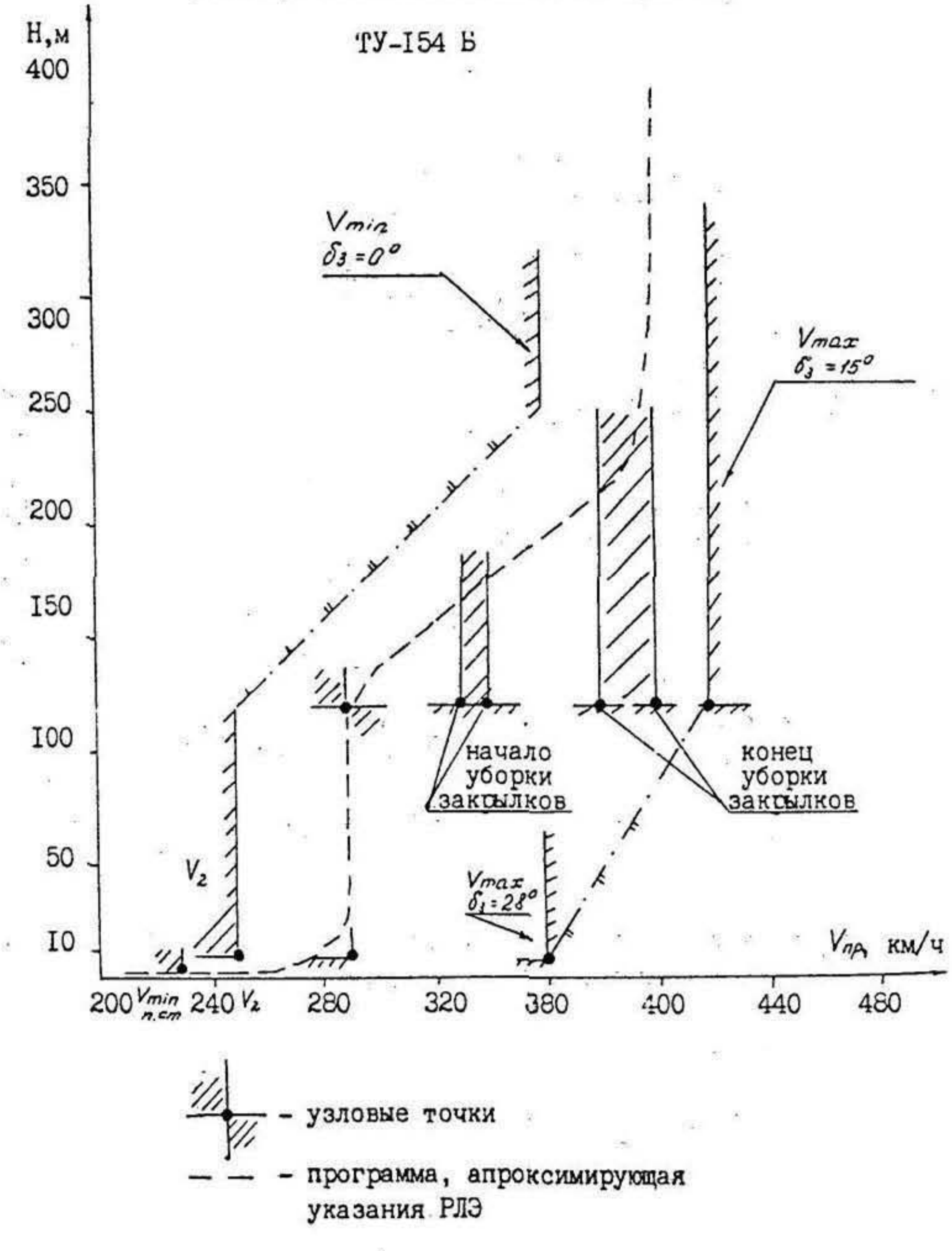


Рис.4.

ПРОГРАММА ПИЛОТИРОВАНИЯ ПРИ НОРМАЛЬНОМ ВЗЛЕТЕ

ТУ-154 Б

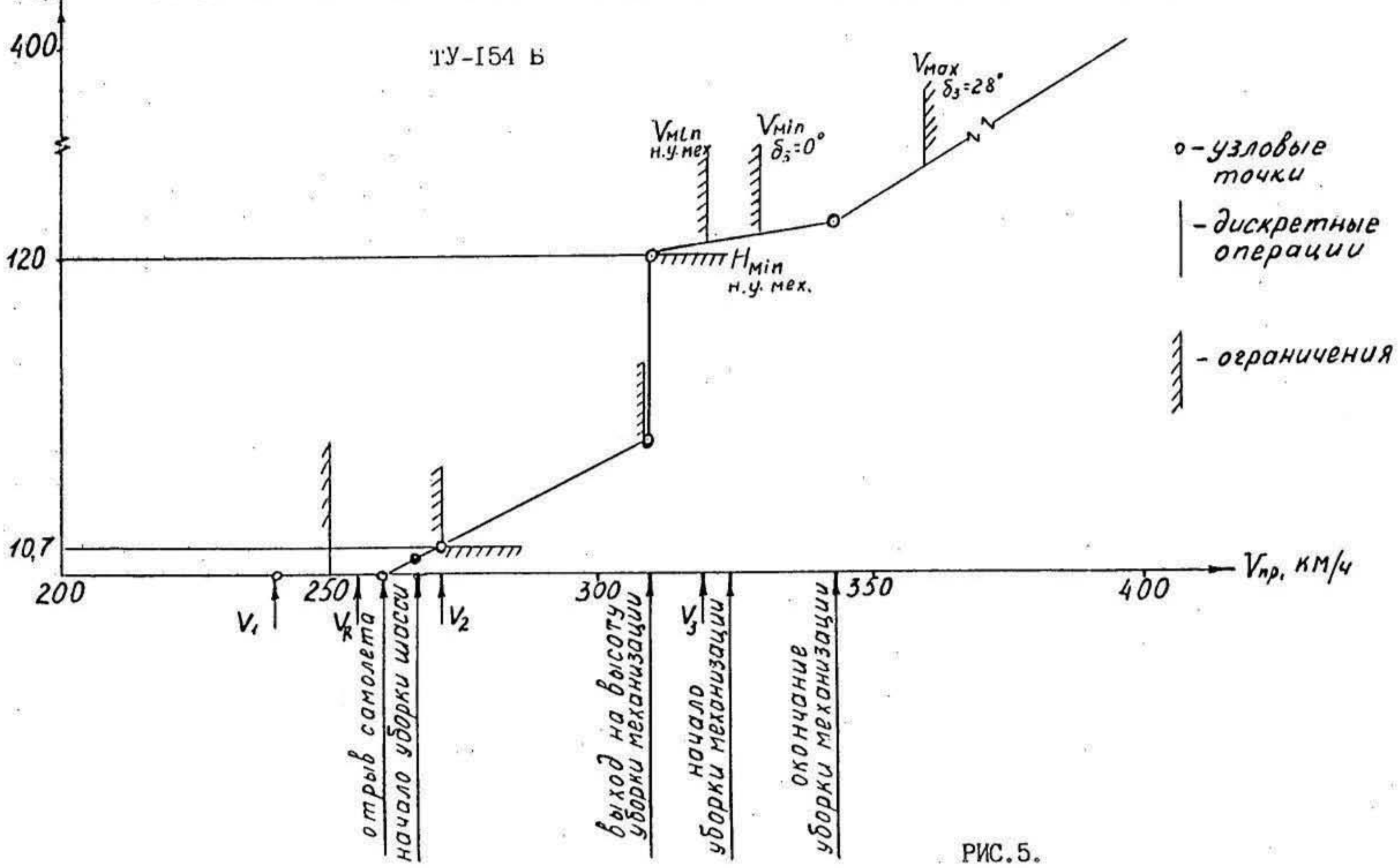


РИС.5.

ДОПУСКИ НА ОТКЛОНЕНИЯ ОТ ЭТАЛОНА ПИЛОТИРОВАНИЯ

(режим взлета)

ТУ-154 Б

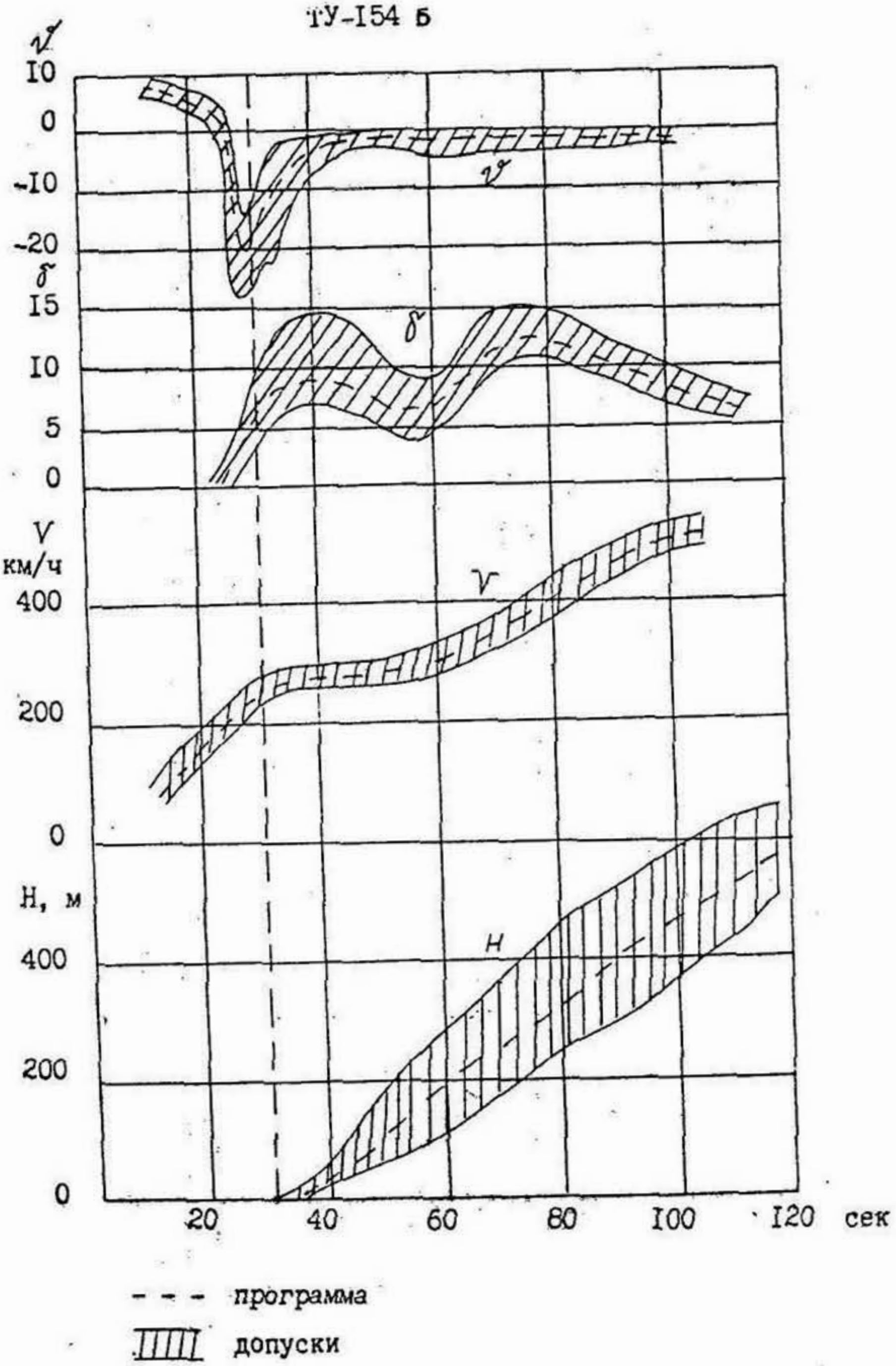


Рис. 6.

АЛГОРИТМ ПИЛОТИРОВАНИЯ В ОС.

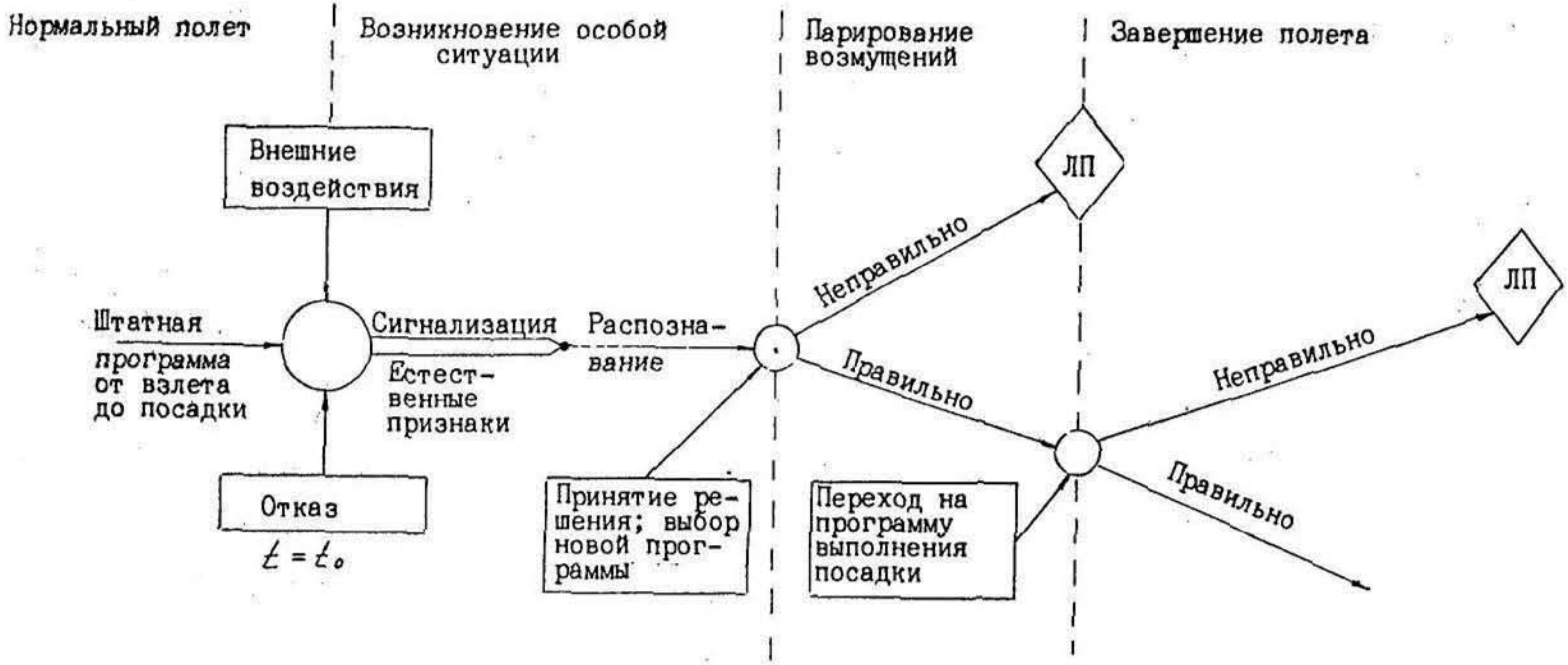


РИС. 7 .

ТИПОВЫЕ ОШИБКИ ПИЛОТОВ, ПРИВЕДШИЕ К ЛП

ШТАТНЫЕ РЕЖИМЫ

I. НЕПРАВИЛЬНАЯ РЕАЛИЗАЦИЯ УЧАСТКОВ ПРОГРАММЫ

2. ЗНАЧИТЕЛЬНОЕ ЗАПАЗДЫВАНИЕ

3. ПЕРЕПУТЫВАНИЕ ИЛИ ПРОПУСК ПРОЦЕДУР, ПРЕДПИСАННЫХ РЛЭ

4. ВЫПОЛНЕНИЕ ЗАВЕДОМО НЕВЕРНЫХ ПРОЦЕДУР

ОС, ВЫЗВАННЫЕ ОТКАЗАМИ

I. НЕРАСПОЗНАВАНИЕ СИТУАЦИИ

2. НЕВЕРНЫЙ ВЫБОР ПРОГРАММЫ

3. ПЕРЕПУТЫВАНИЕ ИЛИ ПРОПУСК ПРОЦЕДУР

4. НЕЧЕТКОЕ, ЗАМЕДЛЕННОЕ ИСПОЛНЕНИЕ

5. ОШИБКИ РЕАЛИЗАЦИИ ПРОГРАММЫ

6. ВЫХОД ЗА ОГРАНИЧЕНИЯ

7. НЕЧЕТКОЕ ВЗАИМОДЕЙСТВИЕ ЧЛЕНОВ ЭКИПАЖА

РИС.8.

ПРОЦЕДУРЫ ПРЕДСТАРТОВОЙ ПОДГОТОВКИ.

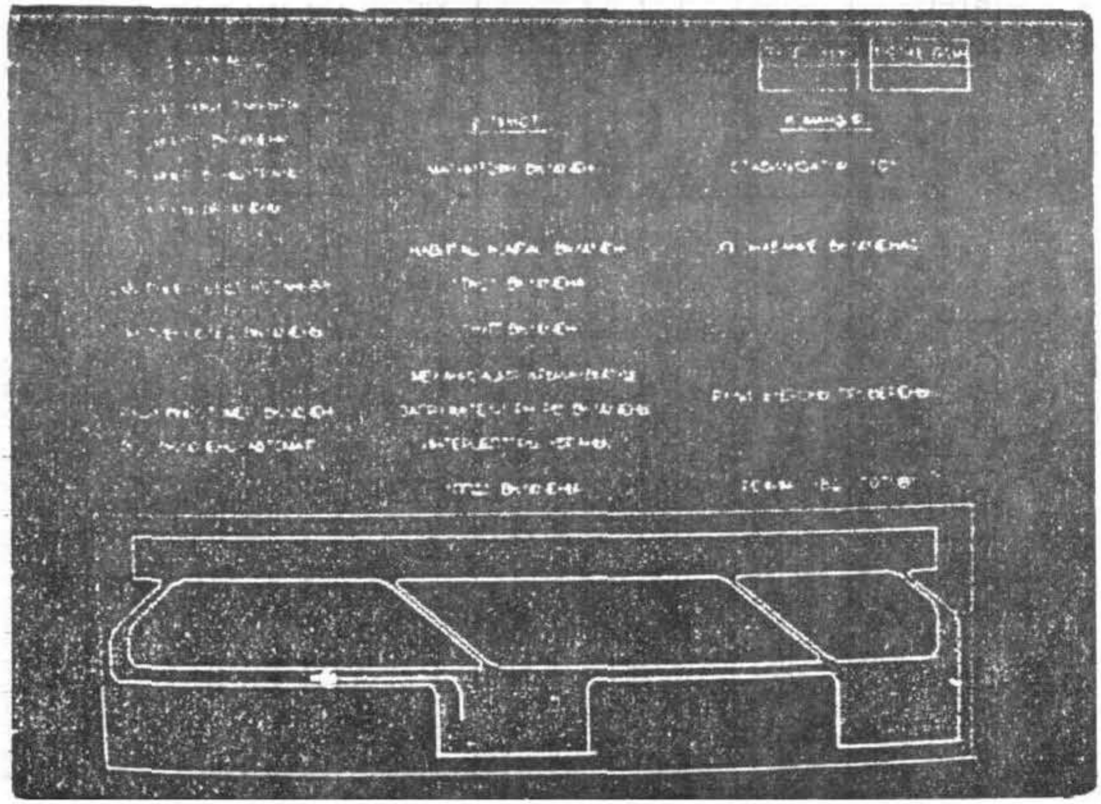


РИС. 9

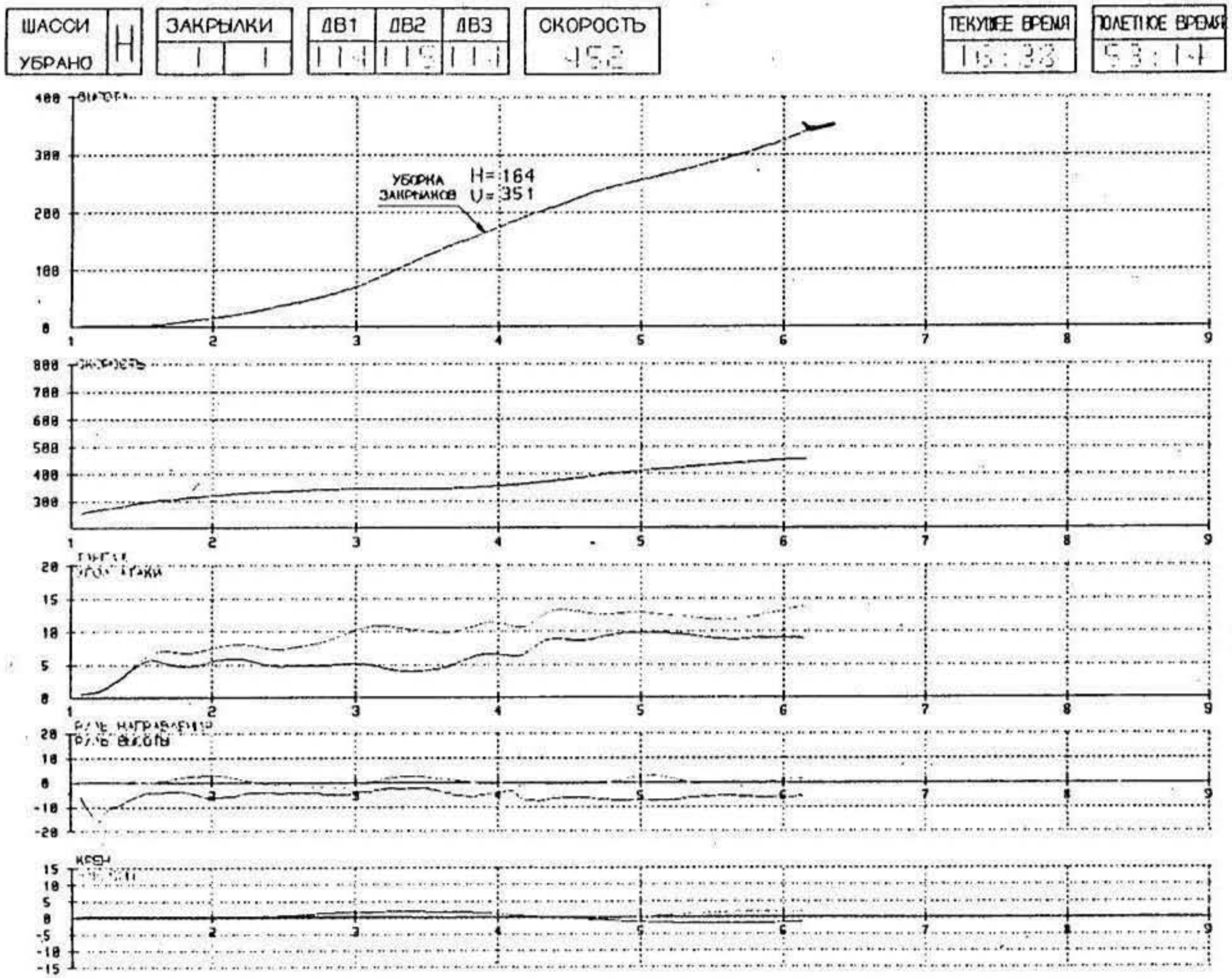

ШАССИ
УБРАНО
Н
ЗАКРЫЛКИ
ДВ1
ДВ2
ДВ3
СКОРОСТЬ
452
ТЕКУЩЕЕ ВРЕМЯ
16:33
ПОЛЕТНОЕ ВРЕМЯ
53:14
ВЫСОТА
УБОРКА ЗАКРЫЛКОВ
H=164
V=351
СКОРОСТЬ
УГОЛ АТАКИ
РУЛЬ НАПРАВЛЕНИЯ
РУЛЬ ВЫСОТЫ
КРЕН
400
300
200
100
0
800
700
600
500
400
300
20
15
10
5
0
20
10
0
-10
-20
15
10
5
0
-5
-10
-15
1
2
3
4
5
6
7
8
9

РИС. 10

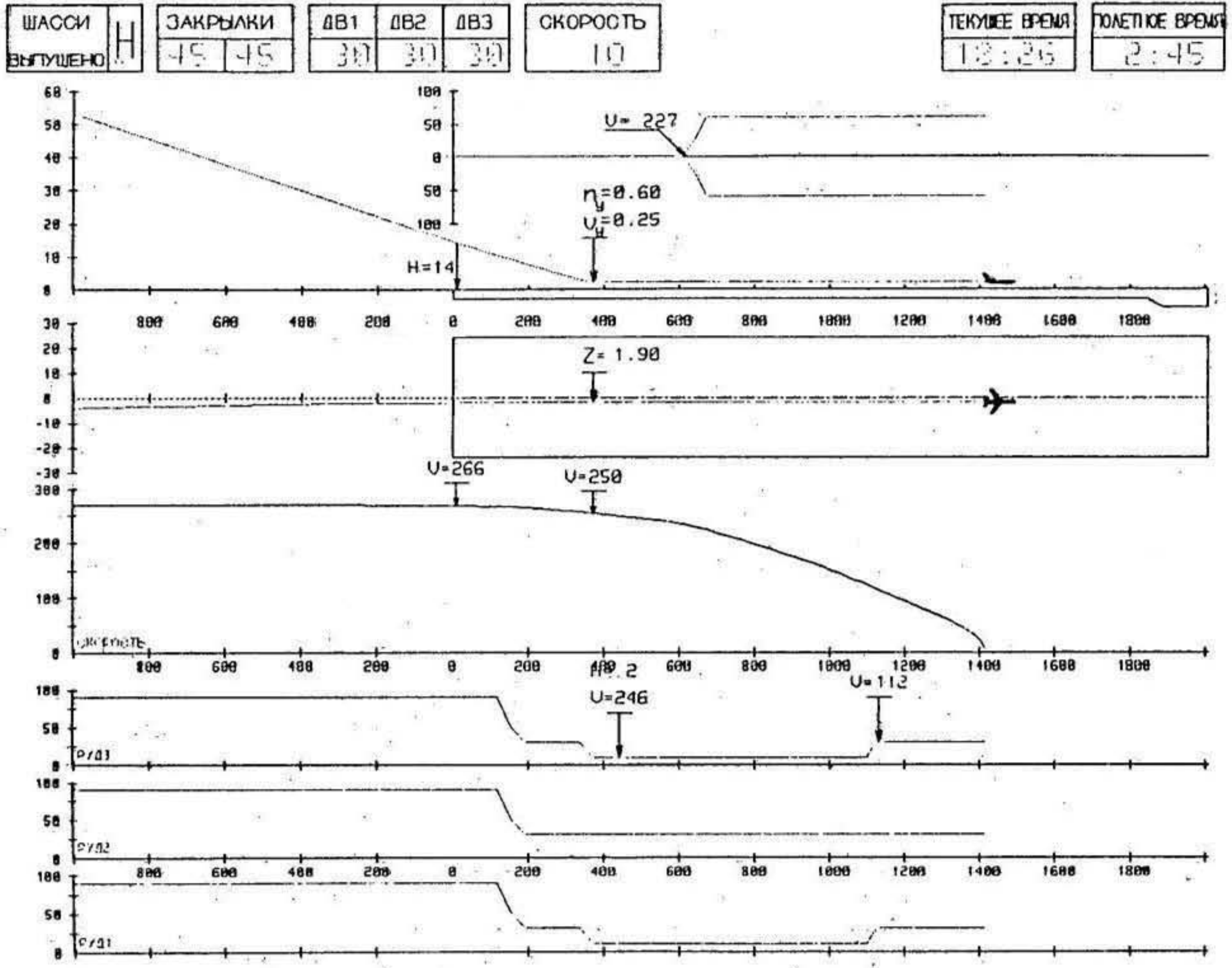

ШАССИ
ВЫПУЩЕНО
Н
ЗАКРЫЛКИ
45
45
ДВ1
ДВ2
ДВ3
30
30
30
СКОРОСТЬ
10
ТЕКУЩЕЕ ВРЕМЯ
12:26
ПОЛЕТНОЕ ВРЕМЯ
2:45
V= 227
n_y=0.60
V_y=0.25
H=14
Z= 1.90
V=266
V=250
СКОРОСТЬ
ДВ 2
V=246
V= 112
Р/Д3
Р/Д2
Р/Д1
800
600
400
200
0
200
400
600
800
1000
1200
1400
1600
1800

РИС. 11

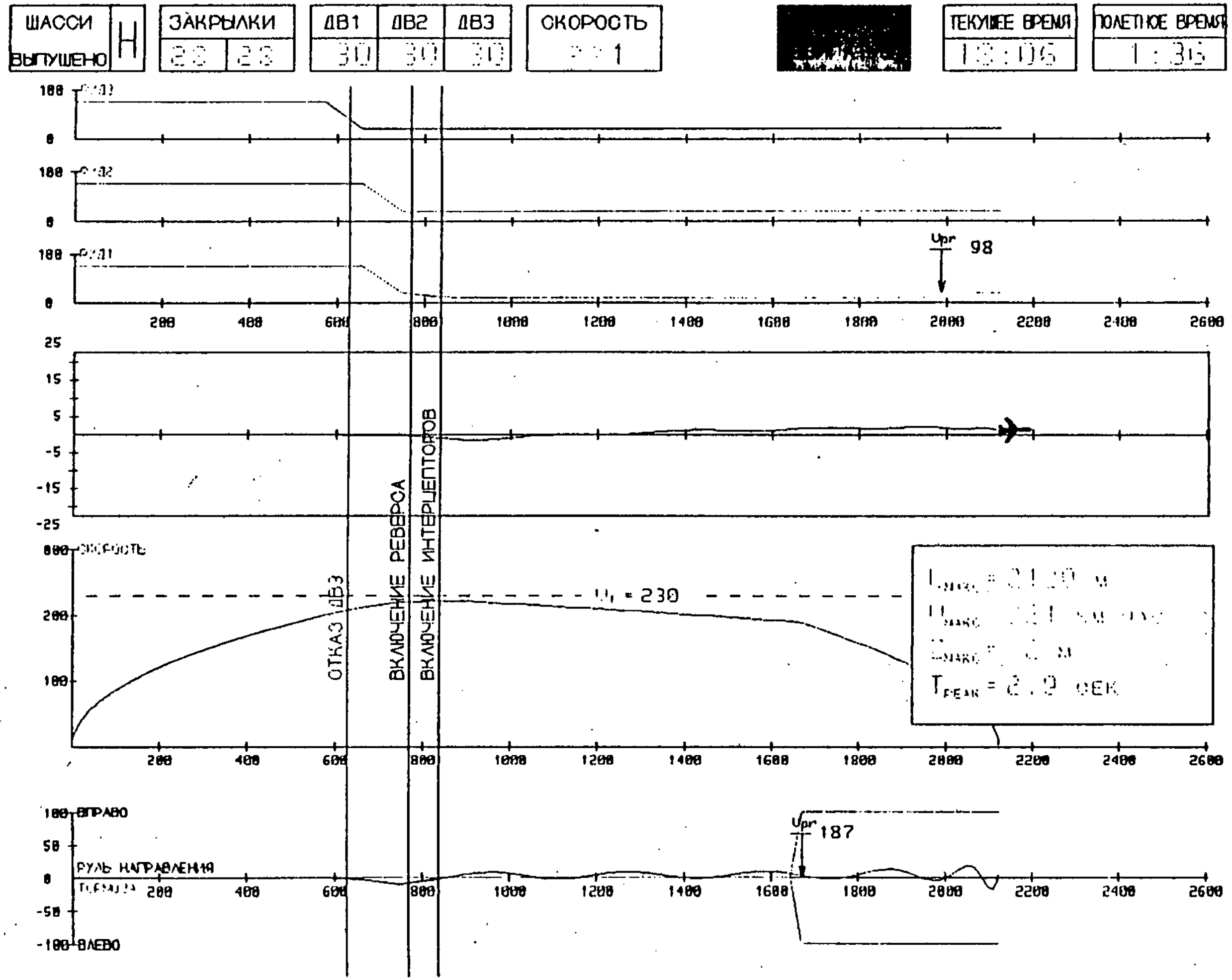

ШАССИ ВЫПУЩЕНО
Н
ЗАКРЫЛКИ
28
28
ДВ1
ДВ2
ДВ3
30
30
30
СКОРОСТЬ
1
ТЕКУЩЕЕ ВРЕМЯ
1?:06
ПОЛЕТНОЕ ВРЕМЯ
1:36
РУД3
РУД2
РУД1
100
0
Vpr
98
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
25
15
5
-5
-15
-25
СКОРОСТЬ
300
200
100
ОТКАЗ ДВ3
ВКЛЮЧЕНИЕ РЕВЕРСА
ВКЛЮЧЕНИЕ ИНТЕРЦЕПТОРОВ
V1 = 230
Lмакс = 2130 м
Vмакс км/час
Zмакс м
Tреак = 2.9 сек
ВПРАВО
50
РУЛЬ НАПРАВЛЕНИЯ
ТОРМОЗА
-50
-100
ВЛЕВО
Vpr
187

РИС. 12

НЕВЫЯВЛЕННЫЕ ОШИБКИ.

I СЕРИЯ ИСПЫТАНИЙ.

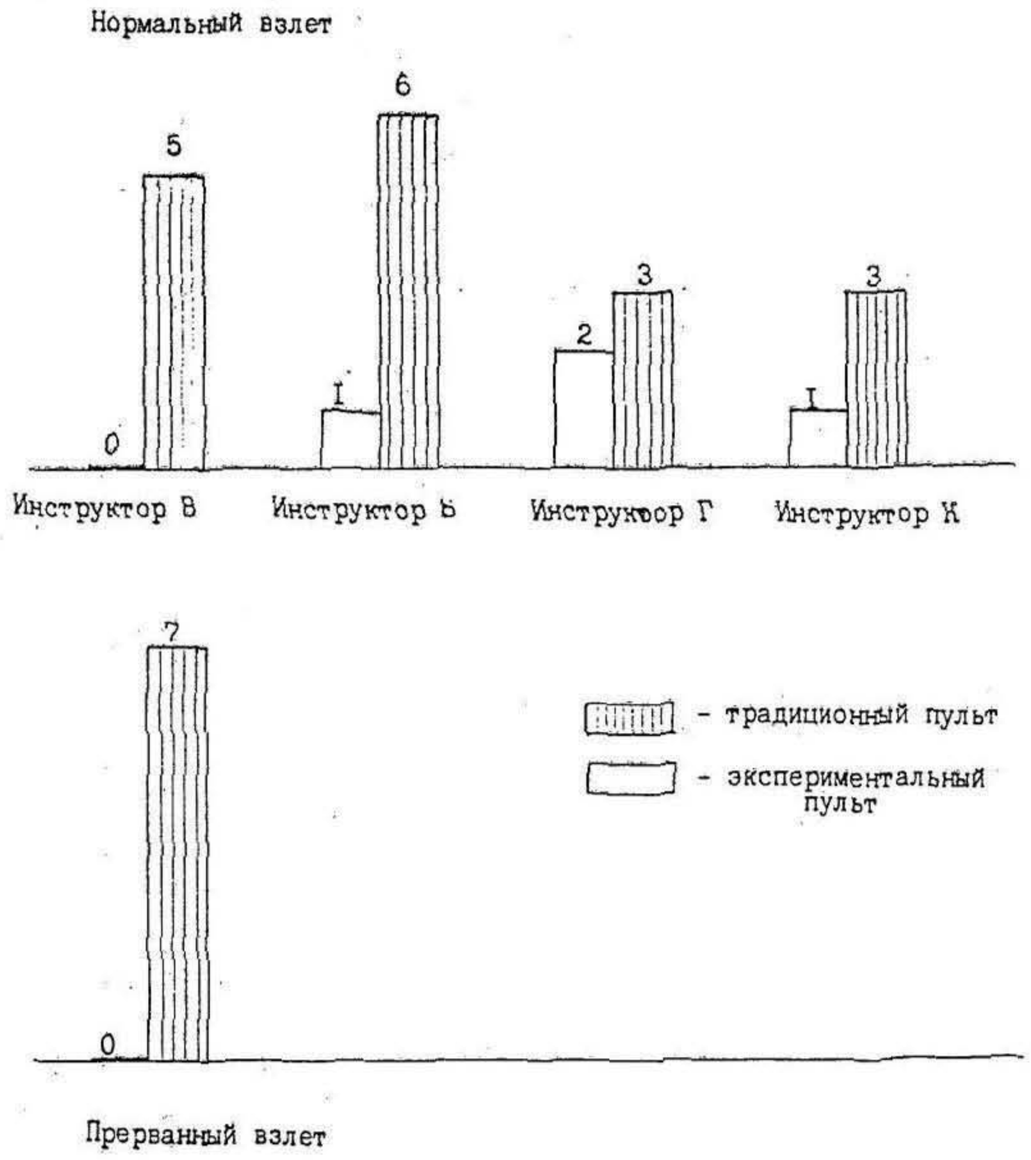
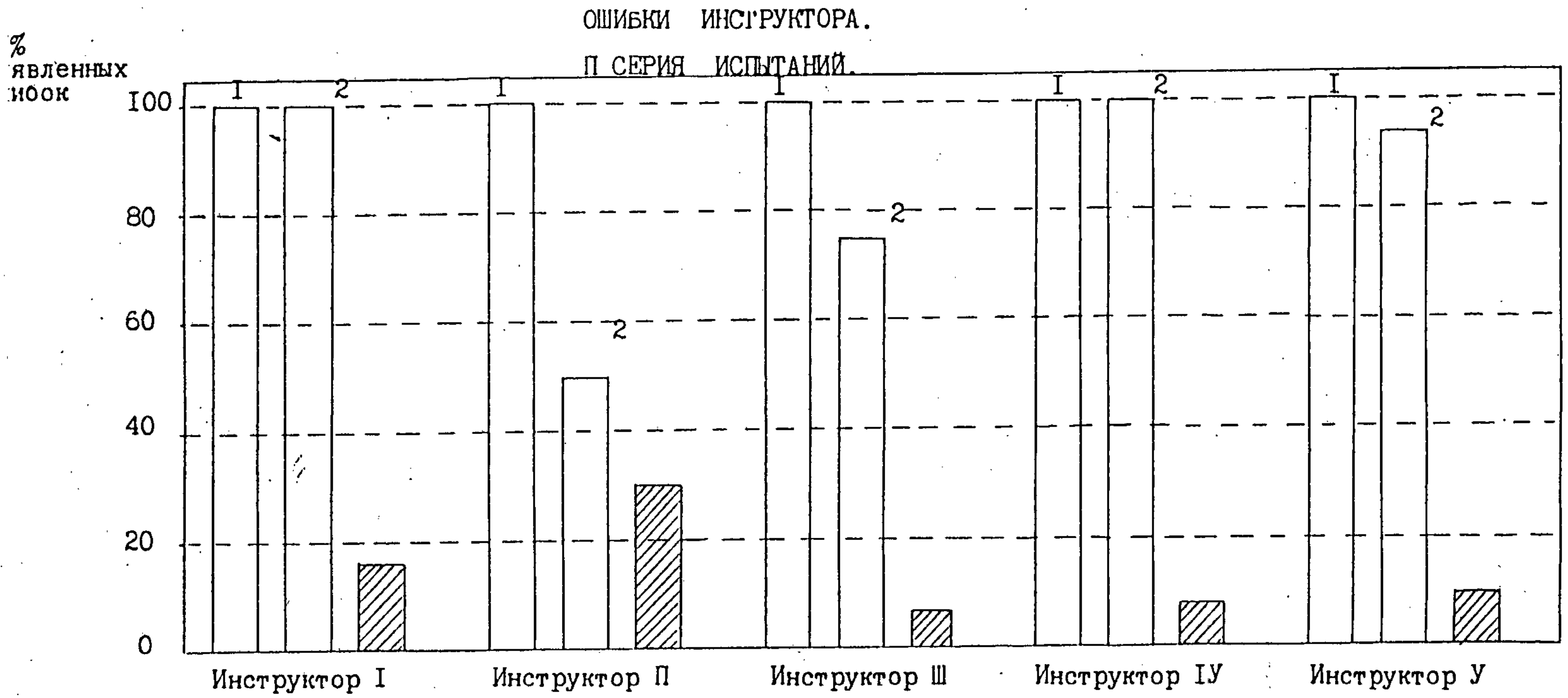


Рис. 13.

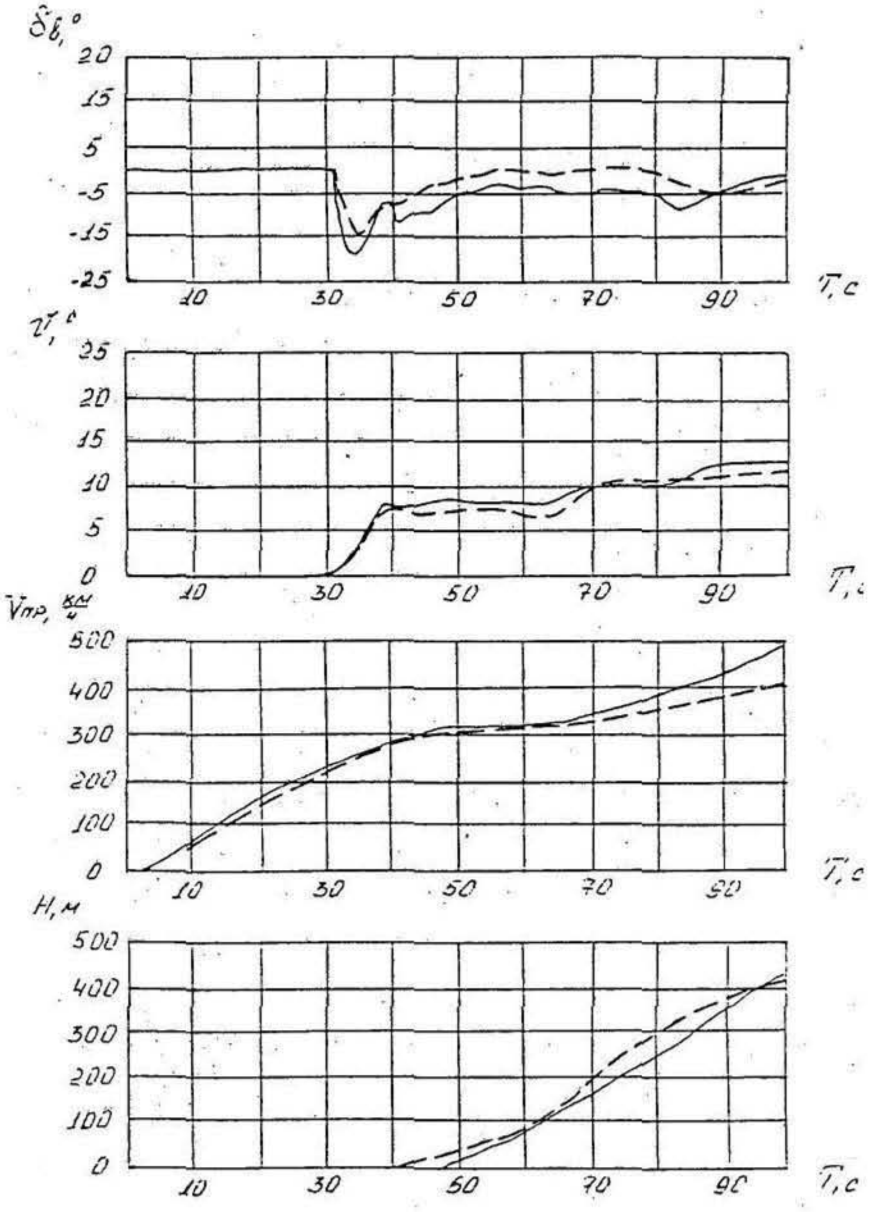


I - экспериментальный пульт
2 - традиционный пульт

▭ - ошибки, содержащиеся в сценариях.
▨ - ложные ошибки.

РИС.14 .

Тестирование тренажера



Нормальный взлет Ту-154Б

— тренажер,
-- самолет.

РИС. 15

А.КАЛЬЧЕНКО, Н. НИКУЛИН

ОБЕСПЕЧЕНИЕ НАДЕЖНОСТИ ДЕЯТЕЛЬНОСТИ ЧЛЕНОВ ЭКИПАЖА В ПОЛЕТЕ

Известно, что из-за отрицательного влияния человеческого фактора на исход полетов в мировой практике происходит ежегодно от 70 до 80% авиационных происшествий и инцидентов. Настораживает и то обстоятельство, что резкого перелома к снижению этих событий пока еще не наметилось.

Исследования советских ученых и летных специалистов в области факторного анализа причин авиационных происшествий (АП) и инцидентов в системе "экипаж - воздушное судно - среда" (ЭВСС) показали ряд характерных признаков, на фоне которых происходит эксплуатация авиационной транспортной системы (АТС). Так, вероятность отказа авиационной техники (АТ) в полете почти в 3 раза больше вероятности допускаемых ошибок летными экипажами, однако переход ошибок членов летного экипажа в катастрофическую ситуацию более чем в 3 раза выше, чем при отказе АТ. Характерным является и то, что природа ошибок членов экипажа еще слабо изучена, а это затрудняет констатацию их причинно-следственных связей на фоне многофакторных событий. Очевидно и, что до 2/3 АП, по сути дела, происходят из-за неправильного принятия решения экипажами в различных эксплуатационных условиях полета.

Эти данные наглядно показывают, что человек является, если не самым слабым звеном в контуре управления большими особо сложными биологическими системами, то, по крайней мере, самым малоисследованным компонентом.

Отрицательное влияние человеческого фактора лежит, прежде всего, в области психологических и психофизиологических ограничений человека, которые наряду с большой информационной загруженностью в полете, создающей острый дефецит времени при принятии решения, высокой эмоциональной нагрузкой на экипаж при локализации особых ситуаций и другими неблагоприятными факторами и их сочетаниями приводят в определенных условиях к авиационным происшествиям.

Разумеется, это не ставит нас на позицию фатальной неизбежности авиационных происшествий, а напротив, позволяет объективно разобраться в проблеме человеческого фактора, установить причинно-следственные связи АП и наметить главные пути мобилизации человеческих ресурсов и неиспользованных резервов на их предотвращение и на качественно новой основе вести профилактическую работу по их предупреждению.

Исследования показали, что повышение уровня надежности функционирования человеческого звена в контуре управления эргатическим комплексом ЭВСС необходимо вести по следующим главным направлениям:

- анализ и последующий синтез (проектирование) процессов управления воздушным судном в ожидаемых условиях и особых ситуациях по критериям надежности деятельности членов экипажа;
- повышение эффективности системы профессиональной подготовки членов летных экипажей по данным критериям;
- профессионально-психологический отбор кандидатов для летной деятельности;
- повышение уровня эргономичности и безотказности авиационной техники.

Понятие надежности человека является логическим выводом из исследований по надежности техники. Это понятие отмечает наличие непостоянства работоспособности человека. Считают, что ошибки появляются, когда работоспособность находися за пределами заданных допустимых границ. Надежность человека тогда определяется как вероятность того, что при этой работоспособности не будут появляться ошибки. В современных теориях описания и оценки систем "человек " техника" используются в основном два понятия: психологической надежности, обусловленной ошибочными действиями без нарушения работоспособности организма (ψ - надежность); физиологической надежности, вызванной временным снижением работоспособности из-за усталости, снижение бодрости и т.д. (φ - надежность).

Для оценки надежности системы "экипаж - воздушное судно - среда" наибольшее значение имеет ψ - надежность, определяющая целенаправленную деятельность членов экипажа. φ - надежность, с одной стороны приводит к изменению ψ - надежности, а с другой - характеризует расход энергии человека, т.е. "цену", которой расплачивается организм за достижение определенной ψ - надежности.

В связи с этим, при определении надежности системы ЭВСС целесообразно исходить не из нарушения работоспособности, как это принято в технических системах, а из нарушения качества функционирования по отношению к заданной цели с учетом "цены" деятельности.

В качестве достаточно информативных критериев при оценке надежности деятельности экипажа могут быть использованы вероятностные показатели безошибочности ($P_{бо}$) и своевременности ($P_{св}$) выполнения поставленной задачи. В качестве косвенного *показателя напряженности деятельности принят коэффициент* загруженности ($K_з$).

Исследования показали, что все множество ошибок членов экипажа по степени опасности может быть классифицировано на три категории:

- ошибки, после допущения которых вероятность авиационного происшествия практически абсолютна;

- ошибки, исправление которых требует от экипажа значительных усилий и психофизиологических затрат;

- прочие ошибки, существенно не влияющие на безопасность полета и легко устраняемые экипажем.

При этом, если A_i - событие, заключающееся в появлении ошибки i -й категории опасности, а B_i - событие, определяющее возможность исправления данной ошибки, то:

$$P_{\Sigma o} = \sum_{1}^{n} P(A_i) \cdot P(B_i/A_i) \;;$$

Реализация модели на ЭВМ с использованием данных видеоконтроля деятельности экипажа и данных средств сбора и анализа полетной информации позволяют формировать основы профессиональной подготовки, контроля деятельности экипажа, сертификации летного состава с учетом "веса" и характера каждой ошибки, развития аварийной ситуации при последующей ее ликвидации.

Наряду с этим, деятельность экипажа, носящая алгоритмический характер, на основе применения структурного метода оценки надежности, может быть разложена на иерархический ряд уровней, каждый из которых представляется в виде определенной структуры. Структура алгоритма на уровне оперативных единиц позволяет производить количественную оценку качества организации технологических процессов по критерию безошибочности.

В процессе исследований установлено, что подавляющее большинство технологических операций структурно предствляют собой совокупность разновидностей четырех блоков оперативных единиц: начальный (командный) блок; блок основных управляющих воздействий, включающий элементы диагностического контроля исходного состояния технической системы и совокупность управляющих воздействий на органы управления; блок функционального контроля результатов операции; заключительный блок. При этом безошибочность выполнения экипажем блоков операций во многом определяется характеристиками средств отображения информации, органов управления и их фиксирующих устройств, количества рабочих и исходных положений органов управления и т.д. Следовательно, повышение надежностных характеристик использования данных блоков путем конструктивных решений с последующим поблочным синтезом структур технических операций может быть использовано в качестве одного из путей и критериев эргономического проектирования кабин воздушных судов и их типизации.

Задача оптимизации структуры алгоритмов технологических операций на эксплуатирующих воздушных судах решается путем введения функций выборочного резервирования определенных элементов алгоритма для члена экипажа, имеющего минимальную загруженность при выполнении операции.

Выбор элементов алгоритма, подлежащих резервирования, производится на основе результатов логического анализа структуры путем выделения единиц функционирования, пропуск или ошибка в выполнении которых **приводит** к непосредственной угрозе безопасности полета. Установлено, что такими единицами, прежде всего, вляются диагностический и функциональный контроль и выбор органа управления.

Решение задачи позволяет получить значение: $P_{бо} \geq 0{,}996$.

Структурные схемы алгоритмов являются основой описания функциональных обязанностей членов экипажа на уровне элементов операций и могут быть применены как при профессиональной подготовке, так и в практике летной деятельности.

Оценка качества организации технологических процессов летной деятельности по критериям своевременности и загруженности производится на основе исследования временных характеристик операций.

Установлено, что располагаемое ($\tau_{р}$) и фактическое

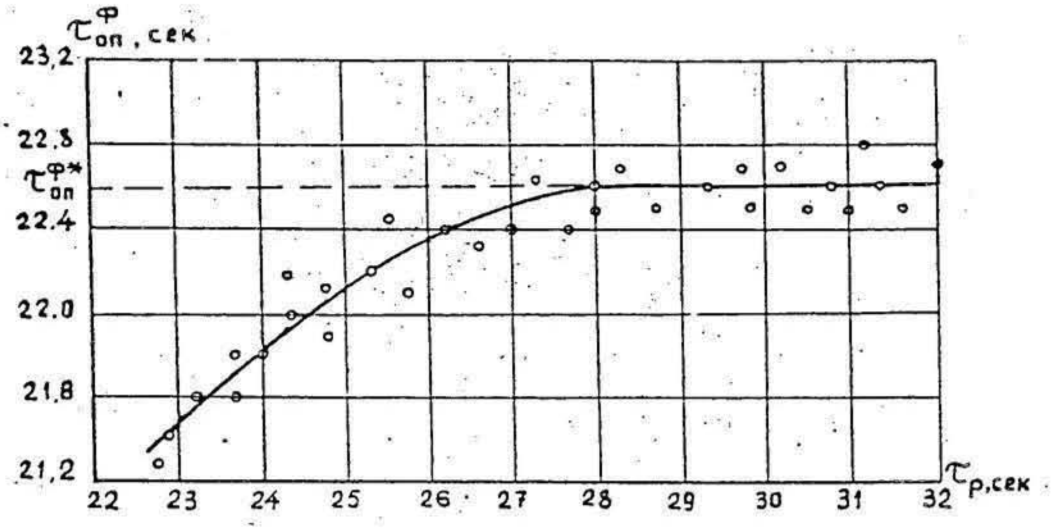

$\tau_{оп}^{ф}$, сек
23,2
22,8
$\tau_{оп}^{ф*}$
22,4
22,0
21,8
21,2
22
23
24
25
26
27
28
29
30
31
32
$\tau_{р}$, сек

Рис. 1.

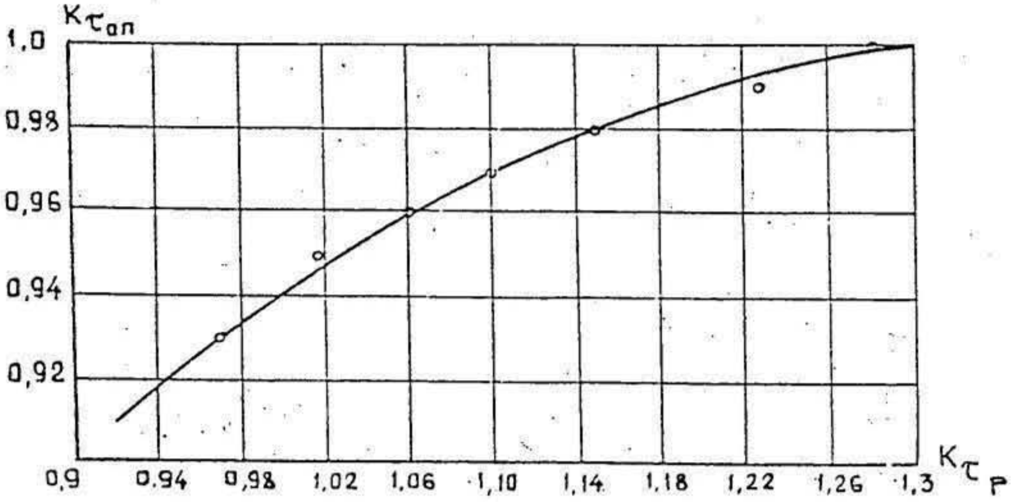

$K_{\tau_{оп}}$
1,0
0,98
0,96
0,94
0,92
0,9
0,94
0,98
1,02
1,06
1,10
1,14
1,18
1,22
1,26
1,3
$K_{\tau_{р}}$

Рис. 2.

($\tau_{оп}^{ф}$) время выполнения технологической операции – случайные величины, подчиненные закону распределения, близкому к нормальному, в связи с чем:

$$P_{св} = 0{,}5 + \Phi_0\left(\frac{\Delta\tau}{\sigma_\Delta}\right).$$

Зависимость коэффициента загруженности экипажа от коэффициентов состояния временных характеристик имеет выражение:

$$K_з = \begin{cases} K_{з\,опт} & при\ K_{\tau_р} \geqslant 1{,}3 \\ \dfrac{K_{\tau_р}}{K_к \cdot K_{\tau_{оп}} - K_м \cdot K_{\tau_р}} & при\ K_{\tau_р} < 1{,}3 \end{cases}$$

где $K_{з\,опт} = \dfrac{\tau_{эк}^{min}}{\tau_{эк}^{ф}} \approx 0{,}75$;

$K_{\tau_р} = \dfrac{\tau_р}{\tau_{сп}^{ф}}$; $K_к = \dfrac{\tau_р}{\tau_{эк}^{min}}$;

$K_м = \dfrac{\tau_м}{\tau_{эк}^{min}}$; $K_{\tau_{оп}} = \dfrac{\tau_{оп}^{ф}}{\tau_{оп}^{ф}}$

Проведенные исследования свидетельствуют о том, что при определенном резерве располагаемого времени: $K_{\tau_р} \geqslant$ I,3 (рис. I, 2) экипаж работает в оптимальном режиме, что соответствует значению $K_з \approx 0{,}75$. Уменьшение $K_{\tau_р}$ до величины I,2 незначительно влияет на увеличение $K_з$, т.е. экипаж почти не воспринимает лимит времени $\Delta P_{св} \leqslant 0{,}02$ (рис. 3). Диапазон I $K_{\tau_р}$ I,2 характеризуется значительным приростом вероятности своевременного выполнения операции ($P_{св} \geqslant 0{,}05$) за счет увеличения темпа деятельности. Уменьшение $K_{\tau_р}$ менее I характеризуется интенсивным ростом $K_з$ и резким уменьшением вероятности своевременного выполнения операции. Следовательно, оптимальными характеристиками организации технологического процесса являются значения $K_{\tau_р}$ = I,3 и $K_{з\ опт} = 0{,}75$.

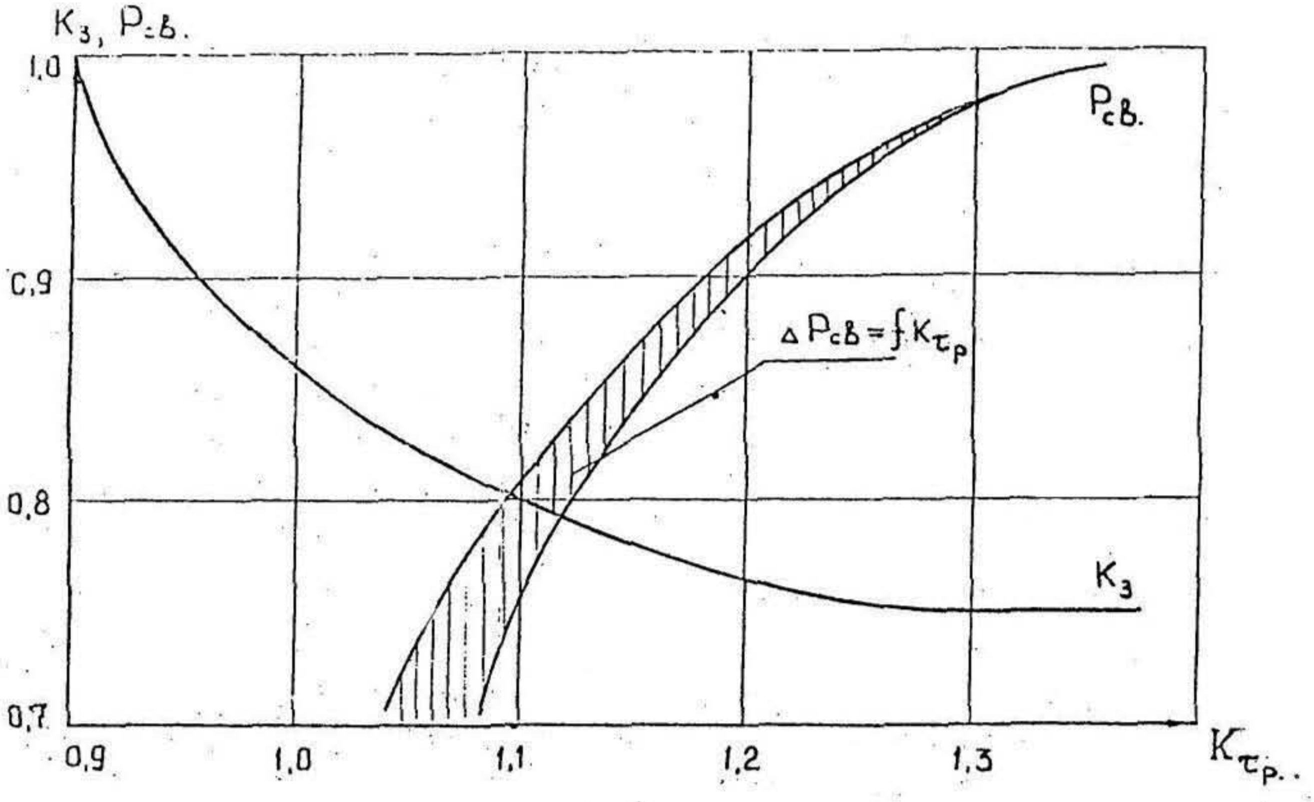


Рис. 3.

Данные критерии могут быть использованы при сертификации траекторий маневрирования воздушных судов при взлете и заходе на посадку из условий обеспечения надежности деятельности их экипажей.

Особую роль в обеспечении надежности работы экипажа играют вопросы распределения обязанностей между командиром воздушного судна и вторым пилотом по реализации процессов пилотирования и принятия решений.

Эксперименты и летная практика показывают, что пилот, осуществляющий пилотирования на предпосадочном снижении, начинает плохо воспринимать и перерабатывать приборную информацию в том случае, когда он выполняет одновременно два и более разноцелевых задач (ведет связь с диспетчером, выполняет операции согласно карте контрольной проверки и другие операции). И наоборот, сосредоточив внимание на приборах, пилот часто не воспринимает смысла сообщения, полученного по радио. Эти свойства при соответствующих обстоятельствах создают условия, при которых пилот не способен перерабатывать всю поступающую информацию, принимать правильное решение, особенно в условиях дефицита времени, что становится причиной развития катастрофической ситуации.

Экспериментальные исследования показывают, что степень нервно-психологического напряжения командира ВС можно снизить вдвое и в 4 раза повысить вероятность безошибочного выполнения необходимых операций, если его освободить от второстепенных функций пилотирования, занимающих 80-90% объема внимания. Таким образом, психологическая напряженность и интенсивность деятельности пилотов являются теми параметрами состояния, которые характеризуют внутренние аспекты функционирования человеческого звена в системе "экипаж - воздушное судно - среда" и существенно влияют на вероятность своевременного и безошибочного выполнения действий по управлению ВС.

На основе проведенных исследований наиболее оптимальным распределением обязанностей в экипаже в ожидаемых условиях полета и особых ситуациях является такое, когда функции пилотирования осуществляет второй пилот, а функции принятия решения как функции повышенного приоритета передаются командиру воздушного судна. Такое взаимодействие позволяет надежно осуществлять пилотирование вторым пилотом, а командиру ВС высвобождает время для оценки ситуации и принятия решения на ВПР.

В настоящее время доказано, что только методом прекращения захода на посадку (при выходе за предельно допустимые параметры полета) и ухода на повторный заход можно предотвратить до 50% тяжелых авиационных происшествий.

По прогнозам ученых и авиационных специалистов за счет внедрения оптимальных методов управления ВС, базирующихся на мобилизации человеческих ресурсов, можно до 30% снизить число АП и инцидентов.

Второй аспект повышения надежности деятельности человеческого звена – разработка и внедрение научно обоснованной системы профессиональной подготовки членов летных экипажей. В настоящее время большинство ученых и специалистов признают, что эффективная система профессиональной подготовки членов летного экипажа должна стать фундаментом формирования надежности деятельности летного состава и быть ключевым элементом обеспечения безопасности полетов. Доказано, что правильно подобранные методы воздействия на адаптационные механизмы пилота мобилизуют человеческие ресурсы и формируют надежность деятельности экипажа по выбранным критериям в ожидаемых условиях и особых ситуациях. В вопросах конструирования элементов системы профессиональной подготовки членов летного экипажа как и в вопросах проектирования основ профессиональной деятельности летных экипажей по выбранным критериям пока больше эмпиризма, нежели научного обоснования. Причиной этого является слабая научная проработка инфраструктуры деятельности летного экипажа по всем потокам решаемых задач в полете, что не позволяет разработать реальную модель действующего на практике экипажа, которая является системообразующим фактором для проектирования всей профессиональной подготовки членов летного экипажа, выбора адекватных методов, средств и содержания обучения по критериям надежности выполнения полета. Расследование авиационных происшествий показывает, что в критических ситуациях командир ВС и члены летного экипажа не используют имеющиеся резервы и человеческие резурсы для локализации особой ситуации из-за отсутствия у них сформированных специальных навыков и умений, приобретаемых специальными тренировками. Задача обучения состоит в том, чтобы сформировать эти специальные навыки работы в особых ситуациях, тренировать и поддерживать их на необходимом уровне. Именно это может стать гарантией безопасности полетов в части надежности деятельности человеческого звена (фактора) в различных эксплуатационных условиях. Необходимо отметить, что в мировой практике уже наметились контуры создания таких систем профессиональной подготовки членов летных экипажей, которые не только формируют стереотип деятельности, но и несут эвристическую функцию познания деятельности в различных ситуациях и формируют профессиональный интелект, позволяющий пилоту выбирать стратегию деятельности и методы локализации особых ситуаций в полете. Такими программами подготовки летного состава в условиях, приближенных к реальным, в США (Line orietated manegement LOFT) и (Cockpit reogource manegement GRM), а также "Оптимизированная система подготовки членов летных экипажей", разработанная в СССР.

Профессиональная подготовка пилотов, обеспечивающая формирование пространственного мышления на уровне концептуалиных образов полета, позволяет обеспечить успешное принятие решения в различных эксплуатационных условиях.

Исследованная и заполнившаяся совокупность операций уже представляет собой профессиональный ителект, обладая которым можно осуществлять поиски различных решений в соответствии с обстановкой. Именно оценка ситуации и принятие своевременного и правильного решения являются профессионально важными качествами пилота, позволяющими надежно действовать в ожидаемых условиях полета и особых ситуациях.

Однако решение проблемы разработки, проектирования и внедрения системы профессиональной подготовки, формирующей профессиональный интелект у пилотов, потребует больших усилий ученых, авиационных специалистов, психологов, инструкторов и педагогов. Такие усилия стоит предпринимать,ибо внедрение системы профессиональной подготовки, базирующейся на критериях надежности деятельности в сочетании с профессионально-психологическим отбором абитуриентов в летные учебные заведения, позволит в будущем снизить количество авиационных происшествий и инцидентов, происходящих в настоящее время из-за отрицательного влияния человеческого фактора на безопасность полетов, почти на 30%.

Таким образом, разработка оптимальных моделей профессиональной деятельности членов летного экипажа по критериям надежности в различных эксплуатационных условиях и на этой основе проектирование системы профессиональной подготовки летного персонала и внедрение в практику обучения является двуединой задачей и стратегическим направлением в области повышения уровня безопасности полетов в гражданской авиации.

БЕЗОПАСНОСТЬ ПОЛЕТОВ И ОСНОВЫ ПРОЕКТИРОВАНИЯ УПРАВЛЯЮЩЕЙ ДЕЯТЕЛЬНОСТИ ЭКИПАЖА ТЯЖЕЛОГО ТРАНСПОРТНОГО САМОЛЕТА НА КОНЕЧНОМ ЭТАПЕ ПРЕДПОСАДОЧНОГО СНИЖЕНИЯ

Терещенко М.М.

В настоящее время 160 стран-членов ИКАО эксплуатируют 36198 аэродромов, используя при этом 10600 воздушных судов со взлетной массой, превышающей 9000 кг. С учетом СССР и Китая эти цифры существенно возрастают. Эксплуатационные расходы составляют около 160 млн американских долларов в год. При этом мировое авиационное сообщество несет значительные убытки из-за потерь воздушных судов и гибели людей при авиационных происшествиях.

Данные из системы ADREP за 1985–1989 гг позволяют охарактеризовать наиболее опасные этапы полета и в первом приближении определить место человеческого фактора в общей статистике по безопасности полетов (масса ВС 5700 кг и более).

Таблица 1.

Этап	Годы					Всего	По человеческому фактору			Всего по технике
	1985	1986	1987	1988	1989		экипаж	другие	Всего	
Стоянка	-	2	3	1	-	6	1	2	3	-
Руление	4	1	1	-	1	7	3	2	5	4
Взлет	9	8	1	4	-	22	13	2	15	16
Маршрут	16	21	6	-	-	43	12	2	14	19
Заход на посадку	6	6	1	6	-	19	13	1	14	10
Посадка	7	15	2	4	1	29	23	2	25	10
Всего:	42	53	14	15	2	126	74	11	85	59

Данные свидетельствуют о том, что 85 из I26 авиационных происшествий произошло по вине человека, а наиболее опасными являются заход на посадку и посадка, – 36 из 74 авиационных происшествий, связанных с виной экипажа. Такая закономерность в причинности событий характерна и для гражданской авиации СССР.

С учетом всех событий по всем типам воздушных судов по вине экипажей (недостаточный уровень профессиональной подготовки и нарушения технологической дисциплины) произошло

I984	I985	I986	I987	I988 гг
59%	48%	58%	50%	70%

от всех авиационных происшествий.

Как показывает практика большинство событий, происходящих на посадке, является следствием ошибочных или несвоевременных действий экипажа при пилотировании самолета на конечном этапе предпосадочного снижения. В процессе расследования авиационного происшествия комиссия располагает речевыми и параметрическими данными, которые представляют собой закономерное следствие управляющей деятельности экипажа.

Психофизиологические особенности летного труда, а также присутствующее множество факторов ставят перед комиссией трудноразрешимые вопросы о степени виновности пилота в случившемся. В таких случаях часто указывается вероятная причина или следствие первопричины, приведшее к возникновению и развитию аварийной ситуации.

Это в определенной мере определяется тем, что до настоящего времени мы не имеет теоретических разработок, определяющих законы проектирования управляющей деятельности пилотов. Практически во всех конструкторских бюро, проектирующих самолеты, разработка РЛЭ ведется на основе опыта людей, и в первую очередь, летного состава. Это в некоторых случаях приводит к повторению уже заложенных ошибок, не выявленных ранее.

Такой подход приводит к тому, что проектирование деятельности в которой нет даже четко обоснованных ограничений, ведется под уже существующую технику.

Наиболее характерная ситуация, когда неблагоприятное сочетание отрицательного влияния внешней среды, выработанного стереотипа пилотирования экипажа и динамических характеристик самолета проявляются при посадках с вертикальной перегрузкой превышающей эксплуатационно-допустимую, сложилось применительно к самолету Ту-154. При этом необходимо отметить, что данный самолет является самым массовым в гражданской авиации СССР.

Примечательным является то, что за период 1983 - 1988 гг 60% грубых посадок совершено в простых метеорологических условиях и 68% - ночью.

Исходя из статистических данных определена степень опасности грубой посадки тяжелого транспортного самолета, в частности для Ту-154

$$K_{оп} = 0,12;$$

т.е. практически каждая десятая грубая посадка заканчивается авиационным происшествием, а на 100 грубых посадок следует ожидать:

- 2 катастрофы;
- 2 аварии;
- 7 случаев потерь летных характеристик ВС вследствие механического повреждения элементов его конструкции.

По заключению комиссий, расследовавших эти события, определяющими факторами являлись нарушения правил взаимодействия в экипаже, такие как:

- позднее вмешательство в управление ВС пилотов-инструкторов при ошибках командира ВС или 2-го пилота;
- пассивное поведение 2-го пилота или штурмана.

Необходимо отметить, что реализованные профилактические мероприятия по этим направлениям ожидаемых результатов не дали, и в течение 1988-1989 гг количество и последствия грубых посадок опасно возросли.

18 января 1988 года, ночью, в 04 часа 20 мин. мск, в простых метеоусловиях при выполнении посадки в аэропорту Красноводск самолет Ту-154 из-за воздействия нерасчетных нагрузок ($П_у$ = 4,8 ед.) разрушился, что привело к гибели людей.

Аналогичные по характеру события, только с более благоприятным исходом имели место 24.09.88 в аэропортах Алеппо (Сирия) и Норильск (СССР), 06.09.89 в аэропорту Днепропетровск.

Однозначто и убедительно ответить на вопрос, в чем причина каждого из событий как для отдельных специалистов так, и для комиссий их расследовавших по мнению летного состава авиапредприятий не удалось. В дополнение к выявленным нарушениям и отклонениям информация бортовых самописцев позволяет определить общие закономерности в главном на мой взгляд, в выработанном стереотипе управляющей деятельности пилота;как реакции на появившееся отклонение от какого-то заданного параметра предпосадочного снижения.

На плакате № 2 представлены фрагменты записи бортовых самописцев в указанных случаях. Даже не претендуя на научную глубину анализа достаточно определенно просматриваются следующие общие закономерности конечного этапа предпосадочного снижения:

- на высоте начала визуальной оценки (за 20-30 м до ВПР) самолет находился выше установленной глиссады снижения;

- после установления контакта с наземными ориентирами самолету придавалась превышающая рекомендованную, вертикальная скорость снижения и полет проходил с пересечением сверху вниз установленной глиссады снижения;

- опасность фактической вертикальной скорости снижения определялась в непосредственной близости от земли и энергичное отклонение руля высоты на кабрирование существенного влияния на исход полета не оказывало.

При этом необходимо отметить, что инструментальной информации об увеличенной вертикальной скорости (по показателям вариометра), экипаж не имел;

Анализ ситуации с момента принятия решения на исправление имеющегося отклонения по высоте, до возникновения ощущения опасности крутого снижения, однозначно указывает на колебательный и неадекватный отклонению от заданного положения, характер пилотирования.

Во всех случаях отклонения руля высоты резкие, с большим размахом по углу отклонения и хаотичны по характеру.

На основании изложенного с достаточной степенью объективности можно сделать вывод о приоритетности характера управляющей деятельности пилота над другими причинами грубых посадок.

В процессе изучения возможных причин катастрофы в аэропорту Красноводск I8.0I.89 в порядке профессионального любопытства было принято решение смоделировать событие таким образом, чтобы не только воссоздать картину происшедшего, но и попытаться определить необходимые управляющие действия пилота для выхода из сложившейся ситуации.

И здесь возник целый ряд сложностей.

Проблема моделирования человека занимает важное место при разработке различных систем. Если пользоваться терминологией разработчиков систем, то ~~оператор~~ является частью замкнутой сервосистемы и его ответы на постоянно возникающие ошибки в соотнесении текущего и требуемого значения управляемой переменной линейны и дискретны.

По содержанию такое описание сводится к подбору передаточной функции, описывающей работу оператора. Достаточно популярно такой подход описан в работе "Измеренные различия в передаточной функции пилота в одномерной задаче" американских авторов Д.Адамса и И.Бергенсона. Но вследствие своего ограниченно-манипулятивного характера он не отвечает на поставленные вопросы.

Идеология исследования определилась на основе работ по инженерной психологии,как советских так и зарубежных авторов, таких как Л.Г.Райков, М.Г.Миримский, Е.Крендел, Э.Фейгенбаум.

Была принята следующая точка зрения:

Управляющая деятельность пилота носит характер ручного слежения, т.е. человек уменьшает визуально воспринимаемое отклонение движением руки так, что к воспринимаемому входному сигналу подбирается соответствующий, выходной двигательный сигнал, являющийся ответной реакцией. Ответная реакция в определенном временном интервале переходит в характер пилотирования который есть не что иное,как управляющая деятельность пилота.

Изучение располагаемой информации по проблеме управляющей деятельности экипажа привело к неутешительным выводам.

Рассматривая задачи, возникающие при пилотировании самолета советский ученый Л.Г.Райков в своих суждениях отмечает, что полнота сведений по пилотированию отрабатывалась годами на опыте летчиков-испытателей, т.е. носит субъективный характер. При моделировании процессов выработки стереотипных движений пилота он, исходит из общих принципов обучения. Программы подготовки летного состава LOFT и CRM, разработанные американскими специалистами, являются на сегодня наиболее прогрессивными, но и они не решают проблемы, т.к. в основе содержат аналогичные эвристические[x] методики и экспертные оценки.

Используя выверенное правило летного обучения "знания -навык-умение" необходимо было решить задачу отработки навыка в пилотировании исключив возможное отрицательное влияние субъективного фактора в виде инструктора, для чего заменить его математической моделью самолета работающей в автоматическом или диалоговом режиме по заданной программе. Программа должна обеспечить выработку не только ситуации, но и необходимых ответных реакций для их заучивания пилотом с целью приобретения оптимального навыка в пилотировании. При этом учитывается, что заучивание ответных реакций проходит через следующие этапы:

- входной сигнал в виде отклонения появляется впервые. В этом случае в обычной ситуации ответная реакция полностью определяется органами чувств, а структура реакции является полностью компенсаторной;

- пилот приобретает способность предвидеть изменение характера отклонения на коротких временных интервалах и возникает ситуация преследования;

- предвиденные ответные реакции полностью заучиваются, становятся синхронными входному сигналу, т.е. отклонению, и переходят в новое качество - навык.

В соответствии с подходами по решению задачи глубокого понимания характера поведения самолета в зависимости от выработанного характера управляющих воздействий было выполнено статистическое моделирование конечного этапа предпосадочного снижения на вычислительном комплексе ЕС-1060 с использованием цифровой модели самолета Ту-154.

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x) Эвристика - это основанное на опыте правило, или иное средство существенно ограничивающее поиск решения сложных задач.

Исследование было направлено на выработку оптимального режима управляющих воздействий и изучение поведенческих характеристик самолета при переходе с предельно-допустимого отклонения до заданного положения.

При этом ставилась задача определить такую структуру и характер управляющих воздействий, чтобы вывести самолет на торец ВПП с параметрами обеспечивающими безопасную посадку.

Для решения задачи было необходимо отработать такую расчетную схему вычислительного эксперимента которая бы удовлетворяла следующим требованиям:

I. Возможность учета и анализа стереотипа управления самолетом приведшего к возникновению и развитию аварийной ситуации на примере имевших место реальных событий;

2. Возможность определения оптимальной траектории полета с минимальным расходом рулей и общих энергозатрат со стороны пилотирующего с целью создания максимального резерва динамических характеристик самолета и возможностей экипажу для успешного ухода на повторный заход в случае возникновения такой необходимости,

Начальными условиями предусматривалось максимально-допустимое (разрешенноеэ отклонение самолета от заданной высоты в ту или иную сторону при пролете ближнего радиомаркета (БПРМ). При этом направление вектора перемещения центра тяжести самолета предполагалось многовариантным.

Конечными условиями предусматривался вывод самолета на торец ВПП на рекомендуемой высоте и с динамическими характеристиками обеспечивающими безопасную посадку.

Графически принятая схема изображена на рис. I

Не менее интересной была выработка расчетной схемы програмного управления штурвалом для вписывания в глиссаду снижения без перерегулирования, как единственной удовлетворяющей второму требованию расчетной схемы решения задачи.

Предварительный эксперимент выявил следующие закономерности:

- отклонение может быть исправлено одной дачей (одним движением) штурвала, но при этом требуется редкодостигаемая (8%) точность хода штурвала и повышение внимания на инструментальный контроль захода;

- многократные (более двух) дачи штурвала не позволяют сохранить запас динамических характеристик самолета и реализовать хотя бы один из выбранных законов вписывания в глиссаду снижения;

- исправление отклонения по высоте посредством двух последовательных дач штурвала является оптимальным, т.к. они несложно выполнимые, сравнительно просто усваиваются, их идеология достаточно проста для понимания летным составом и при этом максимально сохраняются динамические характеристики самолета.

Графически принятая схема програмного управления изображена на рис. 2

Для достижения требуемой корректности эксперимента были определены:

- область допустимых значений отклонения по высоте Но и вертикальной скорости V уд для продолжения захода по земным ориентирам; рис.3.

- область допустимых значений Но и Vуд для продолжения захода по приборам; рис.4

- оценка вероятности нарушения ограничения Vуд - 5 м/сек; Рис.5

- распределение значений параметров полета в функции от центровки;

- вероятность нарушения ограничения по линейному отклонению в сечении Нглис = 20м;

- распределение траекторных параметров вдоль глиссады снижения, в т.ч. и в функции от уровня ремнатной составляющей . рис.6.

В целях повышения реальности условий эксперимента в качестве базового был определен аэропорт Борисполь, допущенных к эксплуатации по II категории.

В процессе эксперимента проведено моделирование более 1500 вариантов управляющей деятельности пилота по исправлению отклонения по высоте при пролете БПРМ при различных положениях самолета и динамики его движения.

В плане заключения можно сказать, что несмотря на высокую корректность эксперимента его результаты заставили по новому осмыслить роль и место имеющихся технических средств в профессиональной подготовке летного состава, а также по другим направлениям. Достоверность возможности проектирования управляющей деятельности пилота была подтверждена летной оценкой на тренажере КТС-154. В настоящее время в летной службе Украинского управления ГА приступили к летной оценке полученных результатов непосредственно в реальных полетах.

В качестве примера реального моделирования даны две полетные ситуации и применительно к ним рекомендуемый оптимальный режим управляющей деятельности пилота по каналу тангажа при продолжении захода на посадку по приборам, см.рис. 7.8;

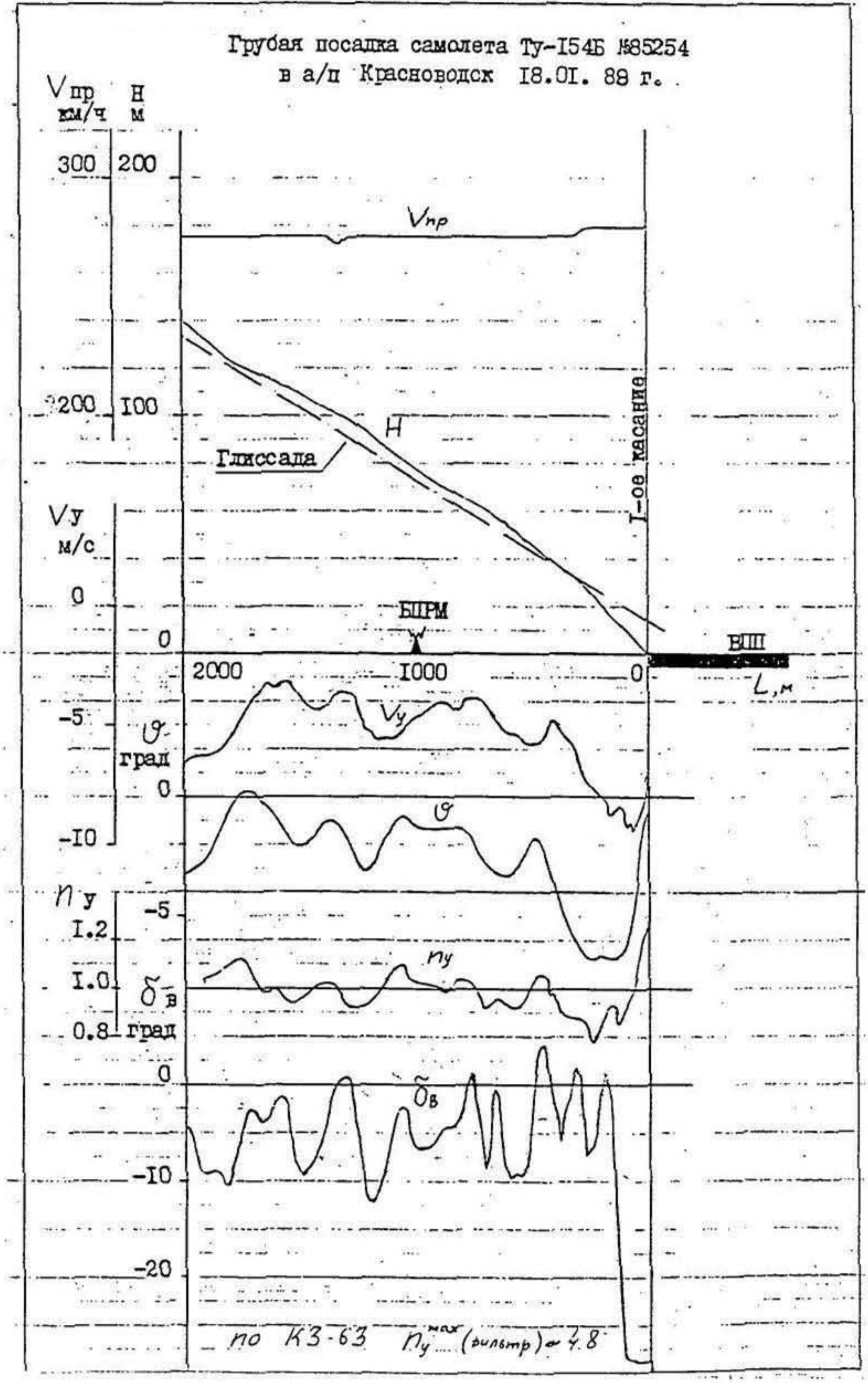
Разработчики Руководств по летной эксплуатации учитывая отсутствие необходимой информации для выработки рекомендаций по пилотированию ВС на высотах ниже ВПР всю ответственность за режим пилотирования и исход полета возлагают на экипаж. В абсолютном большинстве полетов это справедливо, но вместе с тем имеют место случаи, когда экипажу вменяется в вину невыполнение одной из общих рекомендаций, реализации которой пс субъективному мнению расследователя, позволила бы предотвратить возникновение аварийной ситуации. Как правило, экипаж с таким заключением не соглашается.

Экспериментально подтверждено, что достаточно несложно решить задачу по оценке достоверности и достаточности рекомендаций РЛЭ на любом этапе полета можно при наличии моделирующего комплекса и периферийных устройств как показано на рис. 9 .

В основу проектирования управляющей деятельности экипажа положен вычислительный эксперимент с применением моделирующего комплекса. В этом случае один из предполагаемых режимов управляющей деятельности экипажа вырабатывается комплексом при решении задачи по оптимизации режима полета при отклонении по разработанному сценарию в соответствии с известным законом управления. Рекомендуемые воздействия на органы управления самолетом выдаются в виде графика, таблицы или изображения на экране дисплея. Эта информация является основой разработки методологического обеспечения обучения летного состава оптимальному режиму пилотирования в любой возможной ситуации.

Реально данный метод был отработан применительно к самолету Ту-I54 по блок-схеме представленной на рис. I0.

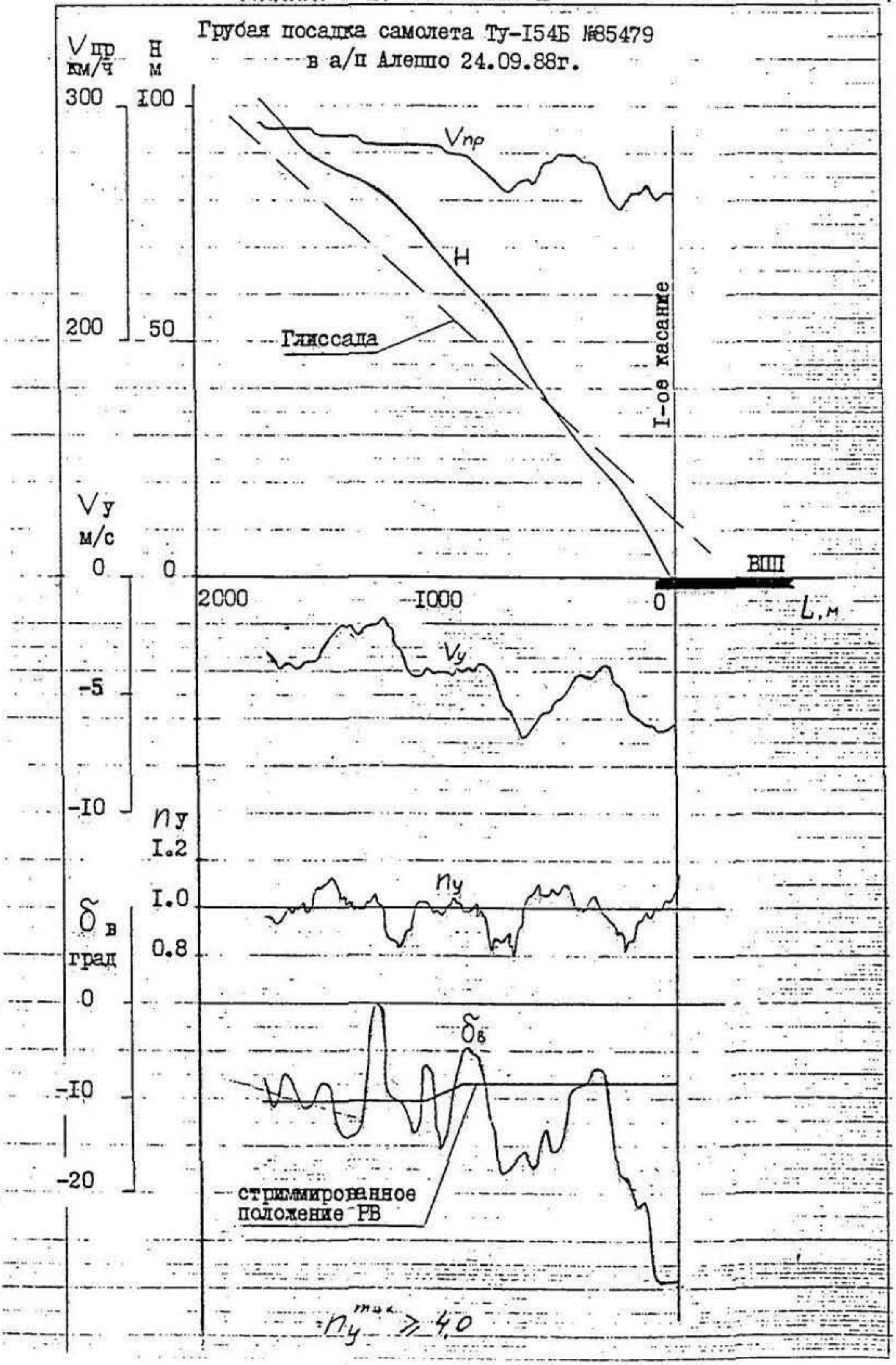
ПЛАКАТ N2, фрагмент 1



Грубая посадка самолета Ту-154Б №85254
в а/п Красноводск 18.01. 88 г.

по КЗ-63 n_y^{max} (фильтр) ~ 1.8

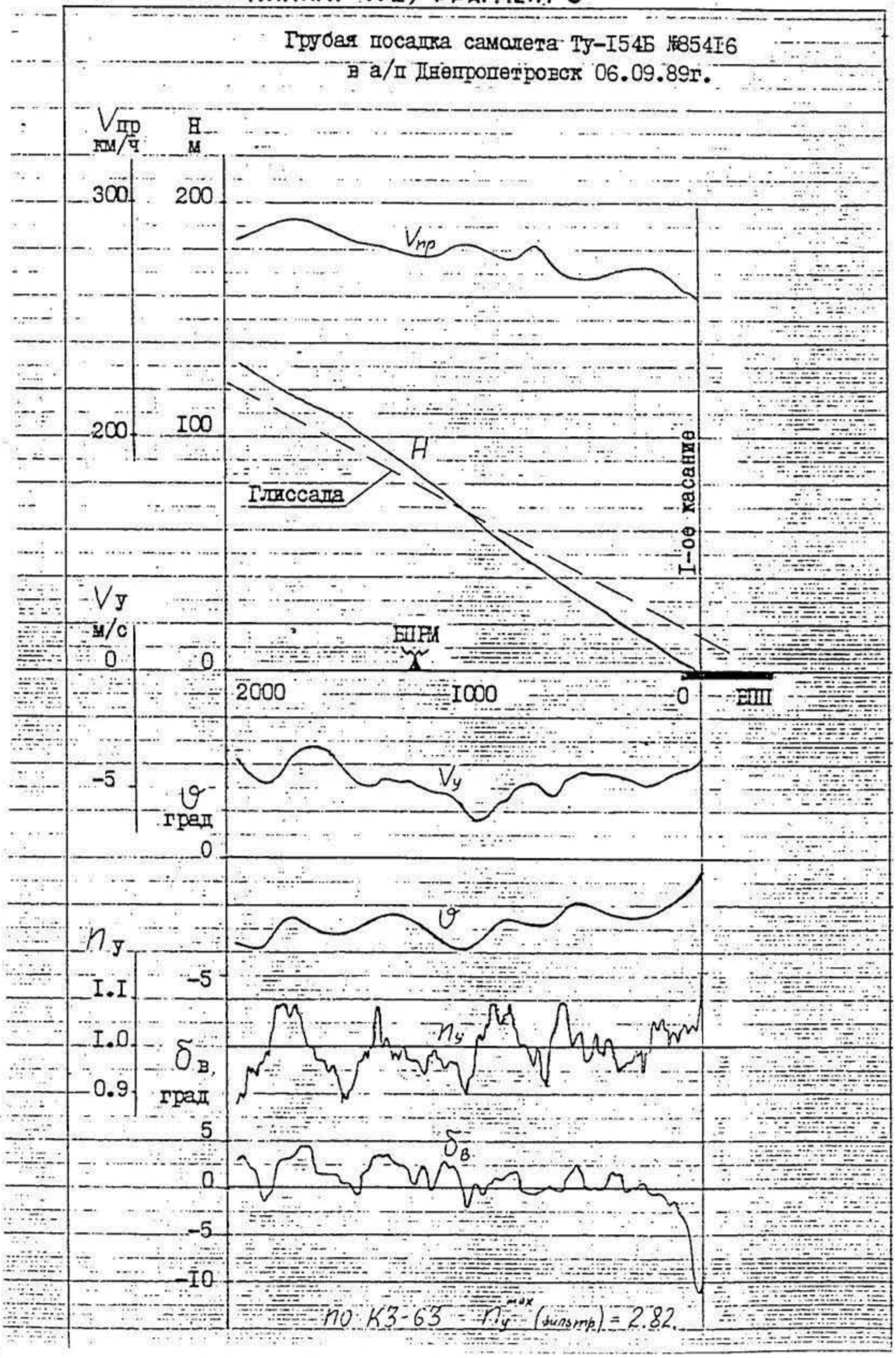
ПЛАКАТ №2, ФРАГМЕНТ 2



Грубая посадка самолета Ту-154Б №85479
в а/п Алеппо 24.09.88г.

$n_y^{тцк.} \geqslant 4,0$

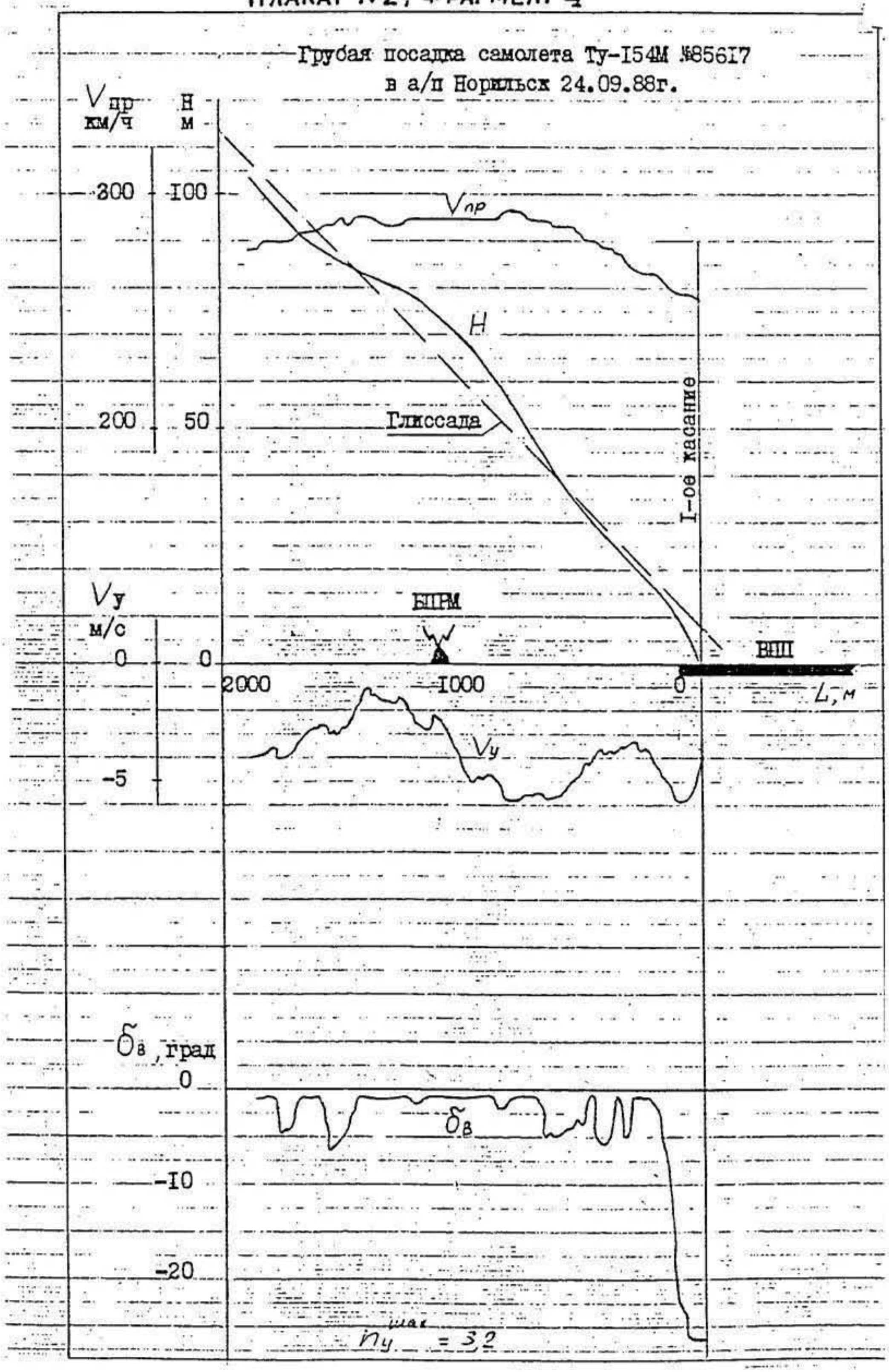
ПЛАКАТ N2, ФРАГМЕНТ 3



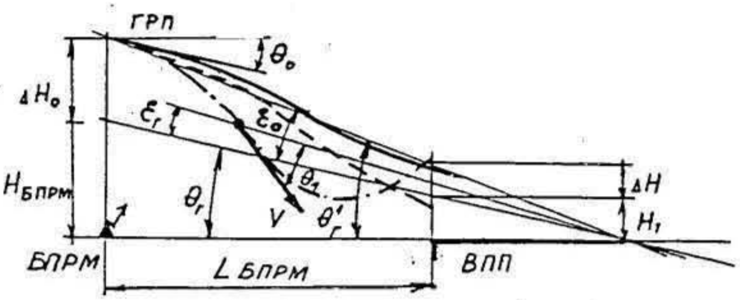
Грубая посадка самолета Ту-154Б №85416
в а/п Днепропетровск 06.09.89г.

по КЗ-63 n_y^{max} (фильтр) = 2.82.

ПЛАКАТ N2, ФРАГМЕНТ 4



Расчетная схема



——— отслеживание программнрго угла наклона траектории θ_r';

— — — вписывание в глиссаду без перерегулирования;

—·—·— вписывание в глиссаду с перерегулированием.

Рис. 1

Расчетная схема программного управления

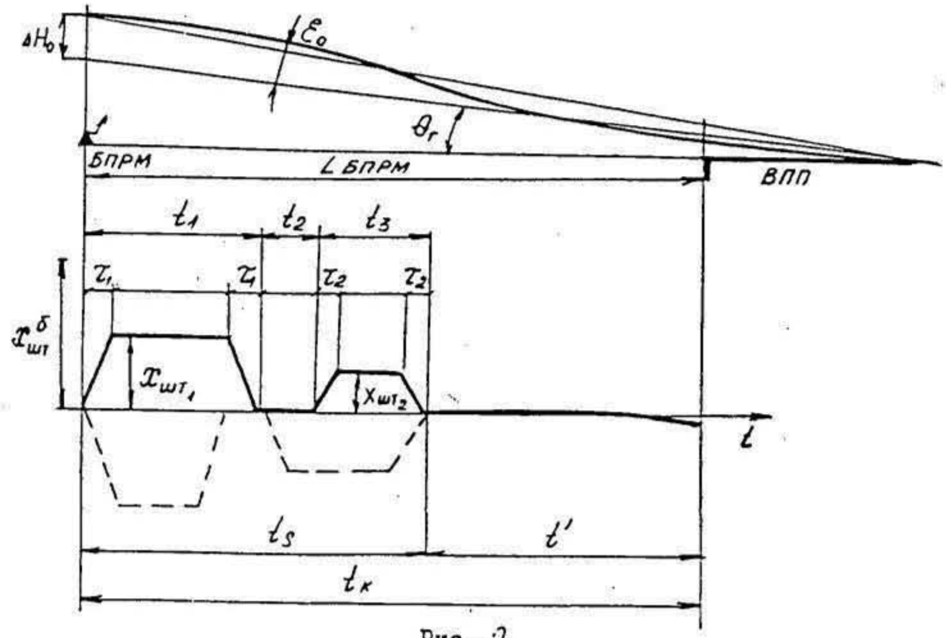
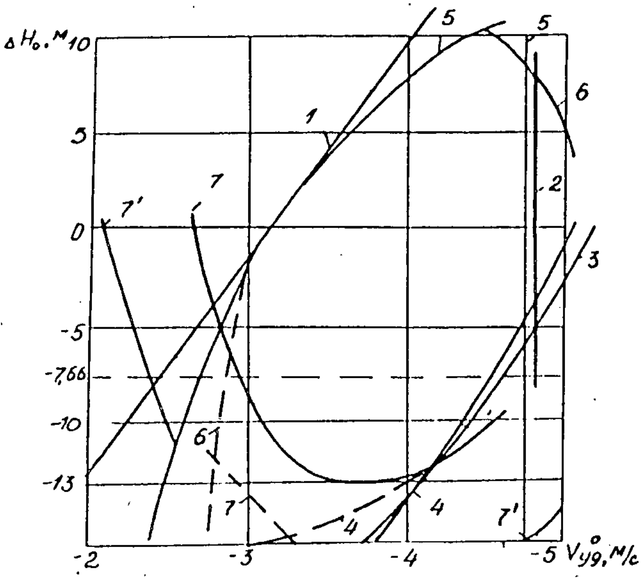


Рис. 2

Область допустимых значений ΔH_0 и V^0_{yg}
(отслеживание точки прицеливания)

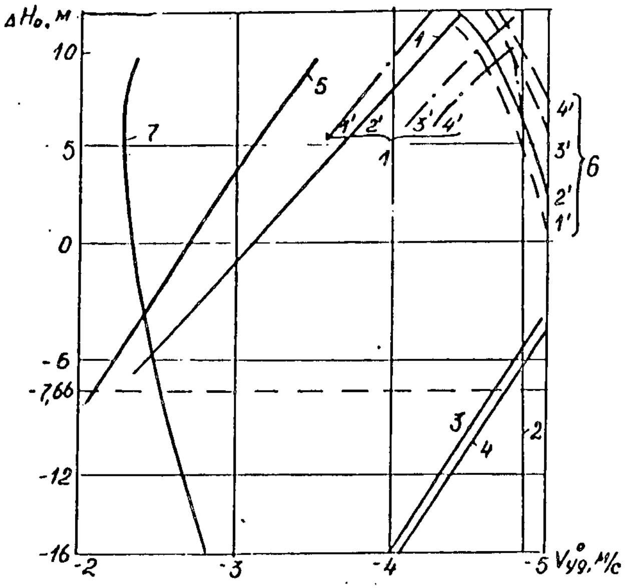


Ограничение: 1,2 - $V_{yg} \geq -5$ м/с; 3 - $V_{yg} \leq -1$ м/с; 4 - $\vartheta \leq 4{,}5°$;
5 - $\vartheta \geq 1°$; 6 - $\Delta H^к \leq 5$ м; 7 - $\Delta H^к \geq -5$ м.

— — — вписывание в глиссаду

Рис. 3

Область допустимых значений V^0_{yg} и ΔH.
(отслеживание начального углового рассогласования по стрелке ПНП или индексу ПКП)



Ограничение: 1,2 - $V_{yg} \geq -5$ м/с; 3 - $V_{yg} \leq -1$ м/с; 4 - $\vartheta \leq 4{,}5°$
5 - $\vartheta \geq 0{,}5°$; 6 - $\Delta H^к \leq 5$ м; 7 - $\Delta H^к > -5$ м;

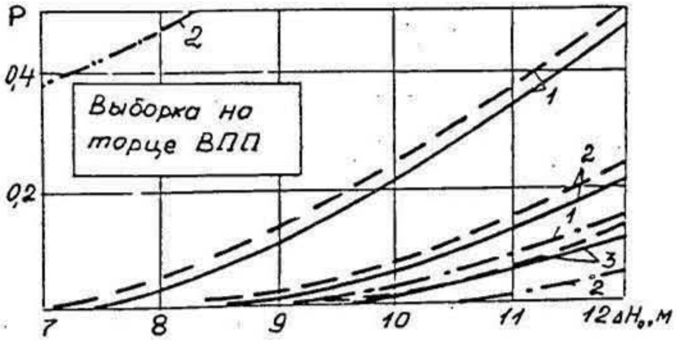
—·— $V_{yg} > -5$ м/с
—— — $\Delta H^к < 5$ м

1' - $V^0_{пр} = 260$ км/ч; 2' - $V^0_{пр} = 265$ км/ч
3' - $V^0_{пр} = 275$ км/ч; 4' - $V^0_{пр} = 280$ км/ч

Рис. 4

Оценка вероятности нарушения ограничения

$V_{yg} \geqslant -5$ м/с.



1 - $V^{\circ}_{yg} = -3{,}4$ м/с; 2 - $V^{\circ}_{yg} = -3{,}8$ м/с; 3 - $V^{\circ}_{yg} = -4$ м/с;

——— отслеживание точки прицеливания на ВПП,

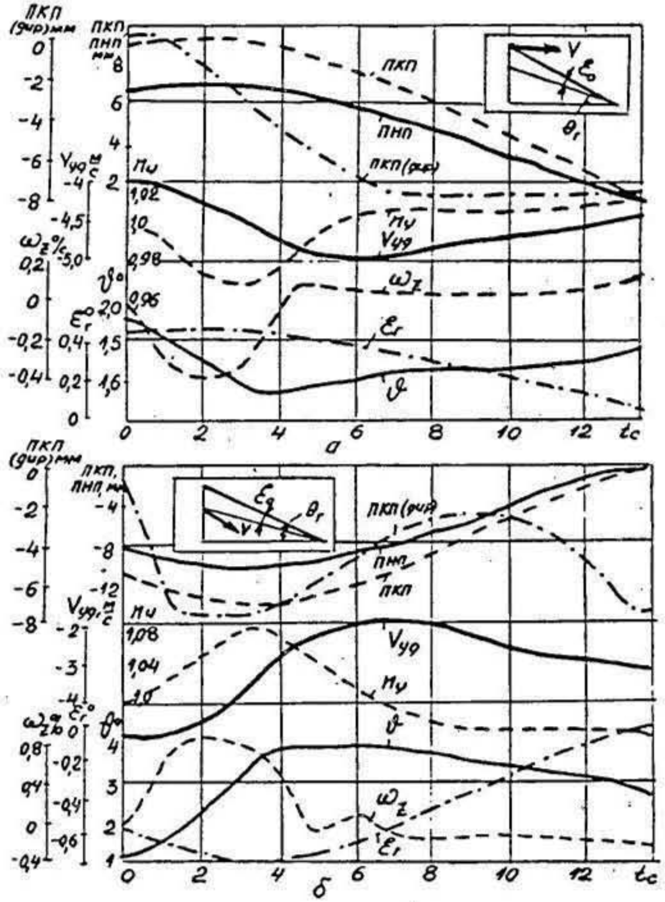
– – – отслеживание начального углового рассогласования с контролем по приборам положения

—·— вписывание в глиссаду с контролем по приборам положения (по стрелке ПНП или индексу ПКП).

—··— вписывание в глиссаду с перерегулированием (выборка вдоль траектории полета)

Рис. 5

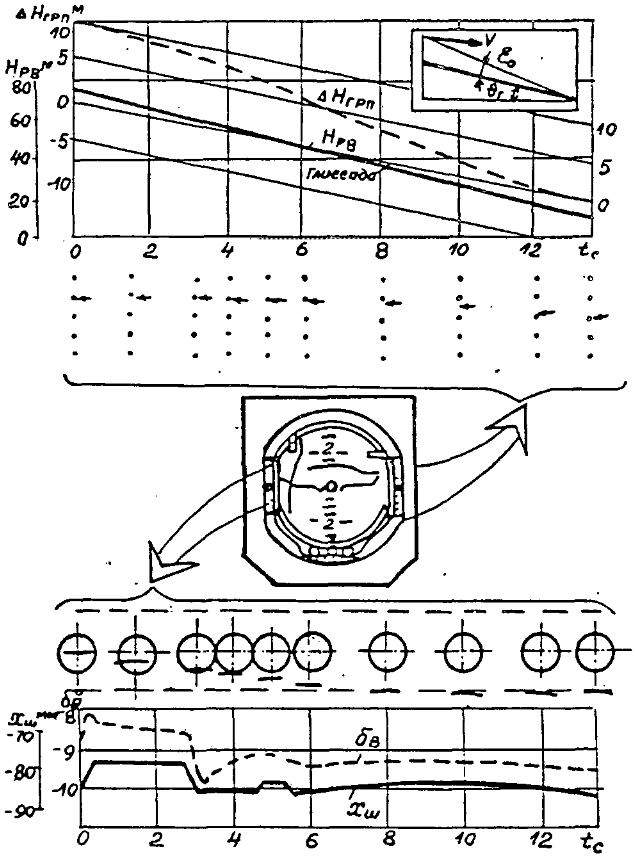
Траекторные параметры режима полета



а - $\Delta H_0 = 10$ м; $\varepsilon_0 = 0{,}43°$; $V^{\circ}_{yg} = 4$ м/с;
б - $\Delta H_0 = 12$ м; $\varepsilon_0 = -0{,}53°$; $V^{\circ}_{yg} = -4{,}8$ м/с.

Рис. 6

Пилотирование по ПКП ($\Delta H_0 = 10$ м; $V^{\circ}_{y g} = -4$ м/с)



Начальные условия:

$\Delta H_0 = 10$ м; $\varepsilon_0 = 0{,}43^{\circ}$; $V^{\circ}_{y g} = -4{,}8$ м/с

Значения параметров полета в характерных сечениях:

$H_г = 20$ м:

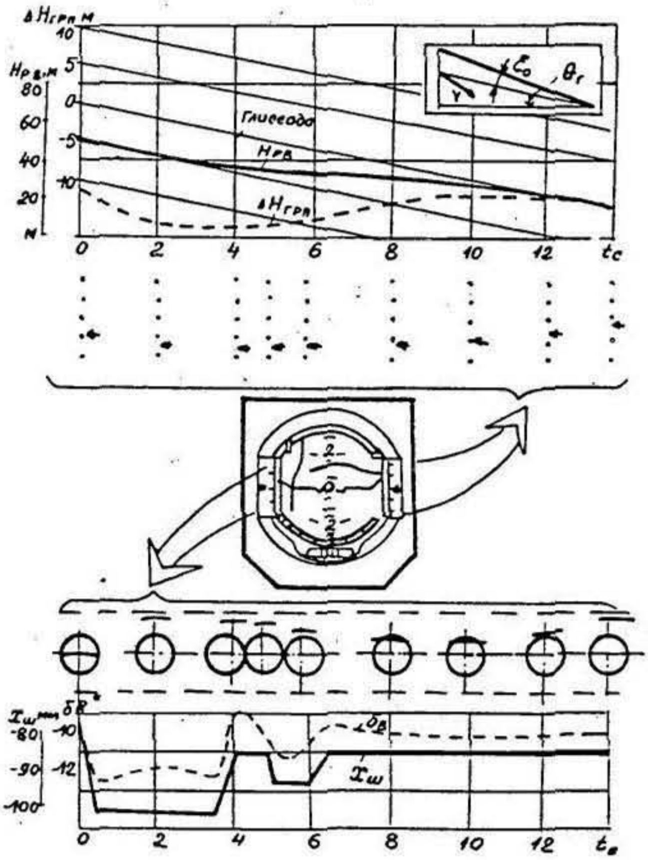
$V_{y g} = -4{,}6$ м/с; $\vartheta = 1{,}6^{\circ}$; $\omega_z = 0{,}09$ °/с; $n_y = 1{,}01$; $\Delta H_{грп} = 0{,}9$ м; $H_{рв} = 17$ м

На торце ВПП:

$V_{y g} = -4{,}4$ м/с; $\vartheta = 1{,}5^{\circ}$; $\omega_z = 0{,}11$ °/с; $H_y = 1{,}01$; $\Delta H_{грп} = 0{,}4$ м; $H_{рв} = 13$ м

Рис. 7

Пилотирование по ПКП ($\Delta H_0 = -10$ м; $V_{yg}^0 = -4{,}8$ м/с)



Начальные условия:

$\Delta H_0 = -12$ м; $\varepsilon_0 = -0{,}53°$; $V_{yg} = -4{,}8$ м/с

Значения параметров полета в характерных сечениях:

$H_г = 20$ м:

$V_{yg} = -3{,}2$ м/с; $\vartheta = 2{,}9°$; $\omega_z = -0{,}22$ °/с; $n_y = 0{,}97$; $\Delta H_{грп} = -0{,}4$ м; $H_{рв} = 16$ м

На торце ВПП:

$V_{yg} = -3{,}4$ м/с; $\vartheta = 2{,}7°$; $\omega_z = -0{,}24$ °/с; $n_y = 0{,}97$; $\Delta H_{грп} = -0{,}1$ м; $H_{рв} = 13$ м

Рис. 8

Оценка достоверности и достаточности рекомендаций РЛЭ.

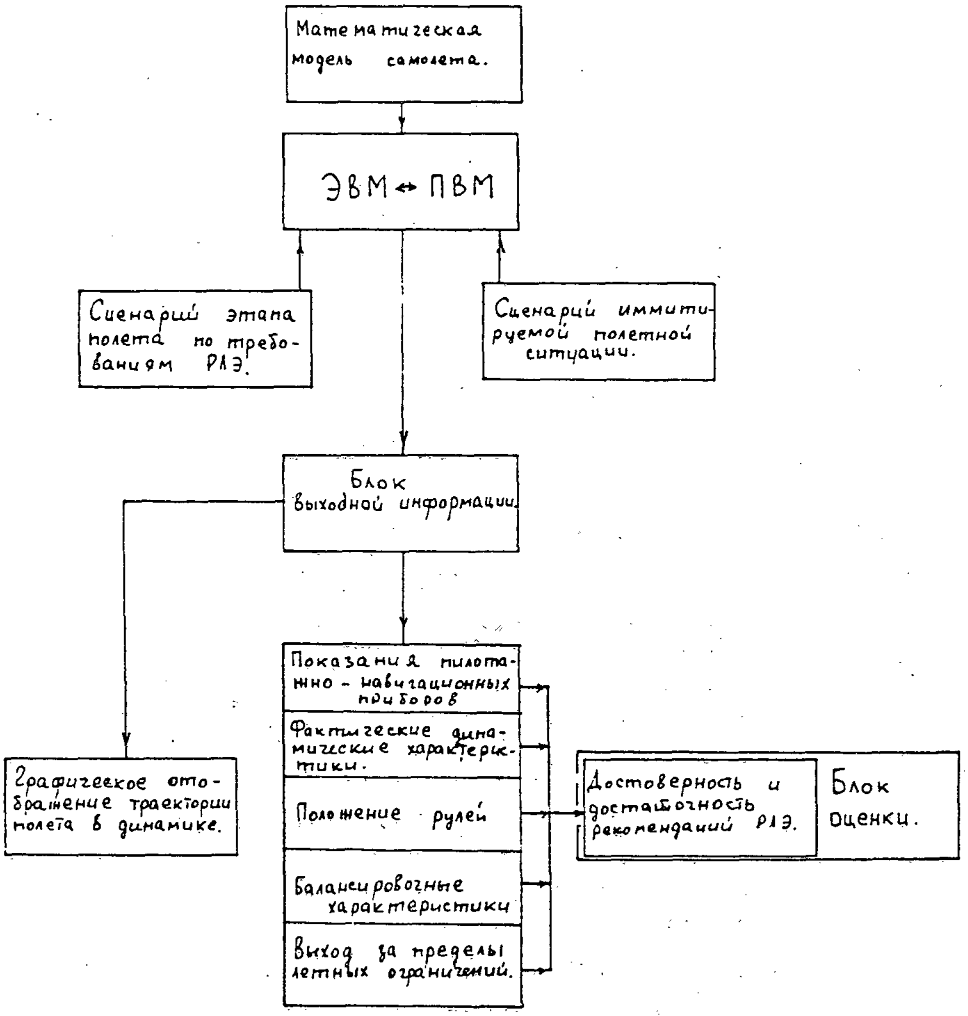


Рис. 9

Проектирование управляющей деятельности экипажа.

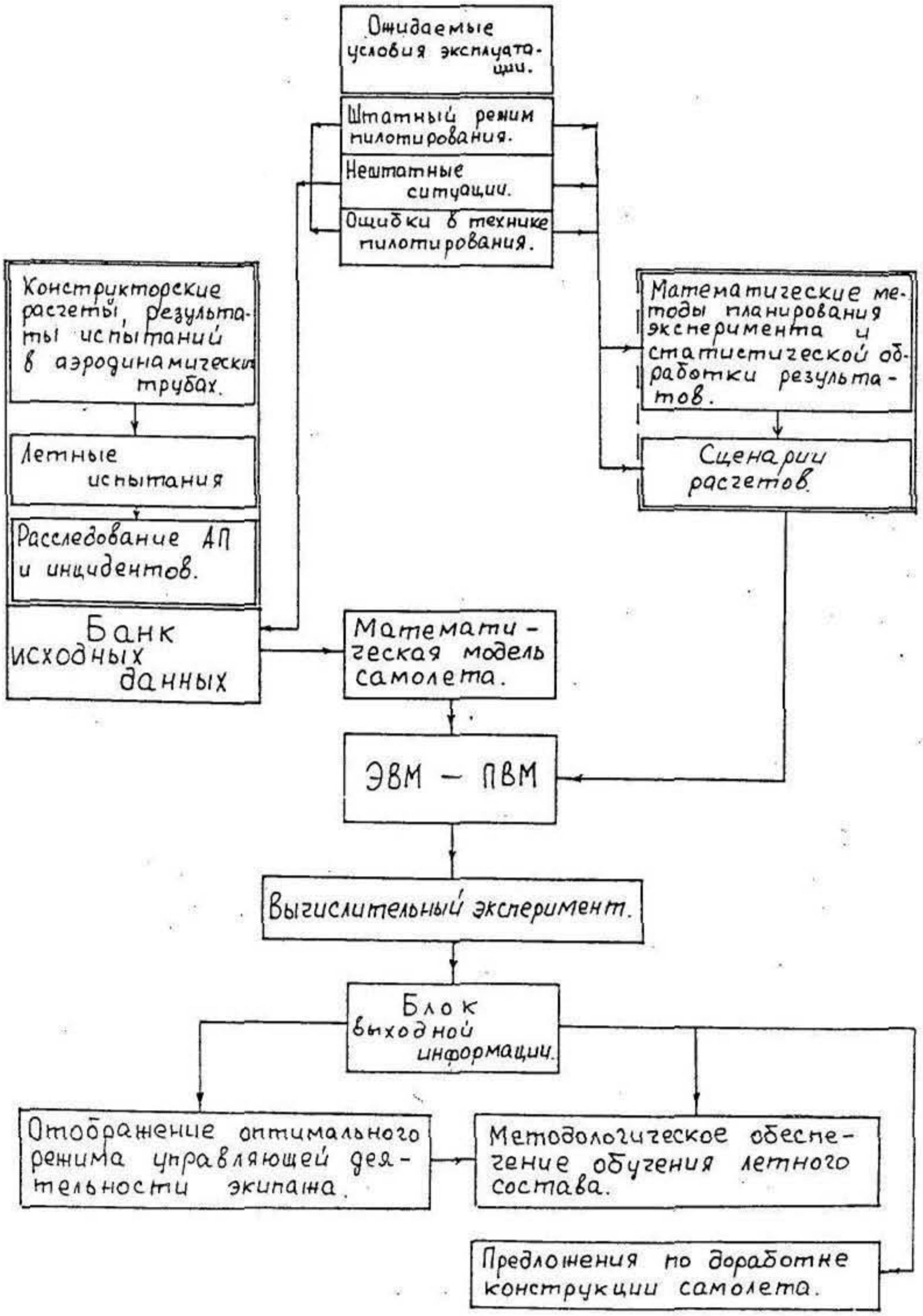


Рис. 10

В.А.Горячев

ИССЛЕДОВАНИЕ РОЛИ ЧЕЛОВЕЧЕСКОГО ФАКТОРА В АВИАЦИОННЫХ ПРОИСШЕСТВИЯХ

Гражданская авиация - сложная система, функционирование которой обеспечивается деятельностью миллионов людей. Они создают самолеты и вертолеты, готовят их к полету и ремонтируют, планируют, организуют и выполняют полеты, управляют воздушным движением, обслуживают пассажиров, строят аэродромы, обеспечивают нормальную работу наземного оборудования и т.д. Поэтому человеческий фактор, то-есть влияние деятельности людей на работу системы, можно рассматривать как главный фактор обеспечения ее высокой эффективности.

Безопасность полетов (БП) - один из важнейших показателей работы гражданской авиации. Высокий уровень безопасности полетов является результатом высокого качества деятельности всех людей, участвующих в этой работе. В то же время авиационные происшествия (АП), какими бы причинами они не были вызваны, всегда связаны с недостатками в деятельности тех или иных специалистов.

Например, отказ техники в полете является результатом ошибок конструкторов или технологов, рабочих завода-изготовителя или ремонтного предприятия, авиационных техников или контролеров и т.п. Попадание самолета в опасные атмосферные условия связано с недостатками в работе метеорологов, ошибками экипажа или диспетчера УВД. Взрыв и пожар на борту самолета может произойти вследствие недостаточно эффективной работы служб авиационной безопасности или бортпроводников. Строго говоря, человеческий фактор лежит в основе любого авиационного происшествия. Однако доля ответственности за происшествие разных групп и категорий людей различна. На рис.I показана диаграмма, характеризующая вклад в причины авиационных происшествий летного, инженерно-технического персонала и других специалистов. В группу специалистов летной службы включены все члены экипажа, летные командиры, инструкторы и т.п., в группу инженерно-технического персонала - работники промышленности и гражданской авиации. Использованы данные статистики гражданской авиации СССР за 1986-1988 годы по авиационным происшествиям, причины которых были установлены.

Диаграмма показывает, что наибольшая часть АП (70÷85 %) связана с недостатками в деятельности летного персонала. Эти данные хорошо согласуются с данными мировой статистики и позволяют сформулировать следующую объективную закономерность:

Независимо от уровня безопасности полетов, достигнутого в отдельных странах и в мире в целом, подавляющее большинство авиационных происшествий связано с недостатками в деятельности экипажа воздушного судна.

Существование такой закономерности можно объяснить тем, что экипаж воздушного судна является конечным звеном в цепи факторов, определяющих судьбу каждого конкретного полета.

Система обеспечения безопасности полетов в авиации строится таким образом, чтобы исключить действие факторов, которые могут быть единственной и непосредственной причиной авиационного происшествия. К таким факторам (их можно назвать катастрофическими) можно отнести, например, одновременный отказ всех двигателей, полный отказ системы управления или разрушение крыла самолета, полный отказ системы УВД или радиосвязи, вертикальный порыв ветра, выводящий самолет на сваливание, полную потерю работоспособности экипажа и т.п.

Устанавливая нормы летной годности самолета, вводя сертификацию наземного оборудования, проводя отбор, обучение и контроль персонала, мы стремимся свести вероятность проявления катастрофических факторов к нулю. При этом предполагается, что возникновение в полете других факторов, угрожающих безопасности полета, но не носящих катастрофического характера, допустимо, так как высококвалифицированный и готовый к неожиданным усложнениям экипаж может благополучно завершить полет и в этих условиях. Следовательно, авиационное происшествие может иметь место только при сочетании проявления таких факторов и ошибок экипажа. Поскольку экипаж состоит как правило из нескольких специалистов, считается, что вероятность их одновременной ошибки мала, а поэтому вероятность авиационного происшествия в результате сочетания некатастрофических факторов и ошибки экипажа близка к нулю.

Все факторы, которые могут угрожать безопасности полетов, можно разделить на четыре независимые группы: самолет, экипаж, наземные службы и атмосферные условия. Вероятность авиационного происшествия можно представить в виде следующей формулы:

$$P_{АП} = P_к^с + P_к^{нс} + P_к^А + P_к^э + P^с \cdot Q_1^э + P^{нс} \cdot Q_2^э + P^А \cdot Q_3^э + P^с \cdot P^{нс} \cdot Q_4^э + P^с \cdot P^А \cdot Q_5^э + P^{нс} \cdot P^А \cdot Q_6^э + P^с \cdot P^{нс} \cdot P^А \cdot Q_7^э$$

$P_к^с, P_к^{нс}, P_к^А, P_к^э$ – вероятность проявления одного из катастрофических факторов, связанных с самолетом, наземными службами, атмосферными условиями и экипажем;

$P^с, P^{нс}, P^А, P^э$ – вероятность проявления одного из некатастрофических факторов, входящих в данные группы;

$Q_1^э \ldots Q_7^э$ – условные вероятности ошибки экипажа при проявлении одного или сочетании нескольких некатастрофических факторов.

Нетрудно видеть, что ошибка экипажа как фактор, угрожающий безопасности полета, присутствует в восьми из одиннадцати членов данного уравнения. В идеальном случае, когда все члены уравнения одинаковы по величине, вероятность авиационного происшествия, связанная с ошибкой экипажа, составляет 73 % от полной вероятности. В реальной действительности члены уравнения хотя и не одинаковы, но имеют близкий порядок величин. Поэтому цифра, характеризующая роль экипажа в АП, существенно не отличается от полученной в идеальном случае. Это справедливо независимо от величины полной вероятности происшествия, характеризующей уровень безопасности полетов.

Анализ уравнения показывает, что существенное снижение роли экипажа в авиационных происшествиях возможно, если довести величины членов уравнения, в которых присутствует вероятность ошибки экипажа, до уровня примерно в 10 раз меньшего, чем уровень величин, независящих от экипажа. При этом следует учитывать, что надежность человека, если понимать ее как безошибочность его действий, не может быть очень высокой. На рис.2 показана кривая, характеризующая порядок вероятности опасной ошибки экипажа воздушного судна в зависимости от числа независимых друг от друга неблагоприятных факторов, при которых осуществляется его работа. Кривая построена на базе анализа статистики авиационных происшествий и инцидентов, носит оценочный характер и нуждается в уточнении. Но она иллюстрирует определенные объективные закономерности, в частности то, что вероятность ошибки резко возрастает при действии хотя бы одного угрожающего безопасности полета фактора. При действии одновременно трех или четырех неблагоприятных факторов опасная ошибка экипажа практически неизбежна. Отсюда следует важный вывод о том, что основное направление деятельности по снижению роли "фактора экипажа" в причинах авиационных происшествий – снижение вероятности возникновения в полете не зависящих от экипажа неблагоприятных факторов.

Второе направление - изыскание резервов уменьшения вероятности ошибок экипажа как в благоприятных условиях, так и при проявлении факторов, угрожающих безопасному выполнению полета. Реализация этого направления связана с необходимостью изучения особенностей рабочей деятельности экипажа.

Экипаж самолета осуществляет летную деятельность, которую можно представить как совокупность следующих видов деятельности:

- пилотирования,
- навигации,
- управления системами и оборудованием,
- связи с землей и другими самолетами,
- взаимодействия между членами экипажа.

Экипаж может включать в себя разное число специалистов: одного или двух пилотов, штурмана, бортинженера, бортрадиста. В зависимости от этого за каждым специалистом может закрепляться тот или иной вид летной деятельности, либо один член экипажа может совмещать несколько видов деятельности. При этом чем больше в экипаже людей, чем сложнее становится организация взаимодействия между ними.

Хотя все виды деятельности в полете тесно переплетаются, каждый из них имеет свои специфические особенности (специфические цели, задачи, способы их осуществления) и предъявляет особые требования к профессионально-психологическим качествам членов экипажа.

Ошибки в том или ином виде деятельности могут быть более или менее опасными. Они проявляются с большей или меньшей вероятностью в зависимости от типа воздушного судна, назначения полета, этапа полета и т.п. Поэтому представляет интерес анализ данных по авиационным происшествиям и инцидентам, позволяющий выявить ошибки, наиболее характерные для пилотирования, навигации, эксплуатации систем и других видов летной деятельности.

Целесообразно начать с определений, с тем чтобы более четко представить особенности видов летной деятельности.

Пилотирование - непосредственное управление скоростью и пространственным положением самолета, представляет собой сложную психомоторную деятельность, выполнение которой требует специфических профессиональных навыков.

Навигация - непрерывное определение и прогнозирование географического положения самолета, является преимущественно интеллектуальным видом деятельности с речевым или моторным выходом.

Ведение радиосвязи - специфическая речевая деятельность, цель которой - обмен рабочей информацией с наземным персоналом и экипажами других воздушных судов.

Управление системами и оборудованием - сложная интеллектуальная и психомоторная деятельность, по включению, контролю параметров, переключению режимов и т.п., требующая высокого развития навыков формирования образа работы системы на основании комплекса отдельных ее показателей.

Взаимодействие членов экипажа - деятельность, имеющая целью повысить надежность коллективного субъекта управления, требующая от каждого члена экипажа умения организовывать свои действия в соответствии с действиями его коллег.

Результаты анализа статистики АП представлены на рис.3,4,5. Она позволяют сделать ряд важных выводов, а именно:

I. Ошибки в пилотировании являются определяющим фактором в авиационных происшествиях с воздушными судами всех типов, особенно с вертолетами, а также с самолетами всех типов при заходе на посадку и посадке.

2. Недостатки навигационной деятельности проявляются при транспортных полетах или полетах другого назначения, связанных с перемещением самолетов на достаточно большие расстояния. При транспортных полетах практически каждое авиационное происшествие, имевшее место на этапах набора высоты, полета на эшелоне и снижения, является результатом навигационной ошибки экипажа.

3. Ошибки в эксплуатации систем и оборудования служат основной причиной примерно 50 % авиационных происшествий на взлете в транспортных полетах и до 20 % АП на других видах и этапах полета.

4. Недостатки ведения радиосвязи и взаимодействия членов экипажа за редким исключением не являются прямыми причинами АП, однако как способствующий фактор отмечаются в большинстве случаев, связанных с ошибками в пилотировании, навигации и эксплуатации систем.

Более детальный анализ подтверждает сделанные выводы.

С точки зрения пилотирования наиболее сложными этапами полета являются заход на посадку и посадка, на которых в полной мере отражаются неблагоприятные особенности поведения и управляемости самолета, а также внешние факторы: ограниченная видимость, ветер, дождь, снег и т.п.

Наиболее частым результатом сочетания этих факторов с ошибками в пилотировании является грубое приземление, посадка до начала взлетно-посадочной полосы или выкатывание самолета за ее пределы.

Такого рода происшествия составляют половину от общего числа АП, связанных с ошибками экипажей на самолетах с взлетной массой более 5,5 т в 1988 году.

Главный проявившийся в этих случаях фактор - неспособность экипажа сбалансировать самолет по угловому положению, скорости и вертикальной скорости снижения к моменту визуального контакта с земными ориентирами, что говорит о слабой профессиональной подготовке пилотов. Большую роль играют и недостатки во взаимодействии членов экипажа, несвоевременное или неправильное информирование, отсутствие взаимоконтроля и взаимопомощи.

Взлет - менее сложный с точки зрения пилотирования этап полета. Авиационные происшествия на этом этапе как правило являются результатом резкого усложнения летной деятельности из-за отказа техники или ошибок в эксплуатации систем и оборудования, допущенных при подготовке самолета к полету, или в процессе взлета.

Например, в 1988 году все происшествия на взлете с самолетами массой более 5,5 т были вызваны этими причинами: экипаж самолета Ан-24 выполнял взлет с неснятыми заглушками приемников воздушного давления, самолет Л-410 выполнял разбег при установленном в положение на уборку переключателе управления шасси, пилот другого самолета Л-410 преждевременно убрал шасси и допустил потерю высоты сразу после отрыва, на самолете Як-40 экипаж по неизвестным причинам уменьшил тягу двигателей непосредственно после отрыва самолета и т.п. Так же как при происшествиях при заходе на посадку, во всех этих случаях проявились недостатки взаимодействия членов экипажей.

Наиболее тяжелые последствия имеют происшествия, связанные с ошибками в навигационной деятельности экипажей, поскольку в подавляющем большинстве это - столкновение с возвышенностями при полетах в горной местности. В 1988 году такие происшествия составляли 22 % от общего числа АП с самолетами с ГТД, в которых проявились недостатки работы экипажа. Смысл навигационной ошибки заключается в том, что экипаж теряет представление о географическом положении самолета. Это происходит вследствие слабой практической подготовки пилотов и штурманов к полетам в горной местности, недостаточной оснащенности горных трасс и аэродромов радиотехническими средствами и неудовлетворительным их содержанием, несовершенством инструкций по производству полетов и схем захода на посадку. Сами по себе навигационные ошибки экипажа не являются катастрофическими, однако совпадение таких ошибок с недостатками в деятельности службы УВД приводит не просто к потере навигационной информации, но к формированию у экипажа ложного представления о том, где находится самолет, что и приводит к авиационному происшествию. Этому способствуют также ошибки в ведении радиосвязи: неоднозначная терминология, нечеткие формулировки сообщений.

Для легких самолетов Ан-2 и вертолетов, которые эксплуатируются по правилам визуальных полетов, характерной причиной тяжелых происшествий является непреднамеренное попадание в условия ограниченной видимости (туман, дождь, снег). В 1988 году такие происшествия составили до 25 % от числа происшествий на этих воздушных судах, связанных с недостатками летной деятельности. Общее для всех таких АП заключается в том, что пилоты, имея достаточный запас времени, чтобы перейти на приборный полет, не используют такой возможности и стараются любым путем установить визуальный контакт с землей. При этом вследствие несогласованных действий членов экипажа, каждый из которых "ищет землю", и отсутствия приборного контроля полета, часто происходит потеря представления не только о географическом, но и о пространственном положении. Характерным является и такой психологический феномен, как отрицание самого простого решения о возвращении назад в зону хорошей видимости. Анализ показывает, что в основе подобных ошибок пилотов лежит слабая профессиональная и психологическая подготовка к полетам по приборам, независимо от общего летного опыта.

Авиационно-химические работы - широкая область применения самолетов Ан-2 и вертолетов. Авиационные происшествия, относящиеся к этому виду полетов, составили в 1988 году 28 % и 19 % от общего числа происшествий соответственно на самолетах Ан-2 и вертолетах.

Главная особенность авиационно-химических работ заключается в том, что полеты выполняются на малых высотах. При этом высокие требования предъявляются к качеству визуального пилотирования и пространственной ориентировки. Парирование отказов двигателя на малых высотах представляет трудную задачу. Поэтому ошибки в пилотировании и эксплуатации систем составляют главные причины АП, а недостатки во взаимодействии членов экипажей усугубляют последствия ошибок.

Наиболее тяжелые авиационные происшествия при выполнении авиахимических работ связаны со столкновением воздушных судов с электрическими проводами. В 1988 году таких происшествий не было, зато в 1987 году было отмечено более двадцати случае.

Более чем в 50 % из них столкновение произошло во время рабочего гона (то-есть полета непосредственно над обрабатываемым участком), либо при входе и выходе из него. Анализ показывает, что главной причиной столкновения с проводами является недостаточная предполетная подготовка пилотов. Дело в том, что провода хорошо различимы только на фоне чистого неба. В пасмурную погоду, при слабом тумане обнаружение их затруднено. Увидеть же своевременно провода на фоне деревьев, холмов, в оврагах и т.п. часто оказывается практически невозможным. Поэтому только хорошее знание местности и ориентиров, тщательная подготовка поля, включая рациональное использование сигнальщиков или сигнальных устройств, может снизить риск столкновения.

Ошибки в эксплуатации систем и оборудования служат причиной авиационных происшествий значительно реже, чем ошибки в пилотировании. Характерная ошибка для экипажей транспортных самолетов с газотурбинными двигателями - неправильная установка барометрического давления на высотомерах, приводящая к ошибкам в оценке высоты полета над уровнем аэродрома. Происшествия по этой причине имеют место практически каждый год.

При полетах на легких самолетах и вертолетах характерными являются ошибочные выключения двигателей и отсутствие контроля количества топлива, что также приводит к выключению двигателей.

Примером авиационного происшествия, в котором наряду с недостатками в эксплуатации систем особенно ярко проявились недостатки взаимодействия, может служить авария самолета Ан-2, случившаяся 31.10.88 днем, в хороших метеоусловиях. Экипаж не выпустил закрылки перед взлетом и заметил это только в процессе разбега по непривычно малому темпу роста скорости. Оценив ситуацию, командир воздушного судна решил продолжать взлет, однако в момент отрыва самолета второй пилот, решив, что взлетать опасно, молча перевел двигатель на режим малого газа. Самолет приземлился. Командир, почувствовав это, перевел двигатель на взлетный режим, не информируя второго пилота о своих действиях. Самолет оторвался еще раз от поверхности полосы. Тогда второй пилот снова поставил двигатель на режим малого газа и выключил его стоп-краном. Самолет приземлился в конце полосы и выкатился за ее пределы, получив значительные повреждения.

Мы рассмотрели наиболее важные группы авиационных происшествий, в которых как главные факторы проявляются недостатки в основных видах летной деятельности: пилотировании, навигации, эксплуатации систем и оборудования. В большинстве случаев они усугубляются недостатками во взаимодействии между членами экипажа. Неблагоприятные атмосферные условия, отказы техники, недостатки в работе службы УВД - усложняют деятельность членов экипажа и существенно повышают вероятность их ошибок.

При расследовании обстоятельств и причин авиационных происшествий ошибки экипажей очень часто объясняются недисциплинированностью, которая выражается в нарушении требований различных инструкций, регламентирующих летную деятельность. Нам представляется, что такое объяснение не открывает конструктивных путей предотвращения ошибок, поскольку ориентирует на принятие административных мер к нарушителям.

Реальная жизнь не может быть введена в рамки инструкции, как бы хороша ни была последняя. С другой стороны, за редким исключением, нарушения инструкций происходят непреднамеренно и являются результатом неправильной оценки обстановки, завышенной оценки своих возможностей, а зачастую - просто тем, что требования многочисленных инструкций забываются.

Возникает необходимость в более глубоком анализе психологической сущности ошибок в летной деятельности. Такому анализу посвящены многочисленные психологические публикации в научной литературе. Однако, психологи не предлагают инструмента для количественных оценок и прогнозирования вероятности ошибок в том или ином виде летной деятельности. На наш взгляд такой инструмент может быть создан на базе модели действия, которую мы назвали структурно-алгоритмической (см.рис.6). Модель описывает элемент любой деятельности, непрерывной или дискретной, учитывает влияние особенностей восприятия оперативной и долговременной паммяти, эмоций.

В заключение сформулируем основные предложения.

Прежде всего для уменьшения вклада ошибок экипажа в аварийность, необходимо в максимальной степени снизить вероятность проявления неблагоприятных факторов, не зависящих от экипажа, особенно одновременного проявления нескольких факторов. Улучшение характеристик управляемости самолетов, повышение надежности систем и оборудования, повышение степени достоверности прогнозов и измерения фактического состояния атмосферных условий, автоматизация процессов управления воздушным движением и снижение на этой базе вероятности ошибки диспетчеров - это основные предпосылки снижения вероятности ошибок экипажей.

Важное условие снижения вероятности ошибки экипажа в нормальном полете (при отсутствии неблагоприятных факторов) заключается в стандартизации и унификации эксплуатационных процедур подготовки к полету, радиосвязи, взаимодействия членов экипажа. В то же время необходимо исключить жесткую регламентацию деятельности членов экипажа в условиях действия неблагоприятных факторов.

Необходимо в максимальной степени освободить членов экипажа от необходимости распознавания тех или иных неблагоприятных факторов, имеющих общие внешние признаки. Автоматизация процессов распознавания отказов техники, опасных атмосферных воздействий, ошибок наземных служб позволит членам экипажа концентрировать внимание на выборе стратегии действий и процессах принятия решений.

Главный упор в отборе и подготовке летного состава должен быть сделан на оценке способности оперативного мышления и самоконтроля и развитии этих качеств.

Наконец важно освободить членов экипажа от страха нарушить инструкцию в нестандартных ситуациях. Только в этом случае можно ожидать творческого поиска решения возникающих проблем, полного использования резервов, определяемых знаниями и опытом, накопленными при профессиональной подготовке и в процессе практической деятельности специалистов.

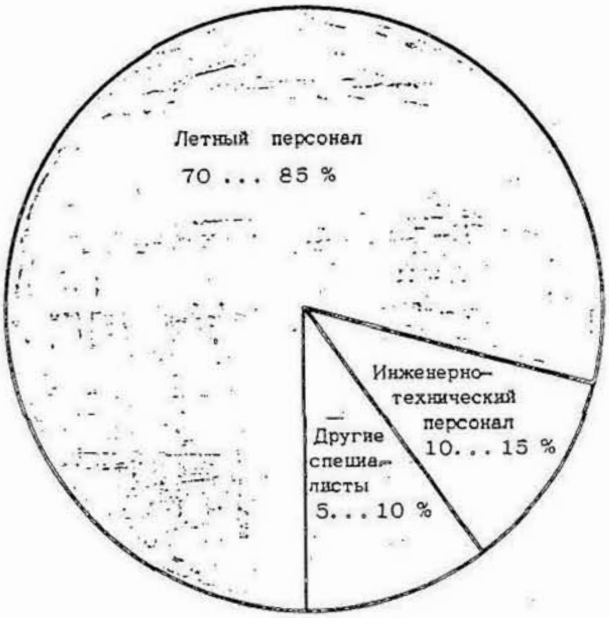


Рис.I. Роль различных групп специалистов в причинах авиационных происшествий. (Статистика АП за 1986 - 1988 годы)

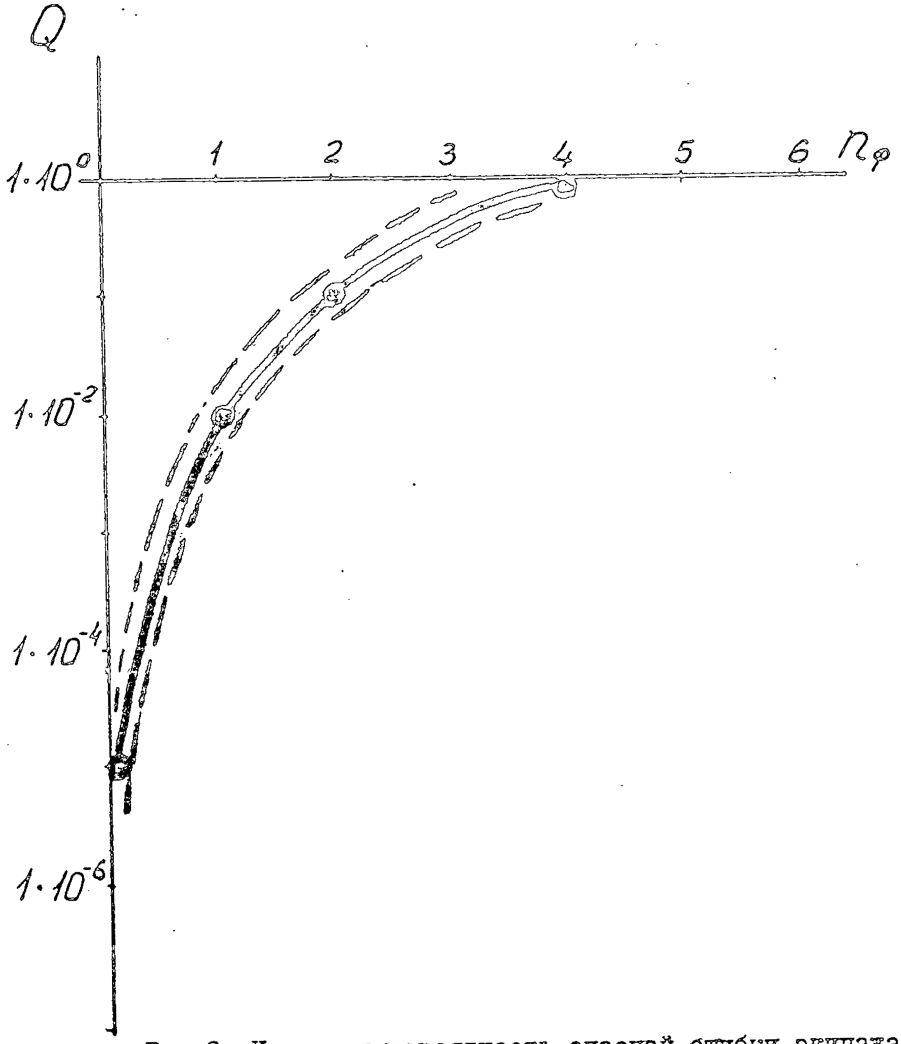
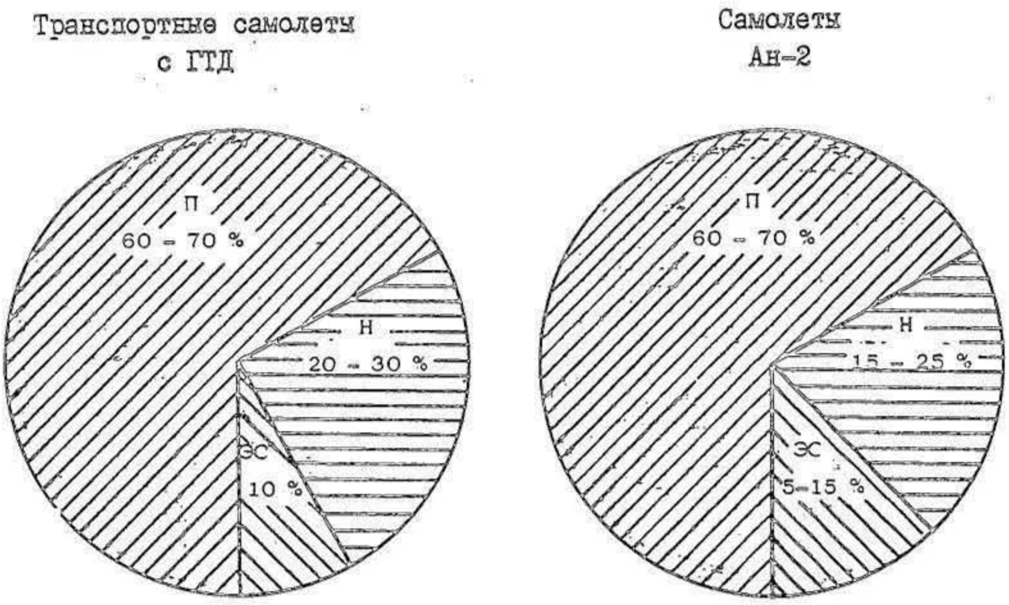
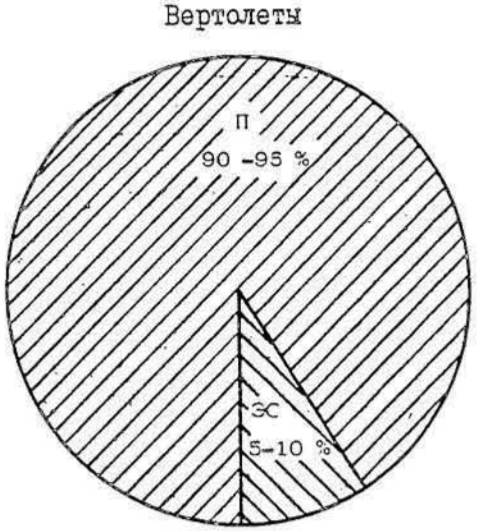


Рис.2. Условная вероятность опасной ошибки экипажа: $n_ф$ – число факторов, угрожающих безопасности полета, при которых осуществляется деятельность экипажа; Q – условная вероятность ошибки экипажа



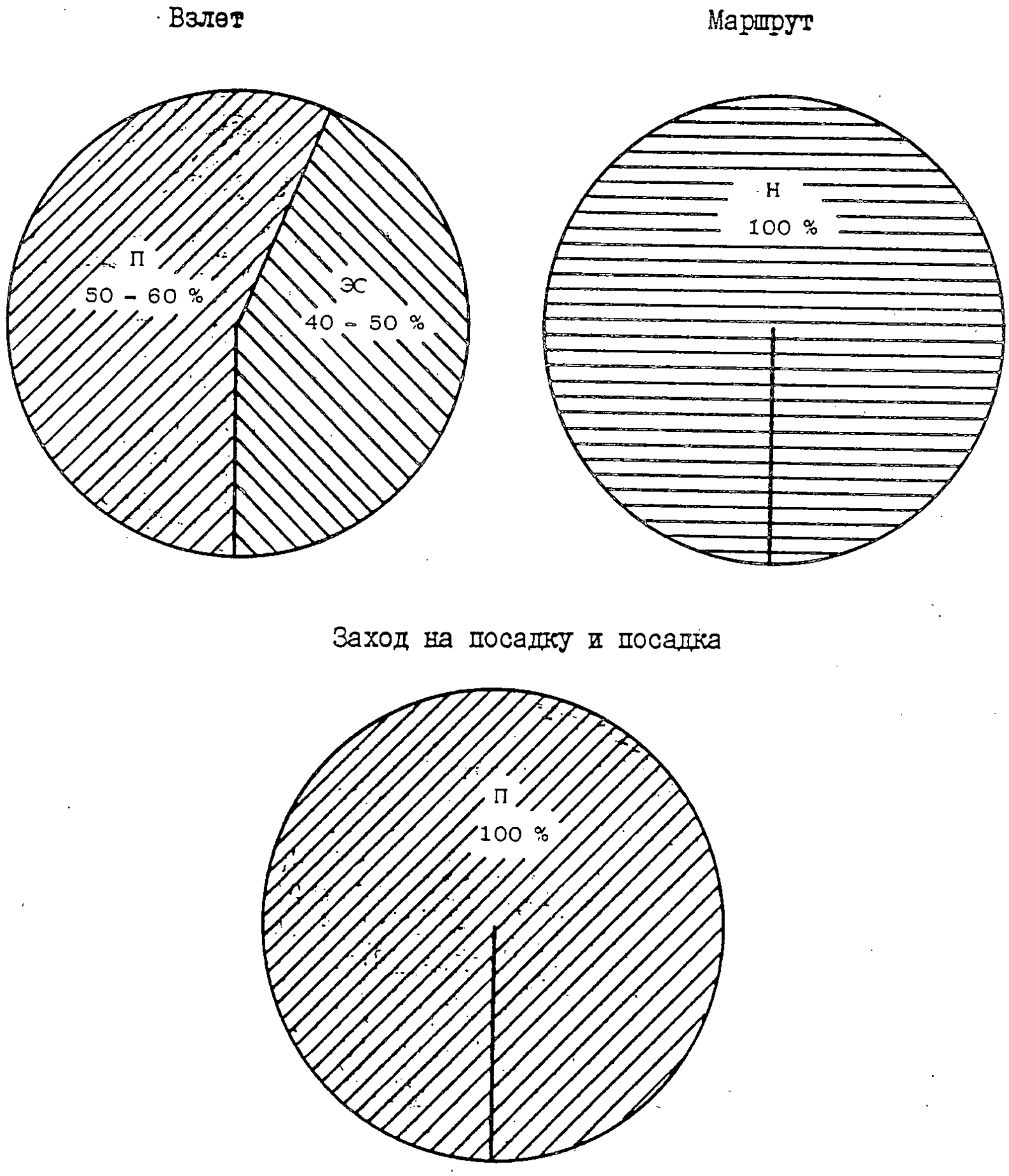
Транспортные самолеты с ГТД

Самолеты Ан-2



Вертолеты

Рис.3. Распределение АП, связанных с недостатками деятельности экипажа: П – пилотирование; Н – навигация; ЭС – эксплуатация систем

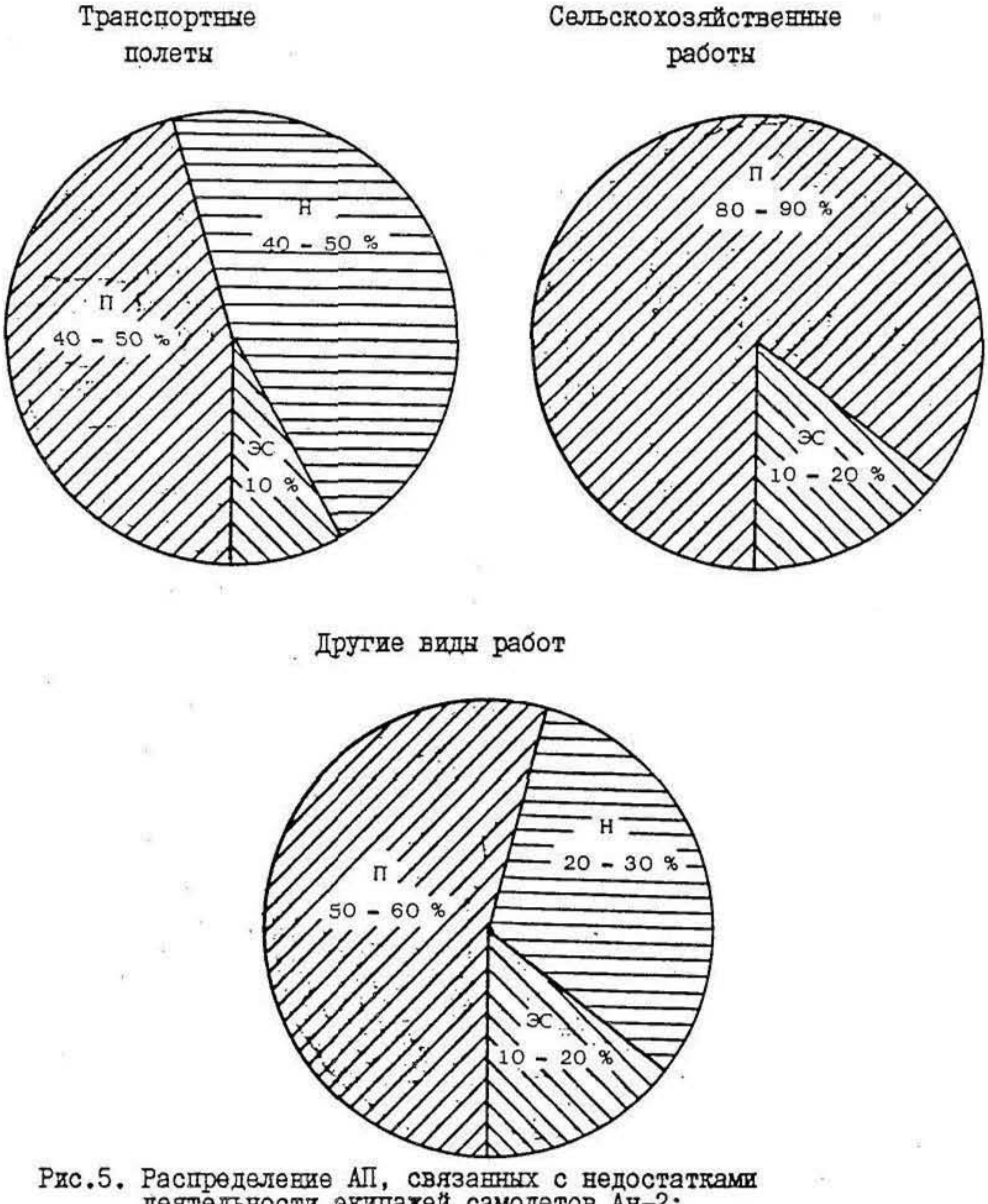


Взлет

Маршрут

Заход на посадку и посадка

Рис.4. Распределение АП, связанных и недостатками деятельности экипажей. Транспортные полеты


Транспортные полеты

Сельскохозяйственные работы

Другие виды работ

Рис.5. Распределение АП, связанных с недостатками деятельности экипажей самолетов Ан-2: П - пилотирование; Н - навигация; ЭС - эксплуатация систем

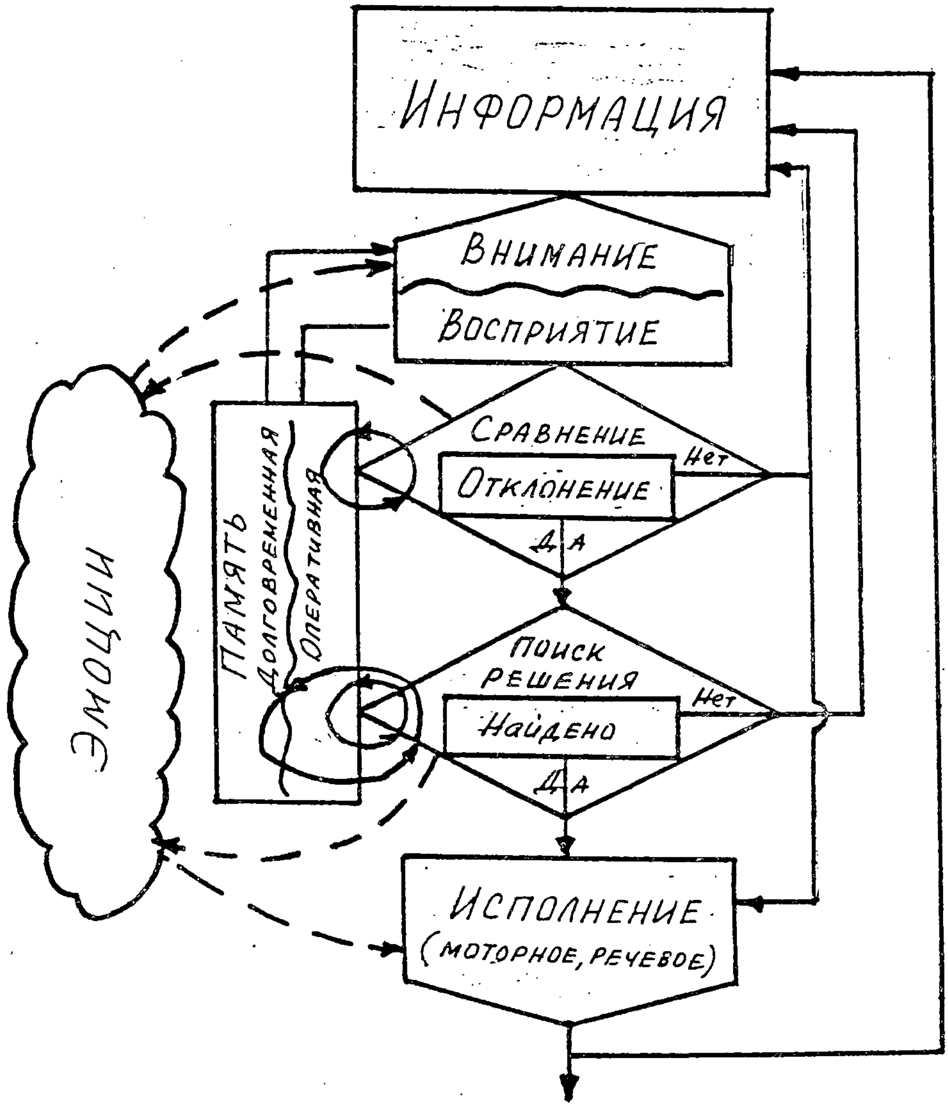


Рис.6. Структурно-алгоритмическая модель действия

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ЧЕЛОВЕЧЕСКИЙ ФАКТОР И БЕЗОПАСНОСТЬ ПОЛЕТОВ ПРИ УВД. ПРОБЛЕМЫ, СОСТОЯНИЕ, ПЕРСПЕКТИВЫ.

Активный поиск путей повышения уровня безопасности полетов определил в качестве приоритетного на 26 Ассамблее ИКАО направление рационального учета человеческого фактора. В рамках рабочей группы "человеческий фактор и безопасность полетов" организованы исследования по этому направлению деятельности. В представляемом докладе мы приводим некоторые аспекты общей комплексной проблемы, разрабатываемые нами. Для более четкого понимания нашей позиции в этих вопросах вначале изложим некоторые общие подходы к проблеме, которые по нашему мнению представляются существенными. Дело в том, что по нашему мнению не совсем справедливо однозначно переносить известные общие характеристики человеко-машинных систем, в т.числе и авиационных, на системы УВД. В дальнейшем изложении приведем обоснование этого.

I. Что такое "человеческий фактор", когда возникает необходимость его учета в человеко-машинных системах и системах УВД.

Наше время характеризуется усиливающимся и расширяющимся антропогенным воздействием на природу и общество. Широко используемый при этом термин "человеческий фактор" (ЧФ) является общепринятым и интуитивно понятным. Обычно этим термином обозначают такие аспекты прикладных наук, в которых влияние человека существенно или определяюще.

При таком подходе ЧФ должен быть определен как философская категория, служащая для характеристики степени влияния человека, через результаты его деятельности например на технику, природу, общество. Здесь мы не претендуем на открытие философских истин, естественно это дело специалистов-философов, мы лишь пытаемся воплотить научную интуицию и опыт работы в практически полезное и необходимое понятие ЧФ.

Применительно к системам УВД под ЧФ мы понимаем совокупность социальных, биологических, психологических свойств, присущих человеку-диспетчеру, коллективам людей, определяющих эффективность общественно-полезной деятельности.

Практика показывает, что к учету влияния ЧФ в человеко-машинных системах (СЧМ) приходят, в основном, в двух случаях:

- когда количество ошибочных действий человека в СЧМ сравнимо или превосходит количество отказов технических средств;
- когда "стоимость" ошибочного действия (достаточно редкого) сравнима со "стоимостью" последствий от отказов техники.

При этом, естественно, мы понимаем, что человек в системе реально может как ухудшить общую эффективность системы при нормально функционирующих технических средствах, так и обеспечить некоторый реальный уровень эффективности системы при отказах технических средств.

2. В чем причина и почему в настоящее время приобретает приоритетное значение учет влияния человеческого фактора при УВД.

Представляется, что система УВД (т.е. авиационная человеко-машинная система "диспетчер - технические средства УВД") может быть отнесена к третьему случаю, для которого оценкой "стоимости" ошибки и отказа технических средств является безопасность. По сложившемуся мнению безопасность является безоговорочным приоритетным критерием для системы УВД, поэтому в системах такого типа учет влияния человеческого фактора должен осуществляться всегда и на всех этапах разработки и эксплуатации технических средств (систем) УВД.

Объективная оценка состояния учета влияния ЧФ приведена в удачной и наглядной графической форме в документе ИКАО "Руководство по предотвращению авиационных происшествий" (ДОС 9422-А № 923) издания I984 г. Не смотря на известную условность таких графических моделей все же следует отметить ее полезность для выявления причин существующего положения (рис. I).

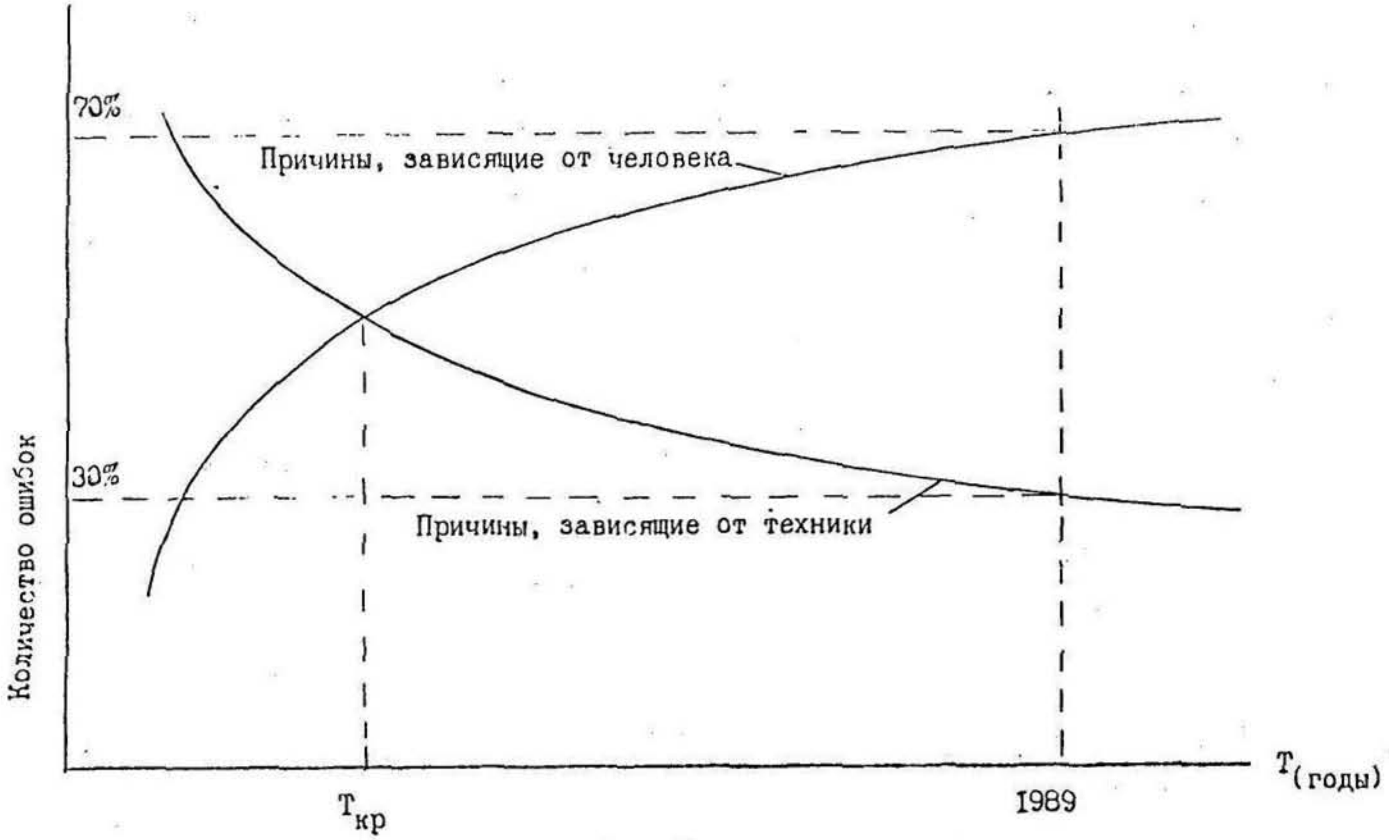

Рис. I .

По нашему мнению такое положение является результатом бурного развития и активного внедрения средств, определяющих технический и технологический прогресс - средств вычислительной техники и некоторым отставанием в исследованиях закономерностей и особенностей человеческой деятельности в СЧМ. По всей видимости, все же абсолютное количество причин ошибок, зависящих от человека, изменилось незначительно, однако резкое увеличение надежности технических средств, а следовательно соответствующее снижение ошибок, зависящих от техники, показывает относительное увеличение доли причин ошибок, зависящих от человека.

С другой стороны новые технические средства, иногда существенно изменяющие психологическое содержание деятельности, требующие профессионального разделения труда и т.п. не всегда рационально совместимы с консервативными характеристиками человека. Практически мы можем говорить об опережении технократического подхода в разработке систем по отношению к рациональному сочетанию технократического и антропоцентрического. По нашему мнению это, очевидно, может привести (и приводит) к экономическим потерям, поскольку ограниченные возможности человека-диспетчера не всегда дают возможность реализовать технический потенциал системы.

Мы полагаем, что стремление к рациональному сочетанию двух подходов, может составить одно из направлений совместных, в рамках ИКАО, исследований.

3. В чем и как проявляется ЧФ в системах УВД. Причинно-следственные связи и зависимости.

Всю совокупность ошибок, связанных с ЧФ, представляется возможным условно разделить на 2 группы.

По нашему мнению в I группу следует включить:

- прямые ошибки, снижающие безопасность при УВД (в основном это ошибки, приводящие к АИ);
- прямые ошибки, снижающие эффективность при УВД (это ошибки, связанные с назначением неоптимальных режимов и условий полета воздушных судов и т.п.);
- ошибки, связанные с неэффективной адаптацией специалистов по УВД к профессиональной деятельности (например, работа в экстремальных ситуациях, создание таких ситуаций в результате собственных непродуманных действий и т.п.);
- ошибки, связанные с недостатками в обеспечении деятельности диспетчеров (режимы труда и отдыха, принятая технология работы в секторе, уровень технического оснащения, условия деятельности и т.п.).

Во вторую группу включаем для рассмотрения:

- ошибки, связанные с неполным учетом известных возможностей человека-диспетчера (проявляются в частичном несоответствии оборудования рабочего места, видов и способов кодирования и формирования информационных моделей, характеристик информационных потоков и т.п.);

- ошибки, связанные с невозможностью учета неизвестных (невыявленных, потенциальных) возможностей человека-диспетчера, в т.числе индивидуальных.

Представленное разделение на 2 группы, несмотря на естественную условность любых классификаций, проведено с целью определения причин, порождающих ошибки. При этом естественно желание определить (установить) такие причины, на которые возможно воздействовать с целью снижения вероятности ошибочных действий диспетчеров при работе.

Такой подход позволяет установить, что причины, порождающие ошибки, отнесенные к первой группе преимущественно лежат в области:

- всех этапов формирования специалиста по УВД: профессиональная ориентация, профессиональный психофизиологический отбор, обучение, переучивание, повышение квалификации и т.п.;

- всех видов обеспечения деятельности специалистов по УВД: уровень и качество используемых технических средств, совершенство технологии работы, технологии взаимодействия, рациональность режимов труда и отдыха, организации и обеспечения работы смен и многое другое. Другими словами это техническое, технологическое, организационное обеспечение деятельности. При этом в организационное обеспечение мы включаем, в основном, эргономическое обеспечение.

Вторая группа причин лежит в области:

- применения нерационального сочетания технократического и антропоцентрического подходов в разработке и эксплуатации систем в УВД и, в первую очередь, автоматизированных и перспективных;

- абсолютно недостаточного объема комплексных исследований деятельности диспетчеров в нормальных и экстремальных условиях, психологического анализа причин АИ, в области нормирования труда, оптимизации условий деятельности, режимов труда и отдыха, совершенствования видов, форм и характеристик информационных потоков, оптимизации взаимодействия по горизонтали и вертикали и т.д.

Дальнейшая дифференциация причин, естественно, приводит к необходимости разработки или совершенствования известных методов и средств, программ и методик по каждой группе причин. Например:

- совершенствование методов и разработка автоматизированных технических средств профотбора и распределения специалистов по рабочим местам;
- разработка системы мер контроля и поддержания работоспособности;
- разработка методов и нормативов деятельности диспетчеров УВД;
- разработка методов психологического анализа АИ;
- разработка эргономических норм и требований к рабочим местам диспетчеров и т.д.

Этим перечнем отнюдь не исчерпываются задачи, необходимые для разработки, они скорее иллюстрируют те направления, по которым мы имеем или конкретные результаты или проработки, приближающиеся к практическому внедрению. Указанные направления могут быть обсуждены предметно и содержательно присутствующими здесь специалистами. Мы же предлагаем в дальнейшем изложении рассмотреть концепции по двум вопросам, которые, на наш взгляд, могут составить основу для расширения научного сотрудничества.

4. Человеческий фактор и автоматизация УВД.

Анализ деятельности диспетчеров различных специализаций, выполненный при разработке нормативов загруженности и эргономических норм и требований к рабочим местам показывает, что по-прежнему наиболее "узким" местом обеспечения деятельности диспетчеров является информационное. Под информационным обеспечением мы понимаем все виды поступающей зрительной (статической и динамической) и слуховой информации по имеющимся в системе каналам. Неоспоримым преимуществом АС УВД является объединение, в основном, на одном носителе всей визуальной информации о динамике воздушной обстановки. При этом следует отметить некоторую, не всегда обоснованную потребность в реализации дополнительных функций отображения и управления отображением. Это явление следует рассматривать как естественный результат интуитивного подхода к разрабатываемым системам, при котором основным является принцип "диспетчеру надо". Противодействуя этому принципу активно действует другой принцип "берите то, что дают, потому что другого все равно нет".

В результате действия таких принципов в автоматизированных системах все более и более возрастает количество "порожденных" функций. "Порожденными" функциями в данном случае мы считаем функции диалога с ЭВМ системы, которые относительно функций УВД являются сервисными, но существенно загружают диспетчеров. Необходимость компенсации этого стала одной из причин разделения труда (диспетчер радиолокационного управления, диспетчер процедурного контроля, диспетчер-ассистент).

Прогноз развития средств отображения информации позволяет надеяться на значительное улучшение светотехнических характеристик индикаторов по разрешающей способности, частоте генерации информации и на возможность формирования многоцветного изображения. Для своевременной подготовки к рациональному использованию цветных индикаторов для УВД уже сейчас необходимо начать осуществление научно-прикладных исследований по обоснованию и выбору оптимальных (в семантическом смысле) видов и способов цветного и графического кодирования. Это позволит в значительной мере "разгрузить" индикатор воздушной обстановки АС УВД и оптимизировать условия зрительной работы диспетчера, уменьшить зрительное утомление.

Второе направление совершенствования представления визуальной информации (способное быть реализованным в существующих АС УВД) связано с поиском нетрадиционных способов формирования визуальной картины воздушной обстановки. Разработка таких алгоритмов и их опытная проверка может также составить предмет совместных работ. Результатом может быть значительное облегчение формирования образа воздушной обстановки у диспетчера и принятия им эффективных решений по разведению самолетов по эшелонам при переменном профиле полетов.

Третье направление связано с поиском путей защиты системы УВД от возможных ошибочных действий диспетчера. Эта задача вызвана тем, что в системе УВД наиболее ответственный канал командной информации – радиосвязь "земля-борт" инструментально не защищен от ошибочных решений диспетчера. Решение такой задачи возможно исходя из оценки уровня развития математического обеспечения АС УВД и работ по анализаторам и синтезаторам речевых сообщений.

При этом, в терминах теории множеств, задача формулируется следующим образом. Если:

$S(T_{n+1}-T_n)$ – состояние системы УВД в интервале времени $T_{n+1}-T_n=\Delta T_i$, $T_{n+1}>T_n$ (a)

UR_i – множество разрешенных воздействий на систему УВД в интервале ΔT_i (b) ;

$S \Rightarrow \{\overline{0,N}\}$ – отображение состояния системы в интервалах чисел (c) , то

$$R_j \in UR_i,\ \forall T \in \Delta T,\ S=0 \qquad \text{(I)}$$

$$R_j \in UR,\ \forall T \in \Delta T_i,\ S\neq 0 \qquad \text{(2)}$$

Другими словами, если выбрано решение для данного состояния системы, не совпадающее с разрешенным, то такое решение не проходит по каналу "земля-борт", а диспетчер информируется системой об ошибке (I).

Реализация этой задачи – фактическое включение человека-диспетчера в систему в качестве контролируемого, в смысле принимаемых решений, звена.

Более отдаленную перспективу по учету "человеческого фактора" АС УВД представляет обоснование и разработка новых принципов создания систем. Структурное построение систем будет осуществляться на основе распределенных вычислительных средств. Это позволит решить вопросы создания адаптивных систем УВД и более полного включения в систему человека-диспетчера в качестве контролируемого системой звена. Строго говоря, элементы адаптивных систем (в очень узком смысле) присутствуют в существующих системах. Это в первую очередь все регулируемые параметры: громкость, яркость, выбор режима отображения информации и т.п. В данном случае мы говорим о более широкой адаптации систем к возможностям и особенностям каждого диспетчера.

Применительно к информационной адаптации систем можно построить следующую вербально-логическую модель. В связи с ростом надежности технических средств УВД, т.е. резким снижением вероятности отказов системы и ее элементов, каждый возможный отказ становится фактором возрастающего стрессового воздействия на диспетчера. Возникает необходимость систематизированной специальной подготовки диспетчеров к обеспечению безопасности полетов в условиях отказов различных элементов системы и поддерживания этих навыков. Это возможно осуществлять на специализированных тренажерах УВД со всеми видами необходимого обеспечения.

Адаптивная в этом смысле система, может обеспечить поддержание необходимых навыков работы в условиях отказов при реальной деятельности. Основанием для этой гипотезы служат выполненные в Центре исследования по нормированию загруженности, в результате которых определены зависимости показателя загруженности от количества ВС на управлении, рис.2 и вероятности ошибочных действий от загруженности, рис.3. Анализируя зависимость рис.3, выделим 3 интервала:

$0 \div K_{з\,min}$ – характеризуется увеличением вероятности ошибочных действий в связи с недогрузкой диспетчера (монотония, сенсорный голод, гиподинамия);

$K_{з\,min} \div K_з^{доп}$ – стабилизация минимального значения вероятности ошибочных действий;

$K_з^{доп} \div 1$ – резкое увеличение вероятности ошибочных действий, связанных с перегрузкой диспетчера.

Решение задачи возможно за счет создания АС УВД адаптивной к загрузке, т.е. системы автоматически реализующей разные варианты информационного обеспечения. Допустим, что для первого интервала (надо дать дополнительную нагрузку) система работает в квазиавтоматизированном режиме (например, существует запрет на формуляры сопровождения, который может быть снят диспетчером), при этом загрузка приближается к допустимой снизу. Для третьего интервала - максимальные возможности автоматизации, рационального распределения функций и т.п. мероприятия, обеспечивающие приближение фактической загрузки к нормативной сверху.

Тем самым мы расширяем диапазон близких к минимальным значений вероятности ошибочных действий за счет "переменного" уровня автоматизации. При этом работа в первом интервале и начале второго может рассматриваться как подготовка к работе и поддержанию навыков ра-

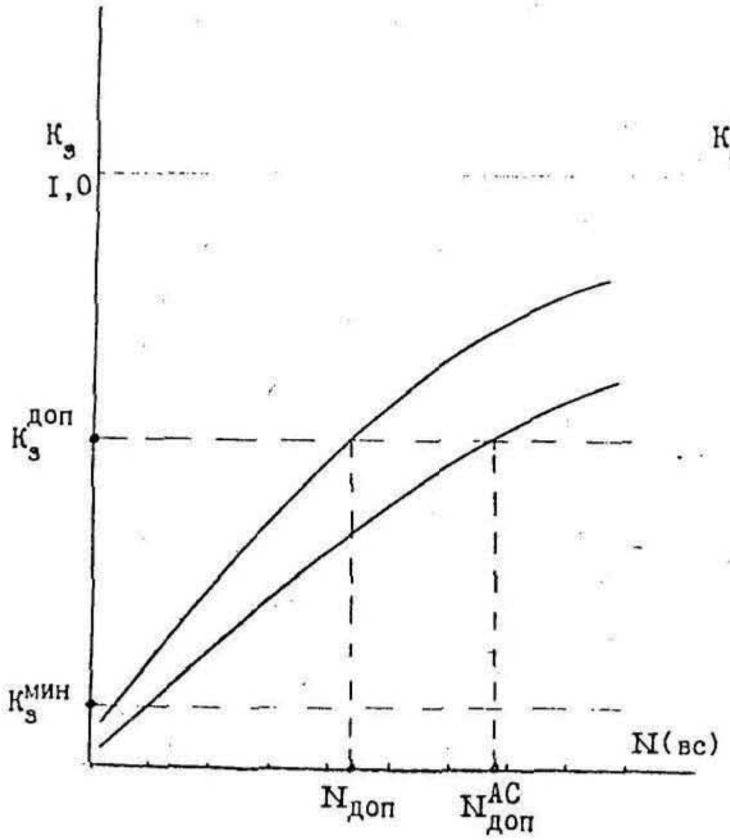

Рис. 2.

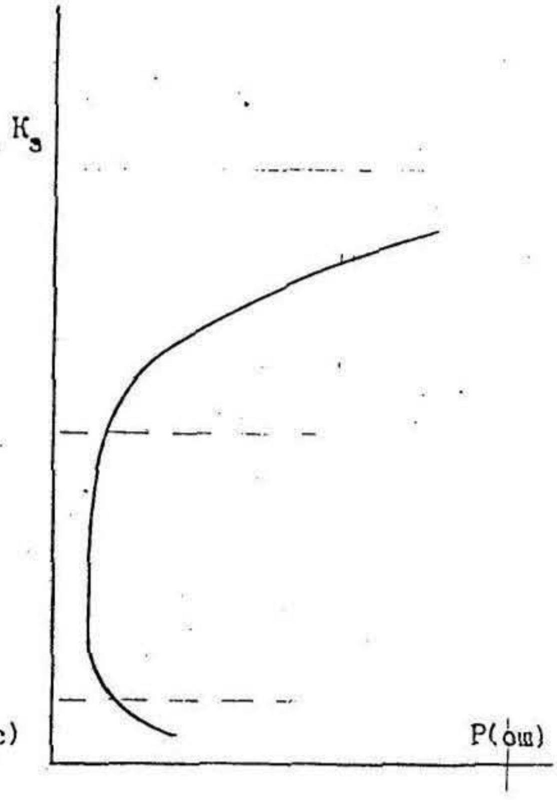

Рис.3.

боты в неавтоматизированном варианте, что соответствует отказу некоторых элементов АС УВД, а работа в третьем интервале – к экстремальным условиям.

Поскольку представлена лишь гипотеза, которая на первый взгляд не противоречит логике, то, по нашему мнению, исследования в этом направлении могут стать практически полезными.

Следующим уровнем адаптации системы следует считать адаптацию по функциональному состоянию (ФС). При этом у человека-диспетчера преимущественно бесконтактным способом автоматически регистрируются параметры состояния физиологических систем и производится оценка ФС. Автоматизированная оценка предстоящей загрузки и динамики ФС позволит выработать прогноз деятельности диспетчера для принятия мер по обоснованной замене утомленного диспетчера.

Дальнейшим развитием адаптивных систем, по-видимому, следует считать их совершенствование в третьем направлении. При этом дополнение. Предполагаем, что в (δ)

UR_i – содержится как минимум одно R_i^{opt} по критерию эффективности Z с учетом (а);

Если выделим некоторую последовательность состояний $S(T_{n+1}-T_n)$, $S(T_{n+2}-T_{n+1}),\ldots S(T_{n+k}-T_{n+k-1})$ или, что (то же) $S(\Delta T_i)$ $S(\Delta T_{i+1}),\ldots S(\Delta T_{i+k})$,... которым соответствуют условия (в), (с), то

$$R_i^{opt} \cap R_{ji} \neq 0 \qquad (3)$$

$$U(R_{ji}^{opt} \cap R_{ji}) \Rightarrow max \qquad (4)$$

При этом условие (3) означает, что принятое и реализованное решение для заданного интервала соответствует оптимальному из множества разрешенных. Условие (4) характеризует эффективность по критерию

решений по УВД для последовательности интервалов или состояний системы. Представляется, что по оценке динамики совпадений (или несовпадений) реализованных решений с оптимальными, можно говорить о системе, адаптивной по оптимальности реализованных решений на интервалах дискретного изменения состояния системы. Результаты разработки могут оказать существенное влияние на повышение эффективности УВД. Это в первую очередь может быть обеспечено за счет специальной подготовки диспетчеров на основе анализа и оценки эффективности реализованных решений по УВД.

Приведенные предложения отражают существующие представления об учете человеческого фактора при разработке перспективных АС УВД.

5. Человеческий фактор и перспективы развития автоматизированных систем УВД.

Предлагаемая к рассмотрению концепция развития автоматизированных систем УВД является логическим продолжением и развитием предложений СССР 26 сессии Ассамблеи ИКАО.

В качестве исходных данных для разработки вербально-логической модели развития АС УВД с учетом влияния ЧФ и ее графической интерпретации воспользуемся данными ИКАО, приведенными на рисунке I. В качестве комментария отметим, что приведенные характеристики и соотношение причин в основном не отличаются и для стран с развитой авиацией. Считая фактическую оценку состояния безопасности и соотношение причин в качестве оценки слева на временной оси, положим справа желаемую или допустимую оценку безопасности для автоматических систем УВД. Под автоматической системой УВД предполагаем отсутствие человека-диспетчера (а впоследствии вероятно и летного экипажа) в контуре системы управления. Отметим, что в этом процессе по времени, очевидно будут улучшаться и характеристики технических средств, т.е. того, что сейчас мы называем "железом". При изложенных условиях графическая интерпретация модели может быть представлена в виде, приведенном на рисунке 4. Другими словами мы предположили, что разрабатываемая и поэтапно реализуемая программа учета влияния ЧФ на безопасность полетов при УВД и развитие технических средств УВД должны обеспечивать эффективность

УВД по форме приведенных зависимостей. Полагаем, что такое рассмотрение позволит построить стратегию и определить содержание работ по "управлению" процессом уменьшения процента причин АП и АИ, связанных с проявлением ЧФ.

Предварительные аналитические проработки показывают, что рационально рассмотреть возможность разделения предложенного процес- достижением определенной эффективности – рисунок 4. На рисунке также приведены укрупненно характерные особенности этапа.

Предполагаем, что:

- I этап – совершенствование и развитие существующих АС УВД;
- П этап – разработка и внедрение частично-адаптивных систем;
- Ш этап – разработка и внедрение адаптивных систем;
- IУ этап – разработка и внедрение систем с искусственным интеллектом.

Сразу отметим, что от этапа к этапу по-видимому относительная эффективность будет уменьшаться, а уровень "интеллекта" систем возрастать. После завершения 4 этапа возможен (целесообразен?) переход к автоматическим системам УВД.

Считаем, что для более заинтересованного и предметного обсуждения изложенной гипотезы, необходимо привести наше понимание характерных особенностей приведенных этапов.

I этап. Предварительные результаты по анализу работ существующих АС УВД показывают, что они имеют значительные резервы, связанные с неполнотой наших знаний о психологических особенностях деятельности авиадиспетчеров. Пополнение наших знаний позволяет определить и реализовать новые возможности в АС УВД, в первую очередь в области информационного обеспечения. В качестве частных примеров реализации таких возможностей приведем два. Выделив для некоторых секторов УВД содержание наиболее часто встречаемых задач, разработаны и проходят экспериментальную проверку способы информационного обеспечения, облегчающие решение этах задач. При плотном движении ВС в одной из коридоров на индикаторе воздушной обстановки можно сформировать отображение вертикального разреза коридора с вполне понятными преимуществами

решения задач оптимизации набора и снижения ВС и следования по оптимальным эшелонам. В других условиях (горный аэродром) наиболее часты задачи контроля режимов набора высоты и снижения ВС. При реальной интенсивности непрерывный контроль диспетчером за совокупностью таких воздушных судов затруднителен. Разработаны алгоритмы для реализации в АС УВД полуавтоматизированного контроля режимов набора и снижения и ~~дискретного контроля со стороны диспетчера~~. Следует особо отметить, что использованы только реально существующие на сегодняшний день возможности АС УВД. Определение и решение таких задач в существующих системах осуществляется в настоящее время. Предполагаем, что эффективность такого учета ЧФ в существующих АС УВД позволит получить ту эффективность которая приведена на рисунке 4.

II этап. Характеризуется разработкой и внедрением АС УВД, реализующих элементы адаптации:

- по информационному обеспечению (его структуре, форме, содержанию и т.п.);
- по загрузке диспетчеров;
- по эффективности решений диспетчеров и т.п.

III этап. Адаптивные системы. Характеризуются адаптацией по:

- эффективности УВД;
- динамике надежности работы диспетчера;
- контролю и оценке функциональных состояний диспетчеров в процессе УВД.

Особо отметим, что переходы от этапа к этапу условны и внутри предыдущих формируются элементы последующих.

IУ. Этап. Системы с искусственным интеллектом. В этих системах диспетчер остается в контуре в качестве активного опера-

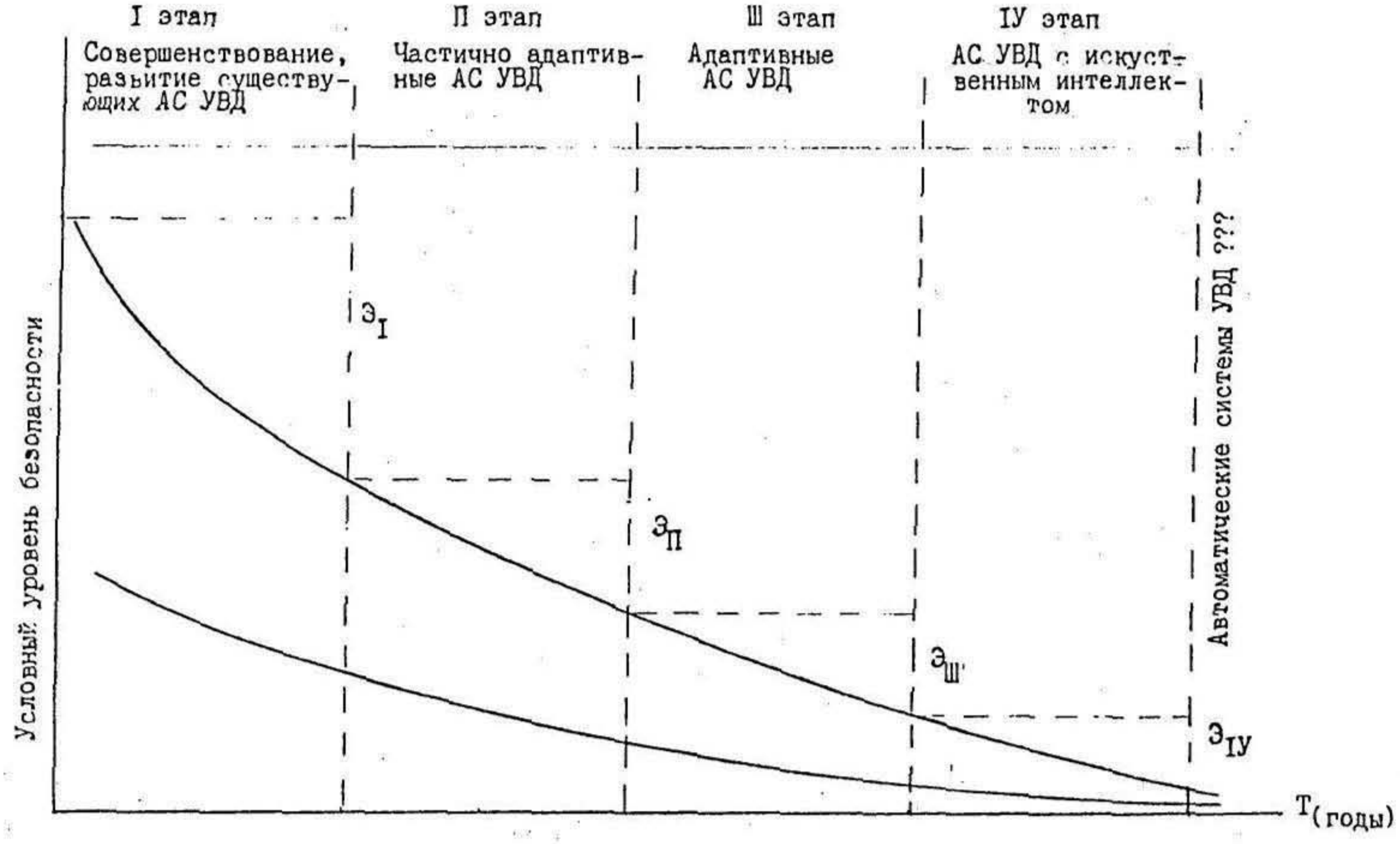
I этап
Совершенствование, развитие существующих АС УВД
II этап
Частично адаптивные АС УВД
III этап
Адаптивные АС УВД
IУ этап
АС УВД с искуственным интеллектом
Автоматические системы УВД ???
Условный уровень безопасности
$Э_I$
$Э_П$
$Э_Ш$
$Э_{IУ}$
T(годы)

Рис.4.

тора, но значительный объем задач управления осуществляется автоматически.

Более подробное рассмотрение задач не проводим, поскольку это дело конкретных специалистов (эргономистов, инженеров, математиков, психологов, медиков, социологов и др.), которые активно работают в этом направлении.

В обсуждаемой проблеме мы намеренно не рассматривали прогноз развития технических средств, к чему приступаем далее. Предложенной модели присущи некоторые общепонятные ограничения, которые не влияют на общую постановку и формулировку гипотезы.

Удобство рассмотрения и построения гипотезы или графической интерпретации вербально-логической модели по предельным значениям слева и справа не может рассматриваться как общность. Поэтому подвергнем более тщательному логическому анализу изложенную стратегию автоматизации УВД с позиции технической части системы (железа).

Процесс развития систем будет сопровождаться не только значительным увеличением объемов математического и программного обеспечения, возрастанием сложности взаимосвязей и т.п., но и, что естественно, возрастанием энтропийных характеристик системы. Это связано не только с указанными причинами, но с проявлением все более существенным влиянием факторов "интуитивных", которые принципиально, системе известны быть не могут. Например, для системы высокого уровня интеллекта важно знать действительные и прогнозируемые с достаточно высокой точностью характеристики скорости и направления ветра по всем высотным слоям, но получить такую информацию с необходимой точностью принципиально невозможно. Или для получения этой информации необходимо строить системы как минимум на порядок сложнее АС УВД и естественно дороже.

Исходя из этого мы можем предположить, что в указанных предельных значениях энтропийная характеристика систем будет иметь возрастающую тенденцию, например в виде рисунка 5.

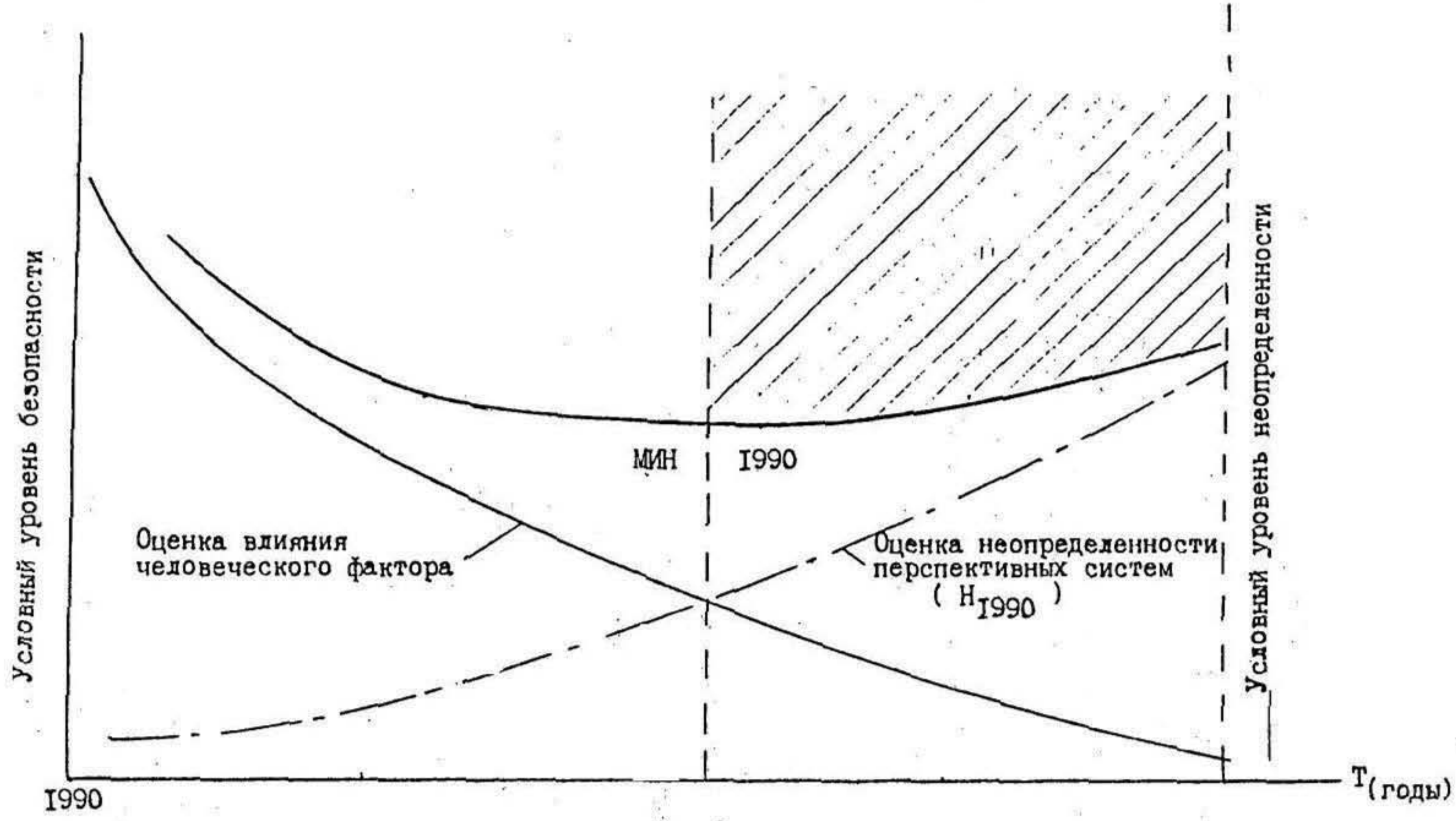
Условный уровень безопасности
Оценка влияния
человеческого фактора
МИН
I990
Оценка неопределенности
перспективных систем
(H_{I990})
Условный уровень неопределенности
I990
T(годы)

Рис.5.

С другой стороны, эта характеристика в каком-то приведенном виде соответствует и может оценивать уровень незнания (неопределенности требований, задач, алгоритмов и т.п.) Заказчика и Разработчика систем, т.е. тоже человеческим фактором другого, отличного от рассмотренного ранее содержания. Скорее всего это некий системообразующий ЧФ (квазичеловеческий фактор),

Рассматривая совместно две изложенных гипотезы (рисунок 6) следует вывод о существовании некоторого оптимума (минимума) уровня автоматизации УВД по уровню понимания задач учета влияния ЧФ на безопасность полетов в настоящее время. В рассмотренных нами моделях, естественно, представлен минимум автоматизации, имеющий качественный характер по причине неформализованных вербально-логических моделей.

Развивая далее излагаемую концепцию, следует отметить, что по мере продвижения по временной оси, естественно, исходный уровень энтропии системы будет изменяться. Скорее всего уменьшаться. Поэтому можем построить некую модель "скользящего минимума", представленную на рис.6.

Из представленных моделей следует, что стремление к автоматическим системам УВД является скорее желательным, чем реально осуществимым. По крайней мере с точки зрения сегодняшних научных представлений.

6. Заключение.

В приведенных материалах изложена концепция учета влияния человеческого фактора на безопасность полетов при УВД. Использование этой концепции возможно для:

- определения программ развития технических средств УВД;
- создания комплексных исследовательских программ по учету влияния человеческого фактора на безопасность полетов при УВД;
- разработки программ международного сотрудничества по проблемам человеческого фактора в УВД.

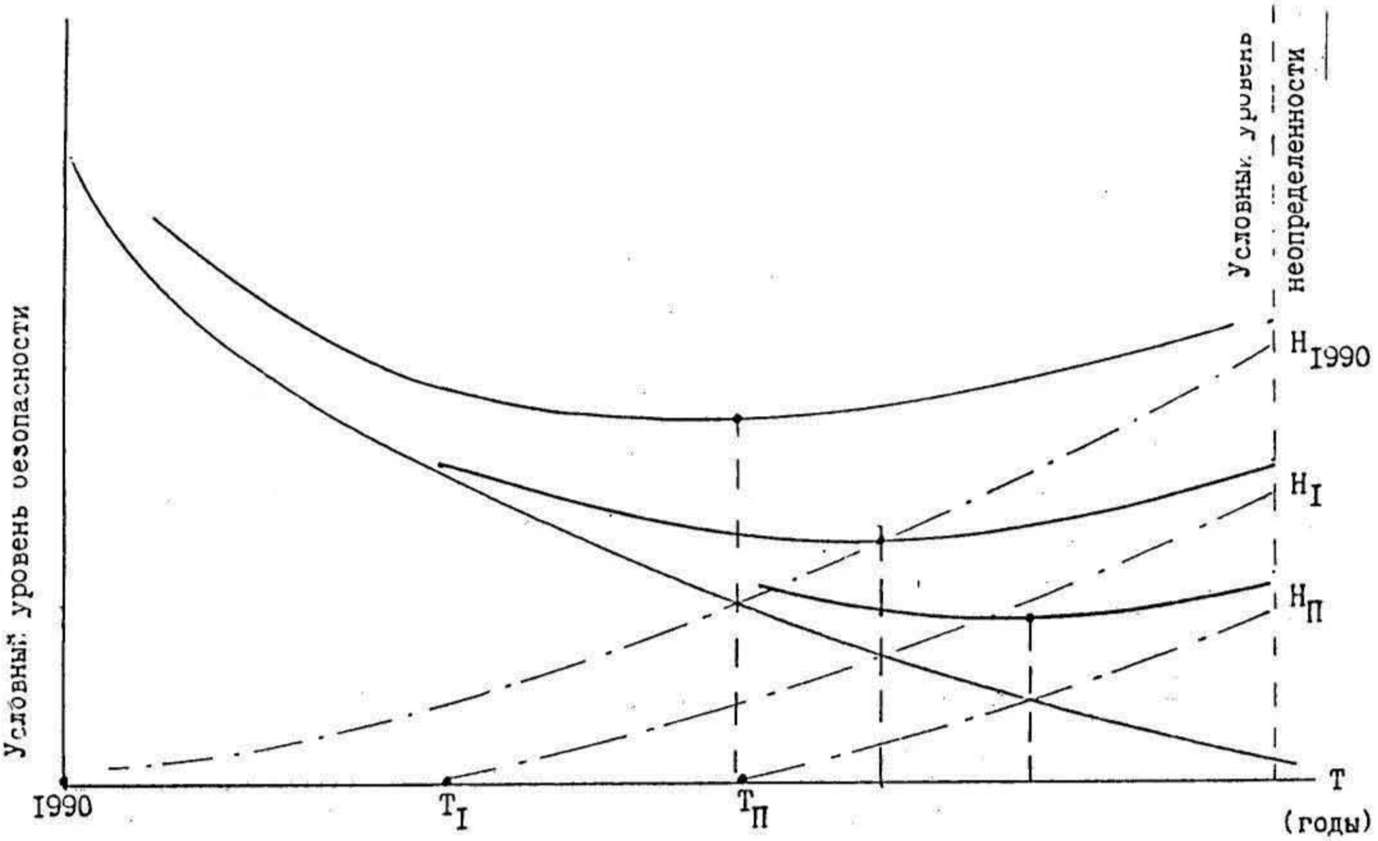

Рис.6.

Представляется, что дальнейшая проработка и совершенствование изложенной концепции, позволит оценить экономическую эффективность от результатов рационального использования технократического и антропоцентрического подходов при разработке технических средств и систем УВД и повышение уровня безопасности полетов.

New Directions in Crew-Oriented Flight Training [1]

J. Richard Hackman
Harvard University

Over the last couple of years, our research group has been examining how cockpit crews function as teams [2]. Our view is that understanding the behavior and performance of cockpit crews requires careful attention to team-as-a-whole issues, not just to the behaviors of individual team members. To accomplish this, we have been following cockpit crews through their entire life cycles, from the moment members first meet prior to a trip until the team ultimately disbands--usually several days later. So far, we have data from several U.S. airlines, three U.S. military units, and three overseas carriers.

Although we have not yet completed data collection, some possible directions for the next generation of Cockpit Resource Management (CRM) programs are starting to emerge from the research. I will describe three of these directions in this paper. They are:

1. To take seriously the fact that cockpit crews are teams, and to design CRM training so that crewmembers become increasingly skilled as team members.
2. To recognize that the Captain is a team leader, and to help Captains become as competent in leading teams as most of them are in the technical aspects of flying.
3. To acknowledge that organizational and regulatory contexts bear powerfully on the degree to which the lessons learned in CRM courses will take root and prosper on the line, and to begin the never-ending process of "tuning" the contexts within which crews operate so that they actively support effective teamwork and crew coordination.

Cockpit Crews as Teams

Despite all the talk one hears these days about crew coordination and team dynamics in the cockpit, CRM training programs tend to focus on improving the attitudes, behavior, and performance of individual pilots. Even those CRM courses that specify improved team functioning as a major educational objective often pursue that objective by attempting to change individual attitudes and behavioral styles. The idea seems to be that improved team functioning will come about more-or-less automatically if each individual in the cockpit understands his or her personal style as a leader or follower and recognizes the need for good communication and coordination.

Although the characteristics of individual team members are indeed important, our research suggests that there is more to the story. It is not uncommon, for example, for an athletic team consisting of several individual "stars" to be defeated by a less-illustrious set of players who work well together. If I were a passenger on an aircraft that developed serious mechanical problems, I would prefer a cockpit crew consisting of average pilots who work well as a team to a group of superb technical flyers who do not.

What would be required if helping pilots develop their skills as team leaders and members were to become one of the central objectives of CRM training? First, a change in mind-set would be required on the part of both instructors and students. Moreover, the training would have to include significant amounts of hands-on practice and feedback in team performance settings. Let us look more closely at each of these requirements.

<u>Change of mind-set</u>. The history and culture of flying is highly individualistic. No pilot forgets his or her first <u>solo</u> flight, and this individualistic orientation is reinforced continuously throughout a pilot's career--both formally (in training and proficiency checks) and informally (through a status system that accords the highest respect to great stick-and-rudder pilots).

The work of a cockpit crew, in this view, can be compared to the performance of a ballet. Although a ballet is indeed an ensemble performance, each member of the company has his or her own part to play, and those parts are carefully choreographed beforehand. If each dancer does precisely the right thing at the right time, the performance can unfold beautifully. One crew we observed lost a crewmember (for personal reasons) in mid-trip. While we waited for a reserve pilot to appear, I asked the Captain if he was concerned about having a change of membership halfway through the trip. "No problem," he responded. "Every pilot in this company knows his job, and the new First Officer will pick up right where Bob left off." Because we were already quite late departing, the Captain called for push and the pre-start checklist immediately after the reserve pilot arrived. Engine start, taxi, and takeoff proceeded normally, and only when we were well into the climb were introductions made all around.

Was there anything wrong with the Captain's behavior? Should he have taken a further delay to get the crew re-established as a team before proceeding? In this particular instance, the fact that the work began the moment the reserve pilot arrived did not result in any discernible problems. But what if something unusual and challenging had occurred during taxi, takeoff, or initial climb? Our research suggests that having taken a few moments before push to get the boundaries of the team re-established, to clarify the basic norms and expectations that would guide behavior in the cockpit, and to review together the strategy for taxi and takeoff (including contingencies if problems should develop) would have made a positive difference had something gone wrong. I also predict, based on conversations with pilots in a number of carriers, that many pilots--perhaps most--would disagree with this conclusion.

If my prediction is correct, then team-oriented CRM training will indeed require a change of mind-set on the part of program designers, instructors, and students. A few airlines are now exploring how this might be accomplished. One carrier exploits the parallel between athletic teams and cockpit crews to help students see how team dynamics affect crew performance. In another, students view video vignettes in which they can compare well- and poorly-functioning teams--both of which are composed of fine technical flyers. The intent is to help pilots see the differences between crews that function effectively as teams and those that do not, and to sharpen their awareness of good team functioning as a factor that contributes significantly to the safety and efficiency of flight.

Practice and feedback in team performance settings. My remarks so far have focussed exclusively on what Clay Foushee has called the "awareness" stage of CRM training. Awareness is an essential first step in such training, but more is required. In addition, pilot students need practice, reinforcement, and feedback in using CRM skills.

My informal survey of existing CRM programs suggests that the emphasis in many of them is not so much on skills as on members' behavioral styles. Typically, each participant takes a paper-and-pencil test that, when scored, reveals his or her characteristic style of operating in teams. Instructors then help participants see how certain styles are better than others for promoting team effectiveness. Students may learn, for example, that Captains should behave in ways that foster task accomplishment and interpersonal harmony simultaneously, and that they should avoid both autocratic and relentlessly democratic leadership styles. And they may learn that First Officers and Flight Engineers should be assertive (but not excessively or unpleasantly so) with their Captains when something occurs that concerns them (such as when the Captain is a dot or two low on an ILS approach). In full-fledged programs, participants also have the chance to experiment with the new styles they have been taught. The hope is that the styles taught in the classroom will be used to good effect when pilots return to the line.

Although trainees invariably find tests of behavioral style interesting and informative, I have a number of concerns about such devices. [3] For one thing, they perpetuate the individualistic orientation of aircrew training: the assumption is that crew effectiveness will improve if the styles of individual members become better aligned with what is viewed as desirable by the theorists who construct the tests. Unfortunately, I know of no empirical evidence that supports this assumption.

Even when changes in style are learned in the classroom, they may not generalize to the cockpit. Indeed, those times when a newly-learned style would be most valuable are precisely the times when it is least likely to appear. Research has shown that when a person becomes highly aroused (as typically happens under stress), he or she reverts to well-learned behaviors, exhibiting whatever response is most dominant for that person in that situation (Zajonc, 1965). Learning a new behavioral style in a CRM course does not immediately change someone's dominant responses; they are too deeply ingrained for that. Therefore, when a crew encounters a highly stressful situation, such as an engine fire followed by numerous secondary problems, each crewmember is likely to revert to his or her old, tried-and-true way of dealing with such events. The new behaviors learned in the classroom are unlikely to be seen, at least not until the crisis has passed.

This phenomenon is nicely illustrated in a story told by Capt. Reuben Black of Delta Airlines. Some years ago, an instructor was attempting to get his students to memorize the thirteen steps that were to be taken in the event of a heater fire on a certain aircraft. The students were having trouble committing the list to memory, but the instructor persisted. Finally one veteran Captain captured the essence of the problem when he exploded, "How the hell do do you expect me to remember all this shit when I'm <u>scared</u>?"

How, indeed? And if paper-and-pencil tests of individual behavioral styles are unlikely to do the trick, what alternatives are there for helping crewmembers learn the skills that can help a <u>team</u> function effectively? To *frame the question that way is to begin to answer it: to learn a new skill is* a very different--and more tractable--enterprise than is changing one's characteristic behavioral style. Crewmembers can learn how to get a team off to a good start, how to deal with a change of membership in the cockpit (or a new cabin crew in the back), how to negotiate with uncooperative ramp or maintenance personnel, how to address conflicts among members constructively, and how to draw out and use the full range of expertise that exists in the cockpit. "Ah," a crewmember may reflect, "I know how to do <u>that</u>." And then he or she may proceed to do it, using his or her own, idiosyncratic style.

Although we already know many of the skills needed to help a team become a self-correcting performing unit (see Hackman, 1987, and Hackman & Walton, 1988 for an overview), it remains a challenge to design training that helps pilots learn those skills and become comfortable in using them. Even relatively simple technical skills, such as starting aircraft engines, require practice and feedback before they become settled in a pilot's repertoire. How can practice and feedback be provided for interpersonal and team skills such as those listed above?

In my view, there is no better alternative than Line Oriented Flight Training (LOFT). In LOFT training, pilots operate as a real team in a setting that is uncanny in its realism--but that also provides a safe site for experimentation with new or unfamiliar behaviors. Moreover, video feedback allows pilots to review their behavior, and to assess how (and how well) they exhibited team skills. Finally, the involvement of an instructor during review of the videotapes can provide precisely the kind of coaching needed to help a pilot hone a new skill and become comfortable with it.

Because one is behaving in a LOFT session, it is possible for an individual to analyze the effects of his or her actions on the team and its work. As the videotape plays, the data about the crewmember's behaviors are literally right in front of his or her face. Moreover, the instructor and the other crewmembers are in the same room, available to help in exploring the positive and negative effects of those behaviors.

Let me emphasize that the intent of such training is not to get people to change their styles to some predetermined pattern that has been specified as "best" for cockpit crews. Instead, the focus is on how each individual can exploit the strengths, and contain the weaknesses, of his or her own characteristic way of behaving in teams. Although airlines and military units are still learning how best to use LOFT for such training, the potential benefits of this technique over the long term are enormous.

Captain as Team Leader

Let us return to the parallel between cockpit crews and athletic teams and consider a basketball team that includes a playing coach. There are, without question, a number of constructive things a playing coach can do on the floor during a game--such as adjusting team strategy in response to opponents' behaviors, reinforcing high effort and enthusiasm, and keeping play well-coordinated. Yet what can be done on the court with the clock running is necessarily limited. Imagine a situation in which there are 40 seconds to play, you are three points down, the clock is running, and you have no timeouts left. That situation is akin to being over the marker with no autopilot in rapidly deteriorating weather, and having a flight attendant appear in the cockpit door to say, "Captain, we have a very serious problem in the cabin. All one can do in either situation is to hope the team is ready to handle the situation, and then proceed to deal with it in real time.

Happily, there is a great deal that can be done beforehand to increase the chances that a team will be able to handle a tight situation well. Consider, for example, some of the things that good athletic coaches do <u>off</u> the court: they build the team in practice sessions, they have a pre-game warmup and strategy-setting session, they use halftime to review what has happened so far and to lay plans for the second half of play, and the day after the game they review the films with the players to see what can be learned that may be helpful in future games. A coach that does these things, and does them well, substantially increases the chances that his or her team will develop the capability to deal competently with time-critical situations such as the one I described a moment ago.

The analogy is obvious, is it not? The Captain is the playing coach on the aircraft and may need to do some of the same kinds of things that coaches do. We have been recording all acts of leadership that occur in the crews we observe in our research, including initiatives taken out of the cockpit (or during low-workload times) to build or strengthen the crew, as well as those that are intended to fine tune crew performance in real time. So far, we have found that just over 70 per cent of all acts of leadership fall into the fine-tuning category--managing effort, strategy, or the use of knowledge and expertise in flight. Less than 30 per cent of the leadership acts we have observed deal directly with building or strengthening the team as a performing unit.

Yet this 30 per cent, the things Captains do when the work itself is not very demanding, appear to be just as important to team functioning, if not more so, as are their actions when things get demanding in flight. These team-building activities typically involve establishing team boundaries (including how the cockpit crew and cabin crew will relate), helping the crew come to terms with any special requirements of the day's work, and establishing the basic norms of conduct that will guide behavior in the crew. Research by Ginnett (1986) showed that Captains who had been identified (by check airmen familiar with their work) as excellent team leaders engaged in significantly more of these team-building activities during the first few minutes of a crew's life than did Captains who had been rated as equally good technical flyers but as less expert in team leadership. Moreover, what happened in first few minutes carried forward throughout a crew's life: those that had a good "pre-game" briefing generally fared better than did those that received no briefing at all, or a briefing that undermined rather than affirmed the integrity of the crew as a performing unit.

Our current research builds on Ginnett's findings by seeking to determine what Captains can do later in the life of a crew to further strengthen its capabilities. Preliminary results suggest that other low-workload times, such as during extended cruise or on overnights, also are good times for building a crew's ability to handle difficult in-flight situations.

If these findings hold up, they would have at least two implications for the design of team-oriented CRM training. First, Captains could be shown that there are many different occasions when they can provide constructive leadership to their crews--including times other than the high-workload periods that so often are the focus of attention in accident and incident analyses, and that occupy center stage in many CRM programs. And they could learn that leadership intended to "fine tune" crew performance is both easier and has greater impact if a crew already has been built into a basically sound performing unit.

Secondly, Captains could be taught specific skills that are useful in exploiting the opportunities that low workload times offer. For example, they could learn how to efficiently form their crews into teams; how to conduct initial briefings that get teams off to good starts; how to take advantage of the "halftime" represented by overnights on multi-day trips; how to use extended cruise to further strengthen their crews; and so on. They could be shown that these kinds of activities are precisely what great athletic coaches do, that great Captains do them too, and that--in truly superb crews--such acts of leadership also are initiated from time to time by members other than the Captain.

Let me re-emphasize that this kind of training generally does not require Captains to change their individual personalities or styles. Instead, the trainees learn how to use their own preferred styles to put in place conditions that build and sustain effective teamwork. Still, training in team oriented leadership is sure to require repetition and opportunities for practice, since many Captains will find team-building skills unfamiliar and awkward when they first try them. This is another setting in which LOFT training has much to offer.

The potential benefits of team-oriented leadership training are great. If a Captain has done a good job in forming and building his or her crew as a team, then the chances are good that the resources needed to deal with significant problems and opportunities will be both available and deployable. Then, even if the Captain slips into an ineffective style of leadership during a crisis, help still may be forthcoming from his or her colleagues, precisely because he or she previously took the trouble to build the crew into a strong performing unit whose members are prepared to share responsibility for the crew and its work.

Organizational and Regulatory Policies and Practices

We can view the major influences on cockpit crew performance as three concentric circles. The innermost circle is what happens in real time, on the line. To return to our basketball analogy, these are the acts of leadership that crewmembers exhibit on the court while the game is underway. Although important, they are far from the whole story. The next circle is team-building and team-strengthening activities, the acts of leadership I just discussed, the ones that take place out of the cockpit or during low workload times. If these activities are done well, then less hands-on, real time management of the crew may be necessary--and the hands-on management that is done is likely to unfold more smoothly and with greater success.

To conclude my remarks today, I'd like to reflect for a few moments on the outermost circle. This is the context within which the crew operates. Of special interest here are the policies and practices of the organization where the crew works, and those of government agencies that monitor and regulate flight operations. If what is taught in CRM training conflicts with organizational or regulatory influences, training is almost certain to come out the loser. Indeed, the research literature is full of studies in which well-conceived and well-executed training fails because what is taught is poorly aligned with the culture of the organization where the work is done.

New skills learned in training are like the sprouts of plants that emerge in the spring. If the climate is unfavorable, or if someone inadvertently steps on them, they do not survive. For this reason, Cockpit Resource Management cannot stop at the classroom door. A full-fledged CRM program also must address the context within which crews operate to ensure that organizational policies and practices support rather than undermine the use of CRM skills. Our research thus far has identified six different arenas in which contextual influences--the factors in the outermost circle--can either reinforce or compromise what is taught in the CRM classroom.

<u>Scheduling and rostering practices</u>. Ideally, members of a crew would work together for a considerable period of time, so members have ample opportunity to build themselves into a superb performing unit. Moreover, on any given trip they would fly the same aircraft and work with the same cabin crew. The advantages of a crew having integrity and stability over time are evident in our research and are documented as well in an experimental study conducted by Clay Foushee and his associates (1986).

Airline practice often is at variance from this ideal (although some military organizations, such as the Strategic Air Command, closely approximate it). In one organization we studied, for example, a normal day's flying could involve two or three changes of aircraft and as many different cabin crews. In another carrier, it was not uncommon for the cockpit crew itself to have one or two changes in composition over its life.

Constant changes in cockpit crew composition deprive members of the time and experience they need to build themselves into a good team. Frequent changes of equipment tempt the crew to take shortcuts in accepting an aircraft (when, for example, the crew has to dash down the concourse from a late-arriving inbound flight to pick up a new airplane for an already-late outbound flight). And frequent changes in cabin crew decrease the chances that the Captain will conduct a proper briefing of the lead flight attendant of yet another new cabin crew. Overall, scheduling and rostering instability constrains a crew's ability to "settle in" and develop performance strategies and routines that are uniquely suited to the particular demands and opportunities of a given day's work.

Some real efficiencies in the use of personnel and equipment can be achieved if pilots, flight attendants, and aircraft are switched around from day to day, or even within a given day. The financial benefits of these efficiencies can, with a little effort, be calculated--and they probably are substantial. What cannot be calculated so readily are the costs to crew performance that are incurred when organizational scheduling and rostering practices make it next to impossible for a crew to become established as a stable task-performing unit. Our research suggests that these costs may be substantial--and, indeed, that the full benefits of CRM training may never be realized if crews are kept constantly in a state of flux.

Norms of conduct enforced by flight standards. Ideally, training staff and check airmen would be fully conversant with, and supportive of, what is taught in Cockpit Resource Management courses. CRM concepts would be reinforced in recurrent and upgrade training. Debriefings from check rides would review how the crew operated as a team as well as members' technical performances, and check airmen would both reinforce constructive team behavior and help members identify behaviors that may have detracted from good team functioning.

Once again, standard practice in the airlines we have studied often is at variance from the ideal. Check airmen typically are selected on the basis of their technical skills (coupled, in many cases, with being in the right "network" and known to chief pilots or flight standards managers). We also find considerable variation in the degree to which check airmen themselves understand and practice good cockpit resource management. Some are deeply knowledgeable about such matters, and take it as a personal responsibility to share their knowledge with other pilots and to reinforce behaviors that contribute to effective teamwork. Others, to state it bluntly, view CRM as bullshit: they focus exclusively on the technical aspects of flying, confident that one day CRM, like so many previous programs, will be history. The damage that can be done by even one individual with this attitude is considerable. One Captain told us of an instance when a colleague, fresh from CRM training, noticed an anomalous instrument reading while being given a check ride. He turned to the First Officer and asked for his views about what could be responsible for the strange behavior of the instrument. "Just a moment," interjected the check airman. "I'm checking you, not him. You figure it out." That kind of intervention by someone who has control over your career can un-do days of first rate CRM training.

In all the organizations we have studied, check airmen, like regular line pilots, go through whatever CRM training the organization offers. As yet, however, we have not seen an organization where selection for the role, or continued occupancy of it, requires that check airmen demonstrate their own expertise in CRM. Nor do the airlines we have studied explicitly require check airmen to address CRM items in their debriefings--although there is movement in this direction at a number of carriers. I applaud that movement, because it seems unlikely that CRM will take root and spread until and unless check airmen, who are the front line of quality control, endorse and behaviorally reinforce CRM values.

Pilot selection criteria. Ideally, cockpit crews would be composed of individuals who are well-skilled both in the technical aspects of flying and in working in teams. One of the vulnerabilities of teams is that a single member who is unable or unwilling to work collaboratively can easily undermine the effectiveness of an entire team. And there are some people, including some pilots, who are just not cut out for teamwork.

Once a pilot has been hired, the organization's commitment must be to work with and develop him or her as a crewmember. I doubt that any airline would terminate a pilot solely because he or she was not a good "team player," nor would I advocate such action: the threat of being fired makes it harder, not easier, to learn team skills. Far preferable is for organizations to reinforce positive team behavior and to coach individuals who have trouble working in teams so that they become as skilled as possible in team work.

The time when choices can be made, then, is not after someone is already on the line, but when he or she initially is considered for employment. If every individual selected had at least rudimentary skill in working in teams, then over time the total population of pilots in an organization would become increasingly amenable to team-oriented resource management training and to skilled use of that training on the line.

While it is not simple to assess the interpersonal or team skills of prospective pilots, it is no more difficult or dubious an enterprise than using personality tests for selection--a routine practice at many carriers. Interviews and paper-and-pencil tests can be of some help in assessing team skills, but cannot be relied upon exclusively. Perhaps most informative would be observations of prospective pilots actually operating in a team settings (such as in a group of applicants working on a problem assigned them by selection staff). Observers could be trained to assess the skills that each participant demonstrates in the group setting, and those data could be combined with information from tests and interviews to arrive at an employment decision.

While such procedures would be unusual in most air transport organizations, the long term benefits of basing pilot selection for crewed aircraft partly on team skills are considerable. Organizations surely should do whatever they can to ensure that each flight crew begins its work atop the highest possible "platform" for team formation and development that the organization can provide. A key feature of such a platform, in my view, is that the pilot population itself be composed, to the greatest extent possible, of people who find team work agreeable--and who have at least the basic interpersonal skills needed for team work.

Organizational reward systems. Ideally, excellent team performance by cockpit crews should be recognized and rewarded by their organizations. Such rewards would signal to pilots the importance that the organization places on teamwork and would provide an incentive for continued striving for excellence.

Teams as whole units occasionally are recognized by their organizations, usually when a crew has surmounted an extraordinary performance challenge such as a hijacking or a catastrophic mechanical failure. [4] But what about crews that turn in consistently first rate performance every day? How does an organization recognize a team that has become expert in doing the quiet persuading of others that so often is needed to achieve on-time departures, that routinely deals well with passengers, that operates the aircraft with great efficiency, and that takes a multitude of small extra steps to promote safety and comfort?

Is it even possible for an organization to recognize and reward routine excellence by flight crews? Or is it necessary to rely exclusively on rewards that are self-administered by teams--that is, on the collective good feeling that comes when a team knows that it has done a first rate job? Clearly, it is nearly impossible for an organization to recognize and reward crew performance if crew composition is constantly changing: by the time relevant data become available, the crew no longer exists. If crews are relatively stable, however, a number of possibilities become available. For example, information that routinely is collected for use by management (such as data about fuel burn, passenger complaints and compliments, on-time pushbacks, and so on) could be summarized and routinely passed onto crews. These data would serve two purposes. First, members would have the data they need to monitor their own effectiveness over time, to initiate corrections of chronic problems, and to seek ways of operating that generate performance improvements. Moreover, crews would experience that special good feeling that comes when members know that others in the organization are aware of, and appreciate, their efforts and accomplishments.

Mundane material resources. Ideally, a cockpit crew would never encounter a delay or an unsafe situation merely because the resources (for example, equipment, paperwork, supplies) needed for the work were not available. Among the saddest of all crew failures are those that occur when a team is well designed, well staffed, and well led--but nonetheless unable to succeed because mundane material resources are late or inadequate, or because members have become frustrated and angry in trying to obtain them.

Providing resources and support, in ample supply and on time, is especially challenging for managers of air transport organizations because so many different items must be available and coordinated if a trip is to unfold smoothly. Far too often it falls on the crew to try to figure out how to deal with the absence or tardiness of such basic resources as catering, fuel, de-icing, a tug--or even the aircraft itself. It is hard to focus on achieving superb team performance when you do not even have what you need to accomplish your most basic responsibility--namely, getting an aircraft away from the gate and flown safely to a specified destination.

Managers who place a high priority on providing crews with basic material resources do much to empower the crews for which they are responsible, and to enable crews to give full attention to _their_ special responsibilities--without constant distractions and irritations from problems that are properly someone else's concern.

Regulatory policies and practices. A final set of contextual influences, the policies and practices of government regulators, is located entirely outside the organization. Ideally, these policies and practices also would reinforce CRM ideals. In practice, however, regulations and regulators sometimes get in the way rather than help--even though their intentions invariably are constructive. Thus, airline managers, who often are in a better position than are policy-makers to identify any unintended negative consequences of government actions, need to exercise influence with regulators to ensure that this outermost layer of the context also promotes rather than undermines effective teamwork in the cockpit.

We have observed airline managers take initiatives with regulators to influence proposed rule-making, to obtain exceptions to existing rules, and to influence actions regulatory staff are considering taking vis-a-vis the organization or a pilot in its employ. These are appropriate activities, particularly if they are guided by an overall crew management philosophy and if managers avoid the trap of routinely objecting to any and all regulatory initiatives. But more can be done and, in some organizations, is being done. Some airlines, for example, invite representatives of government agencies to attend CRM courses as participants. They hold informal briefings about the organization's CRM philosophy, and actively seek the ideas and advice of government representatives. They share with them the things that are being done within the organization to strengthen crews as teams and explore with them ways that regulators might be able to help.

Not all government representatives are responsive to such initiatives--but most do recognize that ultimately the goals of the public and the industry, of pilots and passengers, are for the most part congruent. If, by taking constructive initiatives with regulatory agencies, airline managers can achieve the kind of relationship that many carriers already have with their pilot unions (that is, in which there are legitimately adversarial features but also recognition that all parties share fundamental values regarding safety and organizational survival) then these managers will have done much, in a setting about *as far removed from the CRM classroom as one can get, to promote the* implementation of the concepts and skills that are taught in CRM courses.

Conclusion

Cockpit resource management training is moving to the next stage in its evolution. While training that focusses on individual attitudes and skills continues to be important in CRM programs, there is an increasing emphasis on what is required to build, lead, and organizationally support crews as teams. In this paper I have identified some factors suggested by our research that may be worthy of attention in getting CRM established on this next, higher plateau.

In the early days of CRM, attention appropriately was focussed on basic questions of course design, on the construction of LOFT scenarios, and on what was necessary to persuade both airline managers and pilots that CRM activities were worth the trouble and expense. Although there are always opportunities to further refine and improve instructional materials and techniques, and there are always some recalcitrant individuals who need to be convinced that resource management is not just an expensive and irrelevant feel-good activity, it is now time to move on to new challenges.

Our research shows that those challenges have much to do with how well crews are composed, structured, and supported by their organizations--and with the degree to which regulatory policies and practices support teamwork on the flight deck. Indeed, I suspect that among the highest leverage activities managers can undertake to harvest the benefits of their investments in cockpit resource management are those that seek to improve both the basic design of crews as performing units and the supportiveness of the organizational contexts within which those crews operate.

Footnotes

[1] This paper was prepared for delivery at the ICAO Human Factors Seminar, Leningrad, April, 1990. The paper draws heavily on a presentation by the author at the Seventh General Flight Crew Training Meeting of the International Air Transport Association, New Orleans, February, 1988. Parts of the paper also draw on material originally presented by Hackman (1986) and Hackman and Helmreich (1987). The research on which the paper is based is supported by Cooperative Agreement NCC 2-457 between the Ames Research Center of NASA and Harvard University. Helpful comments on have been provided by Robert Ginnett, Linda Orlady, and Tom Salmon.

[2] Members include Linda Orlady of United Airlines, Robert Ginnett of the U.S. Air Force Academy, and Clay Foushee of the Federal Aviation Administration. We also have received valuable counsel and assistance from Robert Helmreich and his associates at the University of Texas.

[3] My credibility on this topic may be lessened somewhat by what happened when I participated as a guest in one carrier's CRM program. I took the test that was offered and, upon plotting my scores, discovered that my characteristic behavioral style was most similar to that of "housewife." Moreover, I was predicted to behave even more like a "housewife" when under stress. This category was not viewed by other participants as among the most desirable. Although they acknowledged that a university professor might well fall into it, a real pilot surely would not. We all laughed about the episode, but I could not help wondering about the feelings of those pilot participants who shared the category with me.

[4] Once again, some military organizations have an advantage: not only do crews remain intact, but training missions are scored on objective criteria (such as bombs on target) and teams that perform well are explicitly recognized and rewarded.

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Determinants of Flightcrew Performance

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ABSTRACT Five critical determinants of flightcrew behavior, *ABILITY, PERSONALITY,—ENVIRONMENT, TRAINING*, and *SYNERGY*, are discussed in relation to an ongoing NASA research program. Major findings and methodological issues are discussed. It is suggested that personality factors have been relatively neglected and should be given additional weight. Problems in changing organizational culture and reinforcing training in crew coordination (Cockpit Resource Management) are described.

The authors have been involved in a study of flightcrew performance for nearly a decade. This program, supported by NASA and participating organizations, involves US and foreign airlines, and units of military aviation. Its primary goals are to evaluate and enhance crew selection and crew training. The study is unique both in being *longitudinal* and in attempting to assess the multiple influences on crew performance. Most research has dealt with one or at most two determinants of performance. This report will attempt to highlight key research issues and operational progress in and across areas.

Ability. The screening of applicants for flight on ability dimensions extends back to the First World War and has included both paper and pencil and psychomotor tests and an extensive literature reports the validity of these endeavors. Our research has not been focused on the issue of ability and our own work has not gone further than the use of standardized measures of intelligence to classify crewmembers and we do not plan to reinvent the wheel. However, we are concerned with assessing the impact of *cockpit and system automation* and how they may change the ability requirements for crewmembers (e.g. Wiener, 1989). Forthcoming generations of aircraft may require less in terms of psychomotor skills and more in the cognitive areas of vigilance and facility with computers. While we are collecting data on "glass cockpit" aircraft, we have not yet been able to draw any conclusions about requirements.

Personality. While pilots have long known that personality factors are major influences on crew performance and interactions, research psychologists have not always shared this belief (e.g. Helmreich, 1986). In fact, the research literature would justify a high degree of skepticism as little hard evidence can be found for the utility of personality traits as predictors of performance. We feel that there are two primary causes for personality's poor track record - the use of inappropriate performance criteria and a concentration on screening out psychopathology rather than selecting in for optimal performance. Examining the literature on pilot selection, one finds that the criteria most often employed are completion of training or performance in training. Our research (Helmreich, Sawin, & Carsrud, 1986) suggests that personality relates much more strongly to performance in operational settings than to behavior during training where motivation to obtain the position may override the influence of stable personality traits - a phenomenon we have labeled the "honeymoon effect".

We have found a constellation of personality traits that predicts superior performance in a variety of demanding vocations including aviation (Helmreich, 1986, 1987; Chidester & Foushee, 1989; Chidester, Helmreich, Gregorich, & Geis, submitted for publication, Spence & Helmreich, 1983). These traits form two broad dimensions - *instrumentality* or achievement motivation and *expressivity* or interpersonal competence and sensitivity. Individuals high on both dimensions have been demonstrated to perform better in multi-person crews during both line operations and experimental simulations. These trait dimensions are orthogonal to ability.

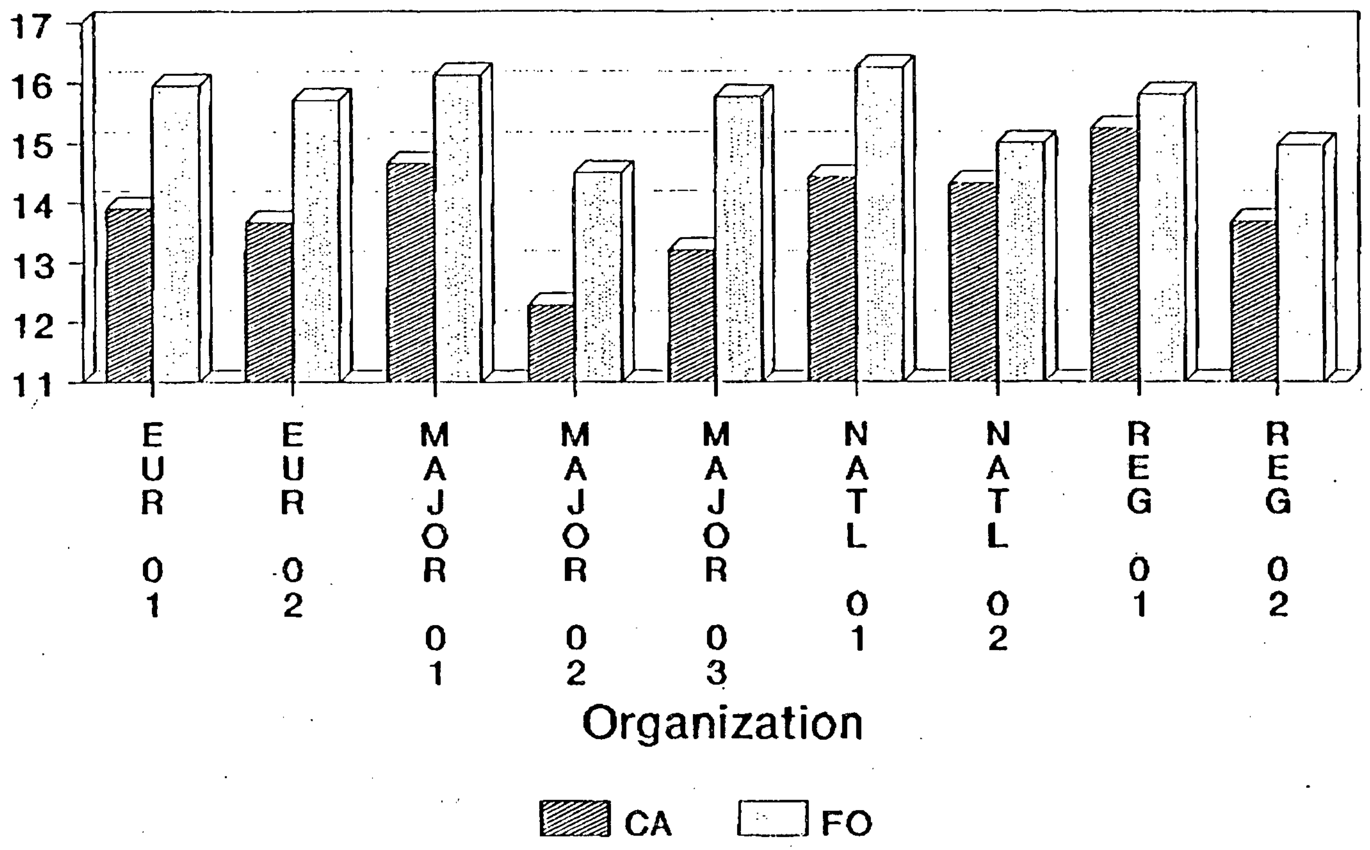
Much of the effort by psychologists in selection has centered on detecting and eliminating candidates who show signs of present or incipient psychopathology. We do not question the importance of this task or argue that clinicians and clinically focused psychometric instruments such as the the *Minnesota Multiphasic Personality Inventory (MMPI)* cannot accomplish this. We do suggest that measures designed with a clinical orientation may not tap factors related to superior performance. We are currently conducting research on Astronaut selection in NASA and have just collected data on the most recent group of candidates (Santy, Rose & Helmreich, 1989). This research is aimed at defining requirements for long duration missions in Space Station Freedom and the results were not used in selecting the current class. The most striking finding was the *lack* of congruence between judgments based on clinical measures (including the *MMPI* and structured interviews) and evaluations based on the personality battery aimed at "selecting in" the best qualified candidates. We feel that this is an extremely important area for research and that, in the case of selecting individuals for sensitive and demanding positions, the optimum strategy may prove to be to conduct parallel assessments to screen out psychopathology and to select in those with the most favorable constellation of desirable traits.

Environment. Professor J. Richard Hackman (1986) has referred to the setting in which flight operations occur as the "organizational shell". The shell includes the physical resources made available to the crews including training and maintenance and the culture and norms that have developed in the organization and industry. Certainly one of the overarching norms that dates back to the earliest days of aviation is training and checking pilots as *individuals* rather than crews (e.g. Hackman & Helmreich, 1987; Helmreich, Hackman, & Foushee, in preparation).

As part of our research we have been collecting data on crewmembers' attitudes about issues in cockpit management and personal characteristics using our *Cockpit Management Attitudes Questionnaire (CMAQ*: Helmreich, 1984; Gregorich, Helmreich & Wilhelm, in press). We now have data from nearly twenty thousand crewmembers in three countries on this twenty-five item survey. The items of the *CMAQ* form three major factors that we have labeled *Communications and Coordination* - items dealing with interpersonal communications and interactions, *Command Responsibility* - dealing with leadership and command issues, and *Recognition of Stressor Effects.* - reflecting awareness of the impact of various kinds of stressors such as fatigue, family problems, and emergencies on personal capabilities. These attitudes have been validated as predictors of crew performance (Helmreich, Foushee, Benson & Russini, 1986) and also provide a glimpse of the "shell" within organizations. We anticipated substantial differences between organizations but were surprised by several other findings. One was the existence of highly significant differences within organizations as a function of crew position. We found that Captains, First Officers, and Flight Engineers differed substantially in their attitudes regarding appropriate cockpit management. Again within organizations, we have routinely found large differences between aircraft fleets. Figure 1 shows data on the *CMAQ* Command Resposibility factor prior to *CRM* training in nine airlines from the U.S. and europe. We feel that the existence of differences in attitudes about flightdeck management within the cockpit must be reflected in less than optimal crew performance and further that the improvement of attitudes and elimination of such differences and may be used as a criterion of training efficacy.

Training. Our work is centered on experienced crews in organizations with highly developed training programs. As a result, we have been able to assume a high level of technical training and competence among research subjects. Accordingly, our research into training has centered on

Fig. 1 Command Responsibility Score on the CMAQ - 9 organizations



Captains and First Officers Only

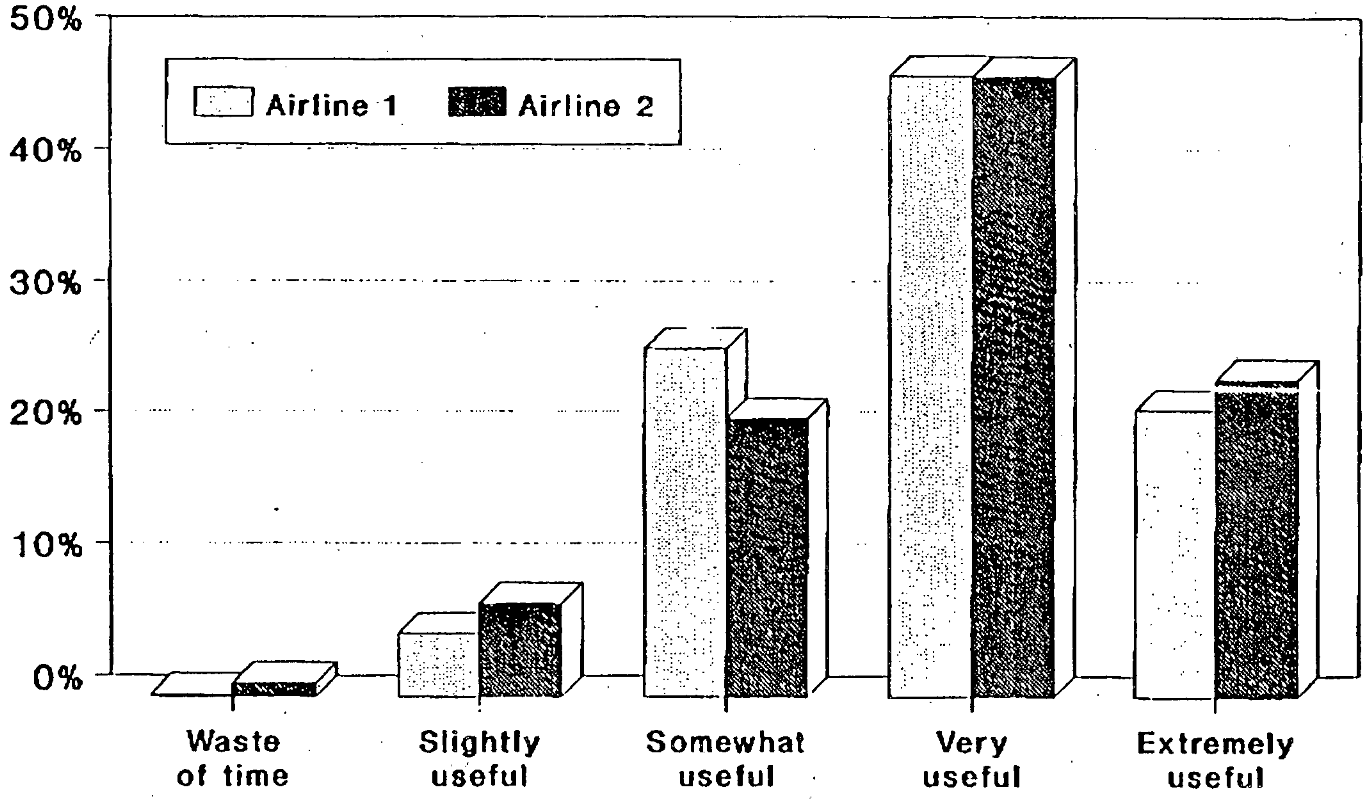
programs designed to improve crew coordination, usually titled *Cockpit Resource Management* training. Such programs are becoming widespread and are optimally combined with full mission simulations (*Line Oriented Flight Training: LOFT*) to allow crewmembers to practice and receive feedback on techniques of communications, decision making, and coordination. It seems highly likely that *CRM* and *LOFT* will be required by regulation in the United States within a few years. Both programs are described in recent or forthcoming *Advisory Circulars* issued by the U.S. Federal Aviation Administration.

We utilize changes in attitudes and participant evaluations as two measures of reactions to *CRM* and *LOFT*. The results are highly consistent, crewmembers overwhelmingly endorse the training as valuable. Figure 2 shows the post-training evaluations of the usefulness of the course in two major airlines. We have also found highly significant improvements in attitudes in every organization. Figure 3 shows pre- and post-training attitudes on the Command Responsibility scale in a major airline. Ratings of crew performance in both line and simulator also suggest better performance from crews who have received formal training in *CRM* (Helmreich, Gregorich, Wilhelm, & Chidester, in press).

Despite these positive indications, the research suggests that some problems remain and that much can and should be done to make the training more impactful. One consistent finding is that, despite the high overall acceptance, some crewmembers reject the training and may even emerge with less favorable attitudes than they brought - a *boomerang effect* (Helmreich & Wilhelm, 1989). As an indication of the complex relationships among the determinants of crew performance, we have found that reactions to *CRM* training are predicted by personality constellations. This suggests that personality may be a limiting factor on the impact of training. An important topic for research is whether training may be customized to deal with individual personalities or whether some individuals may simply be unamenable to the concepts taught.

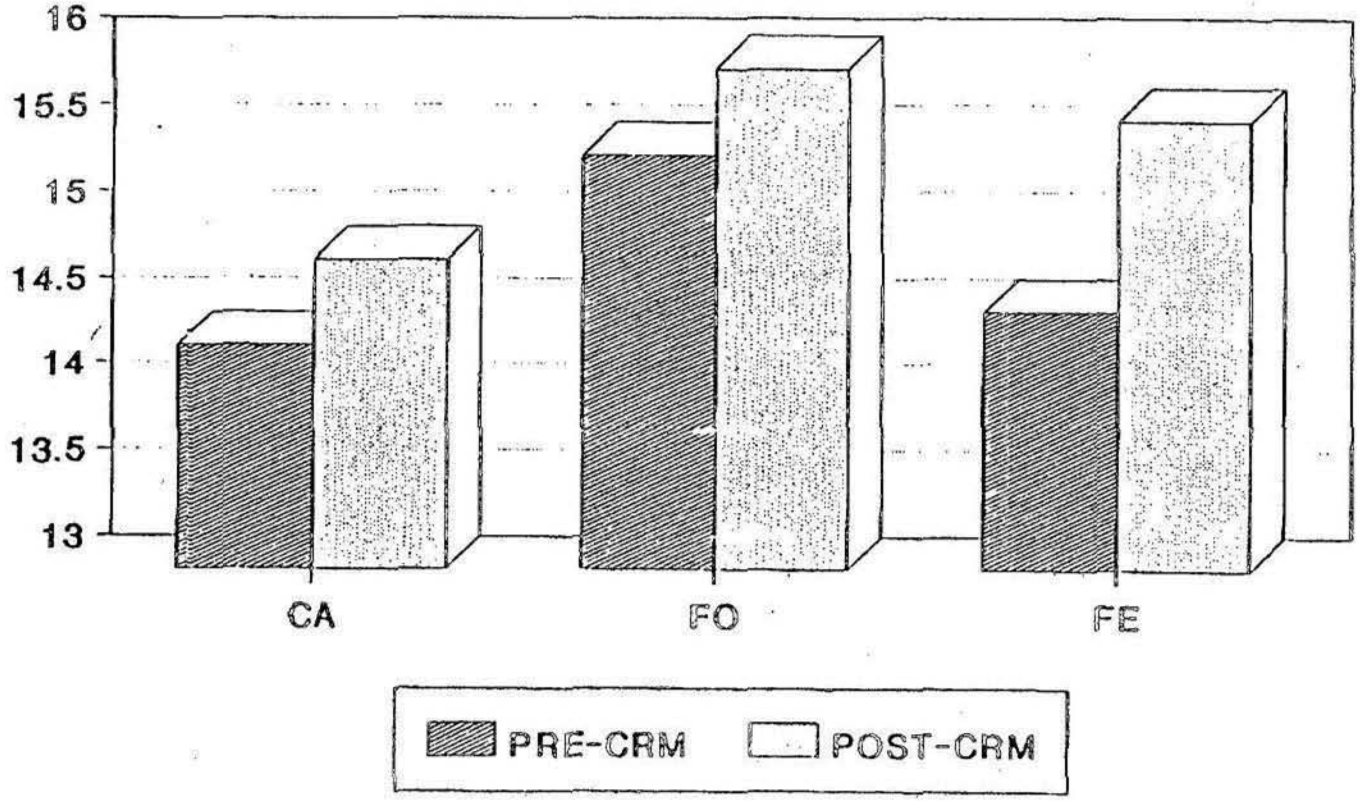
While there is a consensus in the industry that *LOFT* is an essential means of reinforcing the concepts taught in *CRM* training, research suggests that the potential of this tool is seldom reached (Helmreich, Kello, Chidester, Wilhelm, & Gregorich, 1990; Helmreich, Chidester, Foushee, Gregorich, & Wilhelm, 1989; Helmreich, Wilhelm, & Gregorich, 1988; NASA/UT 1990). The training of *LOFT* Instructors is frequently spotty and fails to give them the tools needed to evaluate crew performance and to provide meaningful feedback to participants. The same criticism can be leveled at the selection and training of Check Airman as they are the key role models who are in a position to

Fig. 2. Percentage Ratings of Usefulness of the Initial CRM Seminar in Two Airlines



Data are from line airmen only

Fig. 3. Attitudes on the CMAQ Command Responsibility Scale as a Function of CRM Training



Higher scores indicate more favorable attitudes

enhance or undermine an otherwise good training program. Indeed, Check Airmen and *LOFT* Instructors may be the most critical element of the "shell" as it influences crew performance.

One of the most heralded innovations in *LOFT* is the videotaping of crews and the use of the tape in debriefing. In practice, however, we have found that this resource is frequently ignored or underutilized. Indeed, crews that perform well are often told that since their performance was good, there is no need to view the tape - thus losing a chance to reinforce positive behavior.

We feel that Check Airmen and *LOFT* Instructors should both receive formal training in *CRM* and should also be enthusiastic advocates of its concepts. We also believe that they should receive special, additional training that focuses on formal evaluation of crew behavior and techniques of effective debriefing. Because our project utilizes these two groups as *expert raters* to evaluate the impact of training, we have become involved in developing a model course for Check Airmen and *LOFT* Instructors.[2] The training utilizes videotapes of *LOFT* sessions with crews reflecting "good", "bad", and "average" manifestation of *CRM* concepts. Participants practice rating the crews observed on multiple elements of communication and coordination utilizing the *NASA/UT Line LOFT Worksheet* (Helmreich, & Wilhelm, 1987), a form developed specifically for the evaluation of *crew* performance. Particular attention is paid to defining *behavioral markers* that denote effective or ineffective practice of crew coordination.[3] Training is also given in debriefing techniques and the optimum use of video. It is too early to assess the impact of this training, but we are optimistic that it will enhance both the quality of evaluation-data and the acceptance of *CRM*.

Another critical issue is the design of scenarios for *LOFT* and their integration with initial and recurrent training in *CRM*. Our preliminary conclusion is that scenarios should be developed to exercise particular concepts taught in formal training and should force crews to interact in formulating the solution to a problem without a simple "book solution". We find that in many cases the goals of scenarios are not clearly specified and leading Instructors to modify procedures in accordance with personal preferences with the result that training is highly variable. Despite these observed problems, crewmembers are enthusiastic about *LOFT* and feel that it provides them with valuable training.

Synergy. The formal definition of *synergy* is "working together" and it has become something of a buzzword among those involved in *CRM* training. It is used to emphasize the fact that the behavior of a crew may reflect more than the sum of individual competence and actions. We feel that the concept is critical to the issue of performance and that it has been relatively neglected in aviation psychology. It is certainly axiomatic among aviators that some combinations of individuals produce extremely effective teams while others composed of equally competent individuals result in are quite ineffective. Despite this operational awareness, research has failed to concentrate on isolating the causes of variations in crew as opposed to individual performance. This is the domain in which the multiple determinants of performance intersect.

Personality is obviously implicated. Just as we have learned that some personality constellations are predictive of performance, we are beginning to note the obvious corollary that certain combinations of personalities result in more effective team performance.

The *Environment* is also involved as it has fostered the individualistic tradition in aviation which includes evaluating pilots primarily on the basis of solo, technical proficiency.[4] We are starting to see a shift in both practice and regulation towards greater concern with the crew as a team.

Training is also critical as recognition of synergy requires a change in toward more group oriented training and the development of new techniques for evaluation. The rapid acceptance of *CRM* and *LOFT* is a good indication that major changes are underway.

It is ironic that research has lagged behind practice in this. The study of group behavior has been a relatively neglected area in psychology, in part due to the difficulty in studying such complex phenomena. It is our belief that the growing emphasis on synergy in aviation will serve as a major impetus for new research.

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[2] Wm R. Taggart of Resource Management Associates is collaborating in the development of this course in conjunction with his work for the FAA and in the development of *CRM* training for Southwest Airlines. Dr. John Kello of Davidson College is also participating in this work during his tenure as a NASA Visiting Scientist at the University of Texas. We wish to acknowldege with gratitude the assistance and cooperation of Southwest Airlines in developing this training.

[3] The *CRM* course developed by Captain Robert Mudge of Cockpit Management Resources and employed by Scandinavian Airlines utilizes "Specific Behavioral Objectives" (*SBO's*), behaviors that should be practiced to maximize *CRM* effectiveness. *SBO's* conceptually are highly similar to behavioral markers.

[4] We are in no sense denigrating the importance of individual technical skills and training in specific procedures. Rather we are arguing that organizations need to select individuals with both the right technical aptitude and with personalities reflecting interpersonal efficacy.

FLIGHT CREW QUALIFICATION

by

J. Kern

GOOD MORNING AND THANK YOU VERY MUCH. I'M HONORED TO HAVE THIS OPPORTUNITY TO SHARE WITH YOU THE FEDERAL AVIATION ADMINISTRATION'S VIEW OF AIRCREW AND MAINTENANCE TRAINING PROGRAM REQUIREMENTS. I WISH TO EXPRESS MY GRATITUDE TO THE INTERNATIONAL CIVIL AVIATION ORGANIZATION FOR SPONSORING THIS VERY WORTHWHILE "FIRST-OF-A-KIND" SEMINAR ON HUMAN FACTORS AND TO THE SOVIET MINISTRY OF CIVIL AVIATION FOR ACTING AS A VERY GRACIOUS HOST FOR ALL OF US. IT IS THE EXPRESSED POLICY OF THE U.S. FAA TO PROMOTE AND FOSTER THIS KIND OF INFORMATION EXCHANGE AT EVERY POSSIBLE OCCASION.

IN PREPARING MY THOUGHTS FOR TODAY, I REFLECTED ON MY OWN EXPERIENCES IN AVIATION TRAINING. LIKE MANY OTHER PROFESSIONAL AVIATORS, I AM A GRADUATE OF A MILITARY FLIGHT TRAINING PROGRAM. AT THE TIME I BEGAN TRAINING, MILITARY ORGANIZATIONS THROUGHOUT THE WORLD NOT ONLY HELD THE KEY TO TECHNOLOGICAL DEVELOPMENT IN AVIATION, BUT HAD ALSO LED THE WAY IN DEVELOPMENT OF THE TRAINING METHODS USED TO QUALIFY AIRCREW MEMBERS. THE UNITED STATES MILITARY SERVICES TRAINED AND QUALIFIED A LARGE NUMBER OF NEW PILOTS AND AIRCRAFT MECHANICS EACH YEAR. FOR THOSE OF US OLD ENOUGH TO REMEMBER, FUEL COSTS WERE RELATIVELY INSIGNIFICANT IN THOSE DAYS AND YOUNG AIRCREW MEMBERS WERE ABLE TO FLY ENOUGH TO BECOME WELL EXPERIENCED ON THE MOST MODERN AVAILABLE AIRCRAFT.

MY EXPERIENCE WAS PROBABLY NOT MUCH DIFFERENT THAN THAT OF OTHER YOUNG MEN IN OTHER COUNTRIES. MY MILITARY FLIGHT TRAINING INVOLVED LEARNING TO FLY USING AIRCRAFT AND EQUIPMENT MANUFACTURED AND DESIGNED IN MY OWN COUNTRY. INSTRUCTOR TECHNIQUE, TRAINING MATERIALS AND TRAINING METHODS WERE SPECIFICALLY RELATED TO PREPARING YOUNG MEN FOR FULL CAREERS IN MILITARY AVIATION. WHENEVER ONE OF THESE WELL-TRAINED INDIVIDUALS DID NOT COMPLETE A FULL MILITARY CAREER, THE DOOR TO OPPORTUNITY IN CIVIL AVIATION WAS IMMEDIATELY OPENED. THE AIRLINES AND BUSINESS AVIATION HAD, FOR A PERIOD OF 35 YEARS, A SEEMINGLY ENDLESS SUPPLY OF WELL-EDUCATED, HIGHLY TRAINED AIRCREW MEMBERS WHO REQUIRED ONLY A MINIMUM OF CONVERSION TRAINING TO FLY CIVILIAN AIRCRAFT. IN MOST CASES, THESE CIVIL AIRCRAFT WERE DERIVATIVES OF THE MILITARY AIRCRAFT THESE YOUNG PILOTS HAD PREVIOUSLY FLOWN PERMITTING GREATLY SIMPLIFIED TRAINING REQUIREMENTS. HOWEVER, DURING THE 1970'S, ECONOMIC FORCES BEGAN TO PROMOTE THE INTERNATIONALIZATION OF AERONAUTICAL PRODUCTION. THIS WAS TO HAVE A PROFOUND EFFECT ON AIRCREW TRAINING REQUIREMENTS. IN THE FIRST PLACE, THIS INTERNATIONALIZATION OF PRODUCTION HAS CAUSED A RAPID GROWTH IN AIR TRANSPORTATION REQUIREMENTS. IN RESPONSE TO THOSE REQUIREMENTS, A HOST OF NEW AIRCRAFT HAVE BEEN DESIGNED AND BUILT SPECIFICALLY FOR EMPLOYMENT IN CIVIL AIR TRANSPORTATION. IN RESPONSE TO THOSE SAME AIR TRANSPORTATION REQUIREMENTS, IT HAS BECOME COMMON TO SEE THE MOST ADVANCED TECHNOLOGIES APPEAR FIRST IN CIVIL AIRCRAFT IN A REVERSE OF THE PREVIOUS PRACTICE OF CONVERTING MILITARY AIRCRAFT FOR CIVILIAN USE, WE NOW FIND CIVILIAN AIRCRAFT BEING ADAPTED FOR MILITARY USE. THIS GROWTH IN TRANSPORTATION REQUIREMENTS HAS ALSO BEEN ACCOMPANIED BY NEED FOR A SUBSTANTIAL NUMBER OF NEW AIRCREWS. WE BELIEVE THAT THE NUMBER OF AIRCREW MEMBERS WHICH WILL BE REQUIRED IN THE NEAR FUTURE IS GREATER THAN THAT WHICH CAN BE PROVIDED BY ATTRITION FROM MILITARY CAREERS.

IN THE FUTURE AIRLINE TRAINING ENVIRONMENT, PREVIOUS MILITARY AIRCREW EXPERIENCE WILL NOT PROVIDE THE TRAINING AND EXPERIENCE BENEFITS WE HAVE ENJOYED IN THE PAST. ONE REASON FOR THIS LOSS OF BENEFIT IS THE SIMILARLY RAPID DEVELOPMENT OF NEW MILITARY REQUIREMENTS. MILITARY ORGANIZATIONS HAVE HAD TO COPE WITH NEW TACTICAL PROBLEMS IN TRAINING CREWS FOR THEIR FIGHTING AIRCRAFT. THESE MILITARY AIRCREW MEMBERS WHILE FULLY QUALIFIED IN TACTICAL AIRCRAFT ARE NOT COMPLETELY TRAINED IN OPERATIONS COMPATIBLE WITH FLYING CIVILIAN TRANSPORTS. IN MANY CASES THEY NEED EXTENSIVE RETRAINING TO DO SO. IN ADDITION, TACTICAL AIRCREWS QUALIFIED ON MODERN, LEADING EDGE TECHNOLOGY AIRCRAFT ARE CONSIDERED A PRECIOUS COMMODITY BY THEIR MILITARY ORGANIZATIONS. THESE ORGANIZATIONS DO EVERYTHING POSSIBLE TO MAKE A FULL MILITARY CAREER ATTRACTIVE AND TO DISCOURAGE TRANSFER OF THESE HIGHLY SKILLED YOUNG MEN AND WOMEN TO AIRLINE OR BUSINESS AVIATION EMPLOYMENT. WITH RESPECT TO TRAINING AND QUALIFYING PROFESSIONAL AIRCREWS, WE RECOGNIZED THAT CURRENT CONDITIONS HAVE LEFT US IN A CHALLENGING POSITION IN THE UNITED STATES. HOWEVER, WE SOON DISCOVERED WE WERE NOT ALONE. THE SAME CONDITIONS SEEM TO APPLY THROUGHOUT THE INTERNATIONAL AVIATION COMMUNITY. THE UNITED STATES, AND TO A GREATER OR LESSER DEGREE OTHER NATIONS, HAD ENACTED FLYING REGULATIONS, DEVELOPED AIRCREW QUALIFICATION STRATEGIES, AND DEPLOYED TRAINING RESOURCES IN A MANNER DEPENDENT ON THE ASSUMPTION THAT A LARGE POPULATION OF MILITARY TRAINED PILOTS AND MECHANICS WOULD BE CONTINUOUSLY AVAILABLE. WE CAN NO LONGER RELY ON THAT ASSUMPTION. TOGETHER WE FACE A POTENTIAL GLOBAL SHORTAGE OF QUALIFIED AIRCREW MEMBERS BY THE MID 1990'S.

IN THE UNITED STATES, WE HAVE VERY LITTLE RECENT EXPERIENCE IN SELECTING CIVILIANS WITHOUT PREVIOUS AVIATION EXPERIENCE FOR

EDUCATION AND TRAINING AS PROFESSIONAL PILOTS OR MECHANICS. THEREFORE, WE HAD NO HISTORIC STRATEGY TO DEAL WITH THE POTENTIAL OF A CREWMEMBER AND MECHANIC SHORTAGE. IN OTHER PARTS OF THE WORLD, ENGLAND, GERMANY, JAPAN, AND OTHERS THIS SELECTION PROCESS HAS BEEN ONGOING FOR SOME TIME. THE U.S. WILL BE SEEKING TO BUILD UPON THEIR ALREADY VAST EXPERIENCE. ONCE WE ACKNOWLEDGED THE PROBLEM, WE HAD TO SEEK MEANINGFUL ALTERNATIVE SOLUTIONS. IT WOULD BE NICE TO TELL YOU WE HAVE BEEN SUCCESSFUL AND HAVE A SINGLE SIMPLE, SOLUTION THAT WILL FIT ALL NEEDS. THAT IS NOT THE CASE. THE AIRCREW QUALIFICATION ISSUE WILL REQUIRE INVESTIGATING MULTIPLE SOLUTIONS AS THEY ARE DEVELOPED WITHIN THE INTERNATIONAL AVIATION COMMUNITY. IN THE UNITED STATES, WE HAVE INITIATED SEVERAL REGULATORY CHANGES WHICH WE BELIEVE WILL PREPARE US TO TRAIN CIVIL AIRCREWS AND MECHANICS IN RESPONSE TO THE NEEDS OF THE INTERNATIONAL AIR TRANSPORTATION INDUSTRY DURING THE 1990'S AND BEYOND. WE HAVE BEGUN A PROCESS OF ANALYZING THE JOBS PILOTS AND MECHANICS DO. THIS PROCESS IS CALLED JOB, TASK ANALYSIS OR JTA. THESE ANALYSES ARE CONDUCTED TO DETERMINE WHAT TASKS ARE TO PROVIDE THE KNOWLEDGE, SKILLS, AND ABILITIES AND OTHER ATTRIBUTES NECESSARY TO DO THOSE SPECIFIC TASKS. THIS TYPE OF ANALYSIS WILL PROVIDE THE BASIS FOR A DYNAMIC PROCESS OF IDENTIFYING NEEDED CHANGE IN REGULATIONS DEALING WITH AIRCREW AND MECHANIC QUALIFICATIONS.

WE HAVE BEGUN WORK TO ASSIST SEVERAL UNIVERSITIES IN DEVELOPING A PARTNERSHIP WITH THE AVIATION INDUSTRY (INCLUDING THE AIRLINES) WHICH RESULT IN THE AVAILABILITY OF PROFESSIONAL AIRMANSHIP CURRICULAE, WHICH ARE SPECIFICALLY INTENDED TO PROVIDE FULLY QUALIFIED GROUND AND AIRCREWS FOR THE INTERNATIONAL AIR TRANSPORTATION INDUSTRY. THIS EFFORT REQUIRES PROVIDING BOTH TECHNICAL AND FINANCIAL ASSISTANCE FOR UNIVERSITIES SO THAT THEY MAY DEVELOP THESE PROGRAMS IN TIME TO BE PART OF AN EFFECTIVE STRATEGY IN AIRCREW TRAINING. IN THE UNITED STATES, WE HAVE ESTABLISHED A MEANS OF BETTER COMMUNICATION WITH THE AVIATION INDUSTRY BY MEANS OF A JOINT INDUSTRY/GOVERNMENT TASK FORCE ON AIRCREW PERFORMANCE. THIS TASK FORCE BECAME SOMEWHAT MORE INTERNATIONAL IN COMPLEXION THAN WE FIRST ENVISIONED AS AIRCRAFT AND SIMULATOR MANUFACTURERS FROM MANY NATIONS BEGAN TO PARTICIPATE IN DEVELOPING RECOMMENDATIONS TO IMPROVE THE UNITED STATES FEDERAL AVIATION REGULATIONS AND ASSOCIATED AVIATION ADVISORY DOCUMENTS. THIS TASK FORCE HAS MADE RECOMMENDATIONS TO THE FEDERAL AVIATION ADMINISTRATION WHICH HAVE RESULTED IN A LONG LIST OF ONGOING AND PLANNED ACTIONS WHICH WILL IMPROVE AIRCREW TRAINING AND QUALIFICATION STANDARDS. THE PRINCIPAL RECOMMENDATIONS CAN BE CLASSIFIED IN THREE MAJOR AREAS.

FIRST IS RECOGNITION OF THE IMPORTANCE OF COCKPIT RESOURCE MANAGEMENT TRAINING AS AN INTEGRAL PART OF ALL AVIATION RELATED TRAINING. COCKPIT RESOURCE MANAGEMENT EMPHASIZES DEVELOPING POSITIVE INTERPERSONAL RELATIONSHIPS, INDIVIDUAL SITUATIONAL AWARENESS, AND THE APPLICATION OF TEAM PROBLEM SOLUTION METHODS. WE HAVE DEVELOPED A NEW, AND SOON TO BE PUBLISHED, COCKPIT RESOURCE MANAGEMENT ADVISORY CIRCULAR. ALSO IN DEVELOPMENT IS A REVISED ADVISORY CIRCULAR WHICH PROVIDES FOR WIDER USE OF LINE ORIENTED FLIGHT TRAINING AND ANOTHER ADVISORY CIRCULAR WHICH ENABLES GREATER USE OF ADVANCED FLIGHT TRAINING DEVICES. THE EXPANDED USE OF LINE-ORIENTED SIMULATIONS IN A WIDER RANGE OF FLIGHT TRAINING MEDIA WILL PROVIDE ADDITIONAL OPPORTUNITIES FOR PRACTICE AND EVALUATION OF BOTH INDIVIDUAL AND TEAM SKILLS IN REALISTIC TRAINING SCENARIOS. ADDITIONALLY, STEPS ARE BEING TAKEN TO LOOK AT ALL OTHER DISCIPLINES RELATED TO THE AVIATION FIELD, SUCH AS, MAINTENANCE, AIR TRAFFIC AND SECURITY.

SECOND IS RECOGNITION OF NEED FOR REGULATORY INITIATIVES TO UPDATE REQUIREMENTS IN VIEW OF TECHNOLOGICAL DEVELOPMENT IN AIRCRAFT OPERATIONS AND ADVANCES IN TRAINING METHODOLOGY. THE RECOMMENDED REGULATORY CHANGES INCLUDE:

- ESTABLISHING A REQUIREMENT FOR COCKPIT RESOURCE MANAGEMENT TRAINING FOR ALL AIRLINE FLIGHT CREWMEMBERS
- REQUIRING COMMUTER AIR CARRIERS THAT USE SMALL AIRPLANES TO COMPLY WITH PART 121 AIR CARRIER TRAINING AND QUALIFICATION STANDARDS
- UPDATING FLIGHTCREW REGULATIONS TO ACCOMMODATE ADVANCED TECHNOLOGY AIRCRAFT
- PROVIDING FOR INCREASED USE OF COMMERCIAL "TRAINING CENTERS" AND MANUFACTURERS "TRAINING CENTERS." THIS ACTION IS OF SPECIAL IMPORTANCE TO SMALLER AIRLINES. IN MANY CASES THESE SMALL OPERATORS CANNOT ECONOMICALLY JUSTIFY SOLE OWNERSHIP OF ADVANCED FLIGHT TRAINING DEVICES AND FLIGHT SIMULATORS. IN ADDITION THESE "TRAINING CENTERS" CAN PROVIDE FOR SPECIALIZED CURRICULUM DEVELOPMENT AND SUPPORT ACTIVITIES WHICH MANY SMALLER OPERATORS CANNOT PROVIDE FOR THEMSELVES DUE TO THE LIMITED SIZE AND DEPTH OF THEIR WORK FORCE. IN THE UNITED STATES, REGULATIONS AND SUPPORTING GUIDANCE DO NOT CLEARLY ADDRESS THE CAPACITY IN WHICH "TRAINING CENTERS" MAY FUNCTION MOST EFFICIENTLY. IN MOST CASES, TRAINING CENTERS MUST SUBMIT TO A LENGTHY APPROVAL PROCESS FOR EACH PROGRAM THEY INTEND TO CONDUCT. THERE IS NO CLEARLY STATED NATIONAL STANDARD FOR APPROVAL OF TRAINING CENTER PROGRAMS. REGULATORY CHANGES WHICH HAVE BEEN RECOMMENDED INCLUDE:
    - DEFINITION OF TRAINING CENTERS
    - ESTABLISHING THE PHYSICAL REQUIREMENTS OF TRAINING CENTERS (SIZE, EQUIPMENT, FACILITIES, NUMBER OF EMPLOYEES, AND SO FORTH.)
    - PROVIDING FOR THE CERTIFICATION OF TRAINING CENTERS
    - METHODS FOR APPROVAL OF TRAINING CENTER TRAINING PROGRAMS
    - DETERMINED QUALIFICATION STANDARDS FOR TRAINING CENTER INSTRUCTORS AND CHECK AIRMEN
    - DEVELOPMENT OF "CORE" TRAINING PROGRAMS
    - ESTABLISHING RECORDKEEPING REQUIREMENTS
    - DETERMINING FAA OVERSIGHT OF TRAINING CENTERS
- UPDATING AVIATION MECHANICS TRAINING AND QUALIFICATIONS REQUIREMENTS

THE FAA'S FLIGHT STANDARDS AIRCRAFT MAINTENANCE DIVISION PLANS TO CONDUCT A COMPLETE REVEIW OF FAR PART 65, CERTIFICATION: AIRMEN OTHER THAN FLIGHT CREWMEMBERS. CONCURRENT WITH THIS EFFORT, THE DIVISION IS ALSO DEVELOPING A REVISION OF FAR PART 147, AVIATION MAINTENANCE TECHNICIAN SCHOOLS. THE PART 147 REGULATORY PROJECT HAS MADE SIGNIFICANT PROGRESS, AND A NOTICE OF PROPOSED RULEMAKING IS EXPECTED TO BE ISSUED BY THE END OF THIS YEAR.

THE DEVELOPMENT OF BACKGROUND INFORMATION TO CONDUCT THE REGULATORY REVIEW OF FAR PART 65 WILL CONSIST OF TWO MAJOR EFFORTS. THE FIRST WILL BE A COMPLETE JOB TASK ANALYSIS (JTA) OF WHAT AN AIRCRAFT MAINTENANCE TECHNICIAN DOES. HOW OFTEN A PARTICULAR TASK IS DONE. HOW IT IS ACCOMPISHED, AND WHAT TYPES OF KNOWLEDGE, SKILLS, AND ABILITIES (KSA) ARE REQUIRED TO ACCOMPLISH THE TASK. FURTHER, THE JTA WILL DETERMINE HOW MANY ADDITIONAL NEW TASK ELEMENTS A MECHANIC MUST BE ABLE TO ACCOMPLISH SINCE THE LAST MAINTENANCE TECHNICIAN JTA'S WERE DEVELOPED OVER 2 DECADES AGO. THE ORIGINAL JTA STUDY, CALLED THE ALLEN STUDY (AFTER THE ORIGINAL INVESTIGATOR, DR. DAVID ALLEN), DETERMINED THAT THERE ARE OVER 125 SEPARATE TASK ELEMENTS A TECHNICIAN WAS REQUIRED TO PERFORM IN 1968. SINCE THAT TIME, OBVIOUSLY, MANY NEW TASKS HAVE BEEN REQUIRED OF AIRCRAFT MAINTENANCE TECHNICIANS. MANY OF THE NEW TASK REQUIREMENTS ARE DRIVEN BY THE NEWLY EMERGING TECHNOLOGIES OF DIGITAL ELECTRONICS, FLY BY WIRE, COMPOSITE STRUCTURES EFIS, FAN ENGINES, AND SO ON.

THE WELL PUBLICIZED PROBLEMS OF THE AGING FLEET HAVE ALSO SERVED TO POINT UP SOME GAPS IN THE MAINTENANCE SECTOR. NONDESTRUCTIVE INSPECTION AND CORROSION CONTROL PROGRAMS ARE JUST TWO OF A NUMBER OF NEW OR RAPIDLY CHANGING MAINTENANCE SPECIALITIES THAT ARE REQUIRED TO MAINTAIN THE AGING FLEET. MANY OTHER ISSUES THAT WERE NEVER PART OF THE ORIGINAL REGULATION MAY IMPACT THE FORTHCOMING RULE EVALUATION. SUCH PARAMETERS AS PROPER WORK STATION LIGHTING, TEMPERATURE, MAINTENANCE TECHNICIAN COLOR VISION, ACTIVITY, AND FATIGUE AND DUTY TIMES MAY ALL IMPACT THE DEVELOPMENT OF THE JTA. IN OTHER WORDS WE WILL INCLUDE THE HUMAN FACTOR.

LOOKING MORE CLOSELY AT SOME OF THE JTA ISSUES THAT WILL BE CONSIDERED, WE HAVE AGING AIRCRAFT FLEET PROBLEMS. DURING THE INVESTIGATION OF SEVERAL RECENT AIRCRAFT ACCIDENTS AND INCIDENTS RESULTING FROM STRUCTURAL FAILURE, IT BECAME EVIDENT THAT MORE TRAINING AND POSSIBLY A NEW CERTIFICATION PROCEDURE WAS REQUIRED TO TRAIN AND REGULATE PERSONS ENGAGED IN NONDESTRUCTIVE AIRCRAFT STRUCTRUAL INSPECTION. FURTHER, SINCE NO NATIONALLY ACCEPTED CERTIFICATION STANDARD FOR THIS TYPE OF DISCIPLINE NOW EXISTS, THE FAA CANNOT PROPERLY EVALUATE THE CERTIFICATION OR TRAINING OF THESE PERSONS.

NEW TECHNOLOGY INTRODUCTION: DURING RECENT AVIATION INDUSTRY/FAA MAINTENANCE PANEL REVIEWS, IT BECAME EVIDENT THAT FEW MAINTENANCE PERSONNEL HAVE THE TECHNICAL SKILLS OR THE INDUSTRY TRAINING REQUIRED TO PROPERLY MAINTAIN AND INSPECT COMPOSITE AIRCRAFT STRUCTURES. THE SAME SERVICING DIFFICULTIES, ACCORDING TO THE AVIATION INDUSTRY, WILL ALSO APPLY TO CERTAIN AVIONICS; ELECTROMECHANICAL SYSTEMS; COMPUTER-BASED, BUILT-IN-TEST EQUIPMENT; AND MOST SOLID-STATE ELECTRONIC AIRCRAFT SYSTEMS. NO SPECIFIC FAA CERTIFICATION EXISTS FOR MECHANICS ENGAGED IN MAINTAINING THESE COMPLEX SYSTEMS.

EQUIPMENT TYPE, SIZE, AND COMPLEXITY: MANY AIRLINES AND COMPLEX AIRCRAFT OPERATORS HAVE EXPRESSED AN INTEREST IN FAA CERTIFICATION OF MECHANICS FOR SPECIFIC MODELS OR TYPES OF AIRCRAFT, PARTICULARLY FOR LARGE AND/OR COMPLEX TYPES SUCH AS THE BOEING 747 OR THE LOCKHEED L1011. MANY OF THE INSPECTION CRITERIA NECESSARY TO PERFORM MAINTENANCE ON THESE TYPE OF AIRCRAFT ARE, IN FACT, SPECIFICALLY RELATED TO THE PARTICULAR AIRCRAFT INVOLVED. HELICOPTER OPERATORS HAVE ALSO EXPRESSED CONCERNS THAT MANY OF THE MAINTENANCE OPERATIONS THAT ARE SPECIFIC TO HELICOPTERS ARE OF SUCH A COMPLEX NATURE THAT A COMPLETELY DIFFERENT FAA RATING IS REQUIRED FOR HELICOPTER MAINTENANCE PERSONNEL.

MILITARY AVIATION EXPERIENCE: THE CHANGING ROLE OF THE MILITARY AVIATION MECHANIC HAS REQUIRED THAT A MECHANIC BE TRAINED IN A NARROW SPECIALTY. THIS PERSON MAY HAVE LIMITED BACKGROUND TO QUALIFY FOR THE RELATIVELY BROAD SET OF PRIVILEGES OF AN FAA-CERTIFICATED AVIATION MECHANIC. IN A NUMBER OF CASES, FAA CERTIFICATION OF AVIATION MECHANICS, PURELY ON THE BASIS OF PREVIOUS MILITARY EXPERIENCE, MAY HAVE RESULTED IN THE GRANTING OF FAA MECHANIC PRIVILEGES TO PERSONS WITH NO EXPERIENCE IN SOME REQUIRED TECHNICAL AREAS.

INTERNATIONAL/BILATERAL AGREEMENTS: BOTH THE UNITED STATES-CANADIAN BILATERAL MAINTENANCE AGREEMENT AND THE INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO) WILL BE AFFECTED BY INTERNATIONAL EVENTS, INCLUDING THE SWEEPING AIRWORTHINESS RULE CHANGES CURRENTLY UNDER WAY IN CANADA, AND THE RECOMMENDATIONS FOR CHANGING ICAO AIRCRAFT MAINTENANCE TECHNICIAN STANDARDS PROPOSED BY A RECENT ICAO AIRCRAFT MAINTENANCE ENGINEER LICENSING PANEL. MOREOVER, THE INCREASINGLY INTERNATIONAL CHARACTER OF AIRCRAFT LEASING, PARTS EXCHANGING, AND FAA-CERTIFICATED FOREIGN REPAIR FACILITIES WILL AND ARE IMPACTING THE CURRENT STATUS OF FAA-CERTIFICATED AVIATION MAINTENANCE TECHNICIANS AND REPAIRMEN.

BASED ON THE NEED TO APPRAISE THESE REQUIREMENTS, THE FAA IS OF THE OPINION THAT THE EXISTING PART 65 AND SOME PORTIONS OF ITS COMPANION REGULATIONS ARE IN NEED OF A COMPLETE REGULATORY EVALUATION. IT IS IMPORTANT TO NOTE, HOWEVER, THAT THIS REGULATION IS QUITE GLOBAL IN SCOPE AND DEPENDING ON THE EXTENT OF ANY MODIFICATIONS THAT MIGHT BE PROPOSED, SOME CHANGES COULD

BE REQUIRED IN A NUMBER OF OTHER REGULATIONS. IN ORDER TO ENSURE THAT ANY REGULATORY PROJECT WOULD ENCOMPASS ENOUGH MATERIAL TO PROVIDE A THOROUGH REVIEW, OUR PROPOSED REGULATORY EVALUATION WILL INCLUDE, BUT NOT BE LIMITED TO:

A. TRAINING REQUIREMENTS.
B. CERTIFICATION STANDARDS.
C. RATING SYSTEM.
D. CURRENCY REQUIREMENTS.
E. LIMITATIONS.
F. EXPERIENCE REQUIREMENTS.
G. INSPECTION AUTHORIZATION REQUIREMENTS AND LIMITATIONS.
H. AVIATION MAINTENANCE TECHNICIAN SCHOOL INTEGRATION.
I. MAINTENANCE STANDARDS.
J. IMPACT ON RELATED FAR SECTIONS.
K. IMPACT ON BILATERAL INTERNATIONAL AGREEMENTS AND ICAO STANDARDS.

THIRD IS THE RECOGNITION THAT OBJECTIVELY DEVELOPED, PROFICIENCY BASED QUALIFICATION PROGRAMS ARE REQUIRED. IN RESPONSE TO THIS RECOMMENDATION, THE UNITED STATES FEDERAL AVIATION ADMINISTRATION HAS COMPLETED WORK TO DEVELOP A NEW AIRCREW MEMBER QUALIFICATION REGULATION. THIS SPECIAL FEDERAL AVIATION REGULATION WILL BECOME EFFECTIVE IN 1990. IT WILL PERMIT AIRLINES TO DEVELOP ADVANCE QUALIFICATION PROGRAMS FOR AIRCREW QUALIFICATION AND TRAINING. THE PRINCIPAL FEATURE OF ANY ADVANCED QUALIFICATION PROGRAM IS ESTABLISHMENT OF PROFICIENCY-BASED QUALIFICATION OBJECTIVES. THESE OBJECTIVES WILL BE DEVELOPED AND MAINTAINED SYSTEMATICALLY AND VALIDATED EMPIRICALLY. ADVANCED QUALIFICATION PROGRAMS AFFORD AN OPPORTUNITY TO MEET NEW TECHNOLOGY THROUGH HEAD-ON PLANNING. THESE PROGRAMS WILL ALSO PERMIT DEVELOPMENT OF ADVANCE TRAINING METHODOLOGIES AND PROVIDE EXPERIENCE IN USING VALIDATION DATA TO DETERMINE FUTURE REQUIREMENTS. THIS REGULATION WILL HAVE A 5-YEAR LIFE. THE EXPERIENCE GAINED DURING THAT TIME WILL BE USED TO DEVELOP NEW, PERMANENT TRAINING AND QUALIFICATIONS REGULATIONS.

WE ARE CONFIDENT THAT THESE APPROACHES TO ENHANCE TRAINING AND STANDARDIZE QUALIFICATION REQUIREMENTS WILL PROVIDE FOR A BETTER AND MORE EFFICIENT USE OF TRAINING RESOURCES AND WILL ENABLE OUR AIRLINES AND COMMERCIAL TRAINING ORGANIZATIONS TO MEET THE NEEDS OF THE CIVIL AVIATION INDUSTRY IN THE 1990's.

Human Factors Considerations for Aircraft Maintenance and Inspection Personnel

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Safety in air travel is critically dependent on the performance of personnel assigned to inspect and repair aircraft. Failure to correctly detect and repair aircraft malfunctions has led to catastrophic air carrier accidents. It is imperative that maintenance and inspection personnel have the training and motivation needed to perform their work optimally, but it is equally important that management groups recognize the limits inherent in task performance by the fallible human operator. Managements need to provide *necessary support in the way of specialized training*, equipment, job aides and working conditions. It is inappropriate to blame the technician for failure to detect exfoliation corrosion inside a landing gear bay if he is required to perform this task outdoors, on a winter night and has never received training on the appearance of this form of corrosion. Sometimes, inspectors are required to inspect row upon row of rivets for hours using archaic equipment. Many inspection methods currently accepted do not account for human sensory capabilities and known decrements in vigilance over time. Some technicians are burdened with physical problems such as obesity or poor eyesight which limit their access to cramped work areas or prevent them from seeing small defects.

Often, technicians spend considerable time in airframe and powerplant (A&P) schools training on dope and fabric and piston engine repairs but learn nothing about the electronic fuel management systems or fly-by-wire control systems they must inspect and repair in their jobs.

The scenarios described above are not so extreme as to be unrealistic. Conceptually similar situations occur regularly. Recent accidents and incidents in U.S. air carrier operations have resulted from deficiencies in the inspection servicing and maintenance of aircraft. These events, while few in number, have prompted a closer look at the work of the specialists who must assure the airworthiness and safety of equipment.

It is perhaps surprising to learn that very little study has been accomplished on factors related to the performance of civil aviation maintenance technicians. For years, our attention in the aviation human factors community has been riveted on pilot and air traffic controller performance with scant attention paid to other specialists. The aviation technician has often been the forgotten person on the team charged with safe air transportation. This may be partly due to perceptions we have of various aviation personnel that developed from military aviation. Military pilots are usually officers and accorded the respect due their rank. Technicians are typically enlisted persons with proportionately reduced status. This personnel value system has found its way into civil aviation. Civil pilots usually wear officer - like uniforms and are accorded titles like "captain". Technicians are often still thought of as the coverall-clad "grease monkeys" of earlier times. These attitudes may be expressed by a relative lack of concern for the training, equipment and working conditions for the aircraft maintenance technician. Recent safety-related events, the inexorable increase in complexity of aviation systems and other factors suggest a change in our perceptions may be appropriate.

The maintenance and inspection specialists of tomorrow will necessarily be different than today for many reasons, not the least of which is that fully

60% of the current U.S. air carrier maintenance work force is expected to retire within the next 10 years. At the same time this is happening, the complexity of aircraft and their systems is increasing dramatically. The requirement to diagnose and service new, complex systems will be superimposed on traditional activities such as inspection and repair of riveted sheet metal. The knowledge and skills required may suggest the need for increased specialization in the ranks of the technicians.

Some administrations require certification of non-destructive inspection (NDI) specialists now because of the critical nature of the task and the depth of knowledge required. The NDI certification requirement and perhaps other skills may become more widespread in the future. Servicing of electronic systems for example may require a level of specialized training rivaling that for electronic engineering technicians.

There are some who feel that the tasks of aircraft maintenance and inspection will be so heavily backed up by automated diagnostic equipment that the technicians will need only to remove and replace components.

This is almost certainly an oversimplification and might be compared to the notion that a surgeon performing heart transplants is a similar "remove and replace" technician. Clearly, maintenance specialists will need to know a great deal about system theory and must possess considerable ability to discriminate among malfunction symptoms to determine even where to begin in the search for problems.

Ability to conduct tests and interpret results using specialized automated diagnostic equipment will be vital; Some electronic systems are so sensitive for example, that the misapplication of voltmeter leads can cause thousands of dollars of damage.

If anything the role of the maintenance and inspection technician is becoming more, rather than less, critical. Human Factors scientists must identify and study the areas where there are apparent knowledge deficiencies and specify remedial actions to foster optimal performance of these specialists. The Federal Aviation Administration has embarked on a program of study to seek information in these areas. The plan is to provide details on what might be termed "best" or "better" practices to be applied by people who design, manufacture and maintain aircraft, for those who train maintenance and inspection personnel and for those government specialists whose role is to oversee the actions of these other groups. At the same time, we plan to describe certain "worst" practices to be avoided by these people. We want to synthesize knowledge from other industries such as the nuclear power generation industry and non-aviation manufacturing enterprises, and apply this already existing knowledge base to the aviation maintenance and inspection case where appropriate.

The plan will result in research on topics where there are knowledge gaps.

The current work plan calls for study in eight topical areas. These eight information streams will be blended to produce compendiums which may take the form of reference manuals, video tapes, prototype computer-based instruction modules, and similar types of media. The intention is to make the information as usable as possible to the various groups who may benefit from its application.

The eight study topics are as follows:

1. Task Analysis: Before embarking on other research topics it is imperative that a comprehensive understanding of the current

activities of maintenance and inspection personnel be obtained. This will form the basis for recommended changes in all other related areas such as design and training. Task analyses consist of careful study, observation, and identification of component and *sub-tasks of larger* task units. Included will be identification of critical task elements and associated conditions which are sensitive and likely to contribute to error in maintenance and inspection processes.

2. Analysis and Classification of Human Error: This work will specifically examine error in aircraft maintenance and inspection, and will complement the task analyses. Human error can be related to a number of factors such as knowledge, attitudes and work conditions.

   A hierarchy of error-related factors for certain well-defined tasks will be obtained from on-site study. Observation of tasks and debriefings with involved personnel such as trainers, mechanics, and managers will be conducted to isolate error sources.

3. Training Research: Currently, a great deal of training in the maintenance and inspection of aircraft is conducted on an OJT basis. New technology training systems such as intelligent tutoring systems, and computer - based instruction will be studied and further developed where appropriate for use in aircraft maintenance. The goal is to increase training effectiveness so that a consequent reduction in work error is achieved. More will be said about advanced training systems later in this paper.

4. <u>Job-Task and Work Environment Research</u>: An inspector's job is frequently performed under time pressure, yet the speed/accuracy trade-off is known to be strong. At the least this can lead to job stress; at worst, to reduced performance. Both stress and performance need to be evaluated under different levels of time pressure. Other important job factors will be evaluated in this project, including work site access, lighting, noise and ambient temperature in order to provide a better understanding of how they influence work performance.

5. <u>Equipment Design Research</u>: Existing test equipment, including non-destructive inspection (NDI) equipment frequently shows lack of human factors engineering in its design. It is necessary that equipment be designed and used with recognition of human capabilities and limitations. Work performed under this project will examine existing and planned equipment for adherence to human engineering design principles.
These principles will be refined and specified for the aircraft maintenance case. Results from this work will include guidance for equipment designers and operators.

6. <u>Information Exchange/Communication</u>: There are several communication areas in aviation maintenance that should be studied for possible application of new technologies. Maintenance manuals and similar procedural documents such as work cards may be improved by use of computer-based methods. Also, methods of information exchange among key organizations, such as manufacturers and air carriers, may benefit from use of formal, well-defined communication channels. Existing procedures will be studied and recommendations for modification will be made. Use of

standardized and simplified vocabularies will be investigated for their contribution to safety, as well as means for expediting needed communications.

7. Job Performance Aids: This work will evaluate existing and planned devices and systems in use elsewhere for application to the diagnosis, inspection and maintenance of civil aircraft. The U.S. Air Force is developing a computer-based system known as the Integrated Maintenance Information System (IMIS). Airframe manufacturers are proposing on-board systems to diagnose and report system malfunctions.

Some of these systems will provide instructions to the technician on likely fault sources and details on repair procedures including graphical displays, personnel specialties required to make repairs and repair part numbers. Other industries use such aids as specialized visual scanning devices, and bar-coded part marking to assure proper identification and to help with diagnostic procedures. Current research will identify these systems and recommend their adaptation and use where appropriate.

8. Handbook Development: The final task of the FAA research program on human factors will be to develop the handbooks and other information sources which are products from other tasks. In addition, information will be gleaned from other sources and adapted to the specific case of aircraft maintenance and inspection. Such sources may include publications and procedures from the nuclear power industry and methods used by other

industries to produce technical publications. The intention is to provide a central source of human factors information that will be useful to a wide user group in the performance of their official duties. This group will include manufacturers, maintenance managers, equipment designers, and government regulatory specialists.

In addition to handbook or printed media, the research program may provide information in the form of video tape tutorials, or software for intelligent tutoring systems described under task number 3. These latter systems incorporate new training technology described in the following paragraphs.

New Training Technology for Aircraft Maintenance and Inspection Personnel

New training technology for aircraft maintenance and inspection may be defined as training requiring the use of computers and specialized software. This can include computer-based instruction (CBI), interactive video disc (IVD), computer-controlled simulators (CCSIM), computer controlled real equipment (CCRE), and computer-based testing (CBT). CBI has been in use since the early 1960's and was an outgrowth of the programmed learning materials methodology of the 1950's.

Training technology has advanced considerably in the two decades since the advent of CBI, but to date, little of this available sophisticated training has been provided to the aviation maintenance technician. Most aircraft maintenance training organizations are heavily involved in solving daily training crises related to aging fleet problems leaving them little time to learn about new training technology. Also, maintenance training has historically been very traditional, emphasizing stand-up lecture and OJT methods. However, part of the FAA's research program will be devoted to the development and validation of a computer-based intelligent tutoring system (ITS) for a typical air carrier maintenance task.

The task selected will necessarily be a non-trivial one; one that involves a complex analysis/diagnosis/repair sequence. The purpose of this work is to demonstrate improvements in training effectiveness, with consequent safety benefits.

Figure 1 depicts the components of an ITS. An ITS must contain, at a minimum, a knowledge base about the domain, a means to assess student knowledge about the domain and a means to structure instruction by comparing student knowledge to the system's knowledge. Intelligent tutoring systems differ from traditional CBI primarily through incorporation of models of experts, instructors and individual students. In an ITS, the student interacts with the instructional environment through the interface. The student is able to query the systems as well as provide answers and other input. The instructor model compares current and past student actions with the expert model and provides remediation and subsequent instruction accordingly.

ITS's embody Artificial Intelligence (AI) concepts to provide more user-sensitive training than previous CBI systems. CBI systems may only signal a correct or incorrect choice by a student without providing instruction or correction of student errors. Students don't always learn or err in a consistent and predictable manner. ITS's must be capable of adapting instruction to interact with a variety of student capabilities. An ITS must be able to monitor student actions, infer student intent, assess knowledge states and adjust the sequence of instruction. Several ITS's have been developed for maintenance applications in other areas, included military systems.

The challenge in the FAA's research program will be to develop a prototype ITS for an aircraft maintenance task that is clearly more effective than traditional training methods. This will require comparing task performance of groups of test subjects who have been trained using different methods, one of which will be the ITS for the selected task. Other factors must also be accounted for such as cost of training as weighed against the benefit of more effective training. It will be imperative to bring subject matter experts as well as potential users into this development process. Currently, computer scientists cognitive psychologists and educational technologists play the most prominent roles in ITS development. This project will involve currently active technicians, instructional development specialists, and engineering skills. The involvement of these personnel will insure that the ITS will be aligned with the real training needs of maintenance organizations.

The FAA research for development of an aircraft maintenance ITS is divided into three phases. An assessment of the current status of training technology for maintenance technicians will be conducted during the first phase. This will be accomplished through a series of interviews and evaluations with manufacturers, airlines, repair stations and training schools. Also during this first phase, a preliminary ITS will be developed that can be used as a concept demonstration.

This initial ITS can also be used to help develop the specifications for a fully operational ITS. This later ITS will be developed in the second phase in cooperation with a school, airline or manufacturer identified during the first phase.

The third phase will be devoted to evaluation of this ITS. It is planned that the system will be applied in a training program at a school, manufacturer, or airline. It is expected that the ITS approach will be shown to be more effective and efficient than conventional training. Therefore, maintenance organizations will be more likely to adopt the ITS technology without regulatory impetus from the FAA.

Conclusion

The research program described in this paper is an ambitious one, designed to elicit information and knowledge where currently, large gaps exist. The FAA anticipates that the products of this program will lead to, perhaps intangible, but real benefits in terms of improved aviation safety.

AN ABILITIES-BASED APPROACH TO PILOT COMPETENCY AND DECISION MAKING

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and Maintenance Personnel.

Abstract

The increasing enthusiasm for Cockpit Resource Management (CRM) interventions in post qualification flight training can be interpreted as an interactive effect of changed modern aircraft technology and an increased recognition that variance in human performance is the single most important predictor of safe and effective aircraft operations. Traditionally, flight training has been seen primarily as the acquisition of aircraft manipulation and navigational skills. More recently, to these *ab initio* requirements have been added a constellation of essentially attitudinal skills translating into decision-making, leading and communicating strategies. In an on-going programme (HURDA - Human Resource Development in Aviation) concerned with the identification of hierarchically arranged generic constructs of pilot competency, patterns of process abilities are being identified as predictors of flight crew performance management (FCPM). Further, these abilities are being postulated as competency requirements for inclusion in licensing and training prescriptions from *ab initio* to airline operations.

Introduction

In the first half of 1989 more than 600 people died in 26 aircraft accidents. This compares with an annual average, calculated since 1959, of 567 persons (IATA, 1986). The prognosis for eliminating human error in aviation accidents is not good. A comparison of New Zealand safety levels with those overseas is made difficult by the lack of standardization of definitions (Swedavia-McGregor, 1988). However, an analysis of New Zealand accident statistics for the period 1980 to 1986 show that of a total of 502 reported accidents, 130 could be reasonably ascribed to some type of machine failure (engine failure-malfunction, undercarriage collapse, etc.), with the remaining 74 percent primarily due to pilot error (principally overshooting and loss of control in flight). Although design safety standards for aircraft are very high (1000 million flight hours per catastrophic accident for *each* catastrophic system failure condition and 10 million flight hours per catastrophic accident taking into account the combined effect of *all* system failure conditions), a comparable level of stringency for human effectiveness is still far from being realized.

The consistency and stability of these figures across time, political and cultural boundaries is remarkable. Hawkins (1987) reporting on a German study by Meier Muller in 1940 concluded that in that year 70 percent of all aircraft accidents could be attributed to some form of human factor deficiency. In a more detailed analysis of only judgemental and decision-making factors, Jensen and Benel (1977) identified these two components of human factors to account for 52 percent of all general aviation fatalities in the United States from 1970 to 1974. To sum up, approximately 70 percent of all fatalities are due to pilot or air traffic induced error. Of the remaining 30 percent, probably about 12 percent can be attributed to weather related factors, 9 percent to acts of terrorism of one kind or another, 6 percent to maintenance defects and only about 3 percent to structural failures.

Human Factor research in aviation has had as its focus the reduction and elimination of accidents which originate through inappropriate human interfacing with hardware and software resources. However, as Besco (1989) observes the analytical and diagnostic techniques available for studying the breakdown of this interface have as yet produced little significant reductions to pilot induced accidents. But until the constructs of effective pilot ability are available, the "ambulance at the bottom of the cliff" approach to defining aviation human factors may not provide the preventative prescription the industry so clearly needs. Thus, a shift in emphasis from descriptive procedures to prescriptive processes in defining abilities may prove to be a more fruitful field for research and for the development of more competent flight crew.

The Analysis of Human Competence

The most common way of defining pilot competency for flight instruction purposes has been to anecdotally construct behavioural descriptions of aspects of flight and then break these down into their constituent elements for learning. The genesis of this type of approach has been the time and motion studies of scientific management which were used to maximise throughput in highly sequenced factory production lines. While this method provided descriptions of those tasks which were appropriate in achieving a particular goal, it did not provide prescriptive information on what knowledge and skills formed the basis of competency, nor how the competency might be developed.

To this end, there has been a shift in emphasis from the mere location of tasks to an analysis of the content of the tasks themselves. This has been stimulated by the work of Gagné (1970) and others in identifying learning outcomes in terms of their sequential and prescriptive properties. In this approach, the attainment of problem solving expertise is predicated on the acquisition of pre-requisite discriminations, concepts and rules in an essentially hierarchical progression. Further elaborators saw a differentiation of rules into "structures" and "processes" (Williams, 1977) and increased emphasis on "information" as the focus for analysis (Horne, 1973). But these advances into information mapping systems still did not provide the tools for conceptualizing the nature of the competency itself.

In more recent times information processing approaches have been used to identify the dynamic processes underlying the capacity to perform expertly in multi-tasking situations. These processes when viewed over time and across contexts reveal the presence of generic accomplishments. The work of Glaser (1984) and others have begun to show that highly developed competence in a defined area is the product of the inter-play between knowledge structures and processing abilities. From such studies conclusions are being drawn as to the differences between "expert" performers and "poor" performers. Little evidence suggests that these differences are inherently based nor immutable to training. Rather, the findings suggest that:

> *"relations between the structure of a knowledge base and problem-solving processes are mediated through the quality of representation of the problem. This problem representation is constructed by the solver on the basis of domain-related knowledge and the organization of this knowledge. The nature of this organization determines the quality, completeness, and coherence of the internal representation, which in turn determines the efficiency of further thinking. The representation of the problem consists essentially of the solver's interpretation or understanding of it, and greatly determines how easy it is to solve." (Gagné and Glaser, 1987, pp 68-69.)*

The implication for human factors research in aviation and its application to *cockpit resource management*, is that the nature of effective single and multi-crew performance might rest on the ability of flight crew to interrogate and process cognitive and affective information within the context of situational demands. For this hypothesis to be tested and further developed a map of pilot competency must be established from which individual performance constructs and context applications can be generated. The remainder of this paper describes the results of this effort to date.

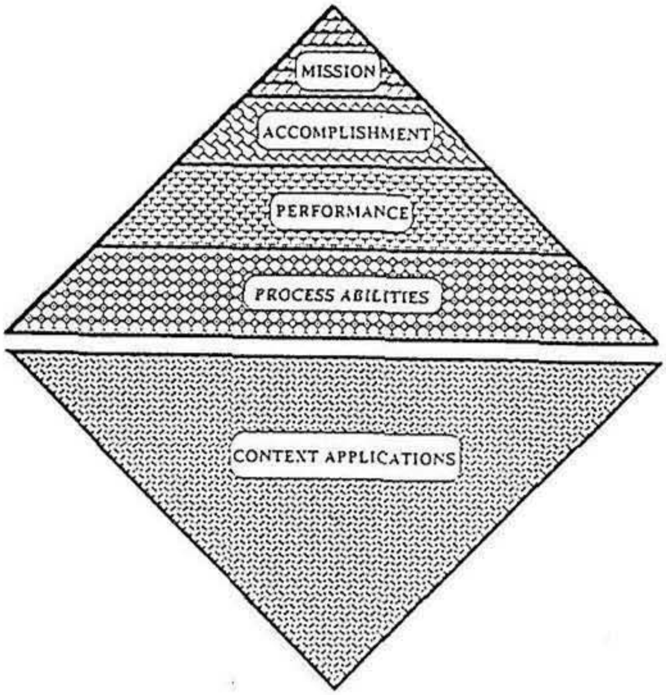
The Knowledge-Process Hierarchy Model

Analyses of requisite pilot performance have traditionally been derived from observations of flying skills and knowledge of flight rules and procedures. When these dimensions have been translated into predictive indices, no more than about 25 percent of the variance of performance at advanced stages of competency have been accounted (Roscoe and North, 1980). However, as these researchers describe, despite the prediction problem, flight crew are able to identify "abilities" such as being able to quickly *estimate* probable outcomes for different courses of action, or *attending* to resolving an emergency without losing control of the on going routine procedures. The trick in developing a map of pilot competency is to be able to relate these types of requisite abilities to context applications. For instance, consider the abilities involved in executing a landing. Two are critical: *assessing* the relative position of the aircraft in relation to the ground; and *perceiving* the changes in the shape of the runway in relation to reducing height. A description of this interaction of *ability* to *context* might be provided in an instruction to a trainee pilot such as:

> *"You will recognize the flare height when the runway appears to expand rapidly outwards. Use this view as the cue for assessing the moment at which you need to flare."*

In this example, the identification of each "process ability" assumes that there is a larger, more integrative ability from which it has been derived. In the knowledge-process hierarchy model of pilot competency, this assumption is declared in a three-level hierarchy of *increasingly general* capacities to process knowledge. This method developed by Hunt (1986) provides a procedure for mapping abilities and their underlying processes in defining human competencies.

Figure 1 Knowledge - Processes Hierarchy (Hunt, 1986)



At the Apex of the hierarchy is the Mission or overriding goal. This is the purpose to which all the accumulating activities are directed. These statements claim their validity on the degree to which all participants in a particular area of human endeavour can agree on their value and usefulness in providing direction and purpose. In civil aviation an acceptable mission for flight crew competency might be to "operate aircraft *safely, effectively* and *efficiently*." Each of these adverbial exhortations provide a means for establishing the conditions and standards from which individual, national and international performance criteria can be explicated and translated into regulatory flight crew standards.

The level beneath the mission provides individual elaborations of the goal's directives. These elaborations or *accomplishments* are the broad functional capabilities which contribute to personal expertise. Each accomplishment is the synthesis of one or two generic knowledge bases which are stored in and retrieved from long-term memory. Flight crew accomplishments include *command, aircraft performance management, aircraft systems management* and *navigation management*.

Each accomplishment is in turn defined by two or more *performances*. The performance defines the procedural knowledge (knowing how) that is required in the execution of the accomplishment. One performance (for example *making in-flight adjustments*) may with other performances provide the particular characteristic of a given accomplishment (say, *aircraft performance management*), and in a different combination of performances provide the construct for another accomplishment (for example, *navigation management*).

The base of the hierarchy is provided by the *process abilities* which define each of their superordinate performances. Process abilities may have both cognitive and affective applications. For example, in the accomplishment of *command* and one of its performances, *crew interacting*, cognitive abilities are included in *assessing*, *decision-making* and *monitoring*, and affective abilities in *leading* and *listening*.

A Map of Pilot Competency

One of the subcomponents of the Human Resource Development in Aviation (HURDA) programme is a project to provide a map of professional pilot competencies. A sample of over 120 professional pilots (that is, pilots qualified with at least a Commercial Pilot's Licence (CPL) and Basic Flight Instructor Rating (C Category) had been surveyed via interviews and an abilities-based needs assessment questionnaire for their perception of the desirable ability attributes for pilot performance. From a mission statement which found more than 75 percent of the sample agreeing to a goal which explicated *a safe, effective and efficient system for operating aircraft* a canonical discriminant analysis generated six statistically significant accomplishments (table 1).

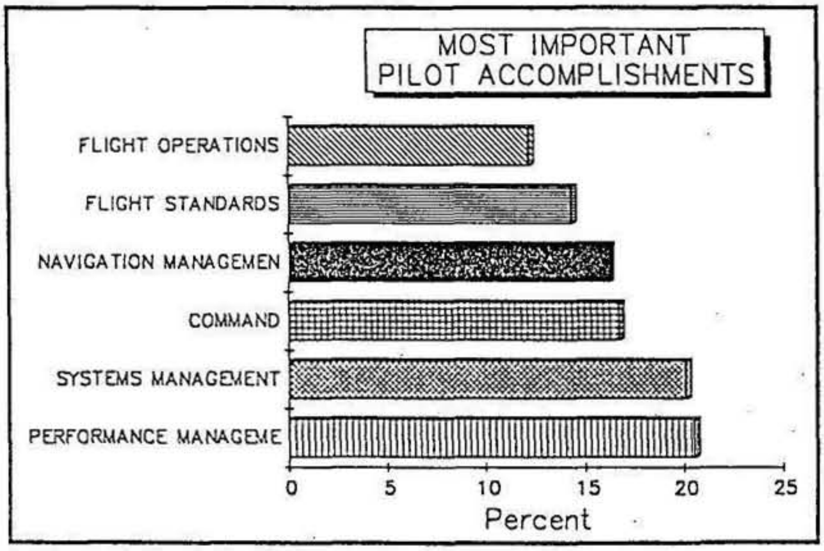
Table 1

Discriminant Analysis of the Most Significant Pilot Accomplishments

Accomplishment	*Wilks Lambda*	*Chi-Squared*	*DF*	*Sig.*	*Level*
Command	.4882	457.43	40	0.00	p<.01
Performance Management	.5016	440.18	40	0.00	p<.01
Systems Management	.4612	493.81	40	0.00	p<.01
Navigation Management	.3272	712.68	40	0.00	p<.01
Flight Operations	.7475	185.69	40	0.00	p<.01
Flight Standards	.6193	305.70	40	0.00	p<.01

The results of the analysis revealed two clusters of accomplishments (figure 2). The first related to the pilot's operational management of the aircraft and its systems. These accomplishments together are described as "piloting accomplishments." The second cluster prescribe the pilot's relationship to the types of operational requirements (air transport, aerial work, etc.,) and flight standards (regulatory and organizational requirements) which impact upon flight crew procedures. These are described as the pilot's "environmental accomplishments."

Figure 2.



In the piloting accomplishments both aircraft performance management (APM) and aircraft systems management (ASM) have a similar magnitude in perceived importance. APM is defined as the accomplished ability to safely and productively control the flight profile of the aircraft under Visual and Instrument Flight Rules (VFR and IFR) from "take off" to "landing." It embraces all the capacities a flight crew must engage in order to operate and control an aircraft through the performance modes of take off, climb, cruise, manoeuvre, descent and land. In contrast, ASM is defined as the accomplished ability to safely and productively manage the aircraft's technical systems in all environmental and performance conditions including the flight crew ability to recognize abnormal aircraft system performance, identify malfunctions and arrive at solutions to remediate the conditions.

The third piloting accomplishment is navigation management. This accomplishment is defined as the dynamic process of systematically determining the position of an aircraft in flight in legally defined operating conditions and taking it safely and productively in those conditions from a given position to the desired destination.

The final piloting accomplishment is command. While there are legal role connotations embedded within this accomplishment for analytical purposes this critical piloting outcome is defined as being the capability to manage interpersonal relationships with inter system relationships (aircraft crews, passengers, and air traffic, with aircraft systems and performance requirements) in order to achieve the operational goal of a flight. It may include the exercise of formal, legal power and authority over other crew members and passengers, but also includes the responsibilities of a First Officer (whether that officer be in a "Pilot Flying" or "Pilot Not Flying" status. It is within this accomplishment, but not exclusively related to it, that much of the focus of "cockpit resource management" (CRM) takes place. Thus, it is this accomplishment which is elaborated further in order to reveal the genesis of CRM type abilities.

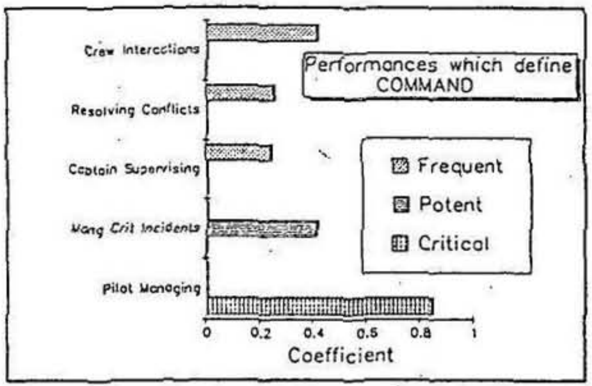
Flight Crew Performance Management

Effective flight crew performance has been defined by Chidester and Foushee (1989) as a joint product of the piloting skills, attitudes and personality characteristics of team members. As Jensen and Biegalski (1989) and others have suggested it is to the first component of this definition that much of the effort in training has been historically expended. Only in more recent times, and especially since the airliner collision at Tenerife in 1977, have attitudinal and personality characteristics received much attention for training purposes. The focus of this attention has been to enhance the problem-solving and decision-making strategies of crews in normal and abnormal operating situations. However, as the studies reviewed by Chidester and Foushee reveal, short training interventions to achieve personality changes which might induce more consultative, open and collective problem-solving leadership offer little promise. Further more, although the evidence is less conclusive, attitude modification training programmes for the same purpose tend not to be effective when delivered over short periods of time. On the other hand, as Rumelhart (1981) has argued, effective problem-solving and decision-making strategies can be established if the information structures which underlie them are built into clearly organized knowledge structures and *schemata*. Such schemata represent procedural knowledge (accomplishments, performances and process abilities) and the interrelationships between objects, events, and sequences of events. Once an appropriate schema is triggered, a schema can release precisely the right procedures to control the solution. However, the variable in ultimate effectiveness is the prior organization and perception of relevance that the stored knowledge has. Flight crew performance management (FCPM) then is seen as a process of developing schemata that will enhance problem-solving and decision making strategies on the flight deck.

An example of the potential for FCPM schemata can be seen from the data obtained thus far in the HURDA study. The key piloting accomplishment *command* is defined by five contributing performances: *crew interactions, resolving conflicts, captain supervising, managing critical incidents and pilot managing* (Figure 3).

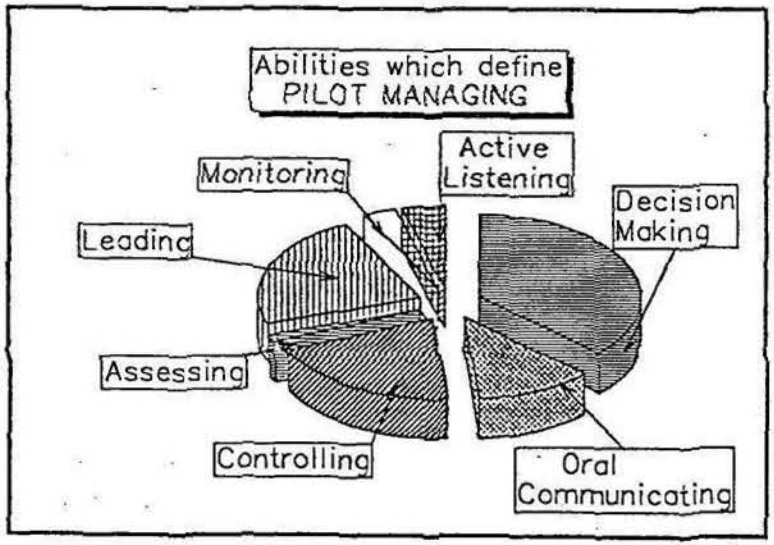
Each of these performances are in turn defined by process abilities which combine in a cognitive and affective manner many of the attributes which have been the subject of CRM type courses (figure 4). As the data demonstrates, the effective execution of a pilot managing performance in both Pilot Flying and Pilot Not Flying modes is predicated on the previously stored abilities for *decision-making, oral communicating, controlling, assessing, leading, monitoring* and *active listening*.

Figure 3



Wilks Lambda .7327 Chi-Squared 121.91 DF 52 Significance 0.00 $p<.01$

Figure 4.



For training purposes, each of the capacities when defined as performances or process abilities can be analysed in terms of the impact they make in defining their superordinate performance or accomplishment. Added to this as figure 3 illustrates, is an instructional weighting continuum which identifies each capacity as being "common," "potent," or "critical." A *critical* performance or process ability is one in which the size of the correlation within the discriminant function is high (approximately at least +.30), while at the same time accounting for a high proportion of the reported observations. The size of the correlation is based upon each capacities pooled within-groups correlation between discriminating variables and canonical discriminant functions. A *potent* performance or process ability is one in which the size of the correlation within the discriminant function is high, but the frequency of reported observations is less than 35 percent of the total observation. At the level of least impact are those performances and abilities which are *common.* These entities have a low discriminant coefficient and are reported on by less than 35 percent of the observations. Common entities tend to equate with the "core" components of a training syllabus, while potent and critical entities suggest crucial capacities for learning and competency acquisition. In the discriminant analysis of the process abilities underlying *pilot managing* both *decision-making* and *controlling* resulted in critical weightings, while *active listening, monitoring, assessing* and *oral communicating* were found to be common.

The ramification of these results for training and regulatory purposes are significant. They provide licensing authorities, trainers and flight crew examiners with an objective means of defining, prioritising, instructing and evaluating FCPM competencies within the overall context of piloting or environmental accomplishments. Given this data it is possible to construct competency specifications identifying the interaction of abilities with any number of their contextual applications. For example, in a competency specification which focuses on the accomplishment *aircraft performance management*, and *motion* as a critical performance, an *ab initio* application for this competency might be:

> *"In a Piper Tomahawk the student pilot will be tasked to fly three consecutive circuits and landings by day with the maximum demonstrated cross-wind component. The student will be required to determine whether the conditions are beyond his or her current level of ability. In addition, the student will be able to recommend and execute whatever alternative courses of action should be taken."*

In this example, the performance of *motion* (moving and manoeuvring) is being examined through the application of the process abilities of *assessing* (determining environmental conditions), *controlling* (manipulating the flight and throttle controls to select and maintain appropriate attitudes and power settings), *attending* to the stimulus sources of flight instruments, attitude, engine and air noise, *monitoring* (selectively discriminating stimulus information), *interpreting* (synthesizing the data and generating conclusions) and *decision-making* (acting on the best of competing alternatives). Cognitive and affective FCPM skills are embedded in the overall mastery of the accomplishment.

Conclusions

An abilities-based approach to competency analysis provides aviation with a powerful cognitive tool to re-examine many of the traditional assumptions which have formed the basis of pilot training, and more recently the decision-making strategies which are critical to CRM programmes. Empirical evidence derived from information-processing models of psychology and the burgeoning array of sophisticated tools (including those which are artificially intelligent) for identifying and verifying abilities, point with increasing certainty that *maps* of stable ability constructs are becoming available for assisting in the selection, training and assessment of pilot performances at all levels of application.

There is little doubt that the skills which are sought to being inculcated through CRM type interventions are necessary contributors to any attainment of missions which espouse *safe, effective* and *efficient* flight accomplishments. However, it is uncertain as to whether personality or attitude modification programmes can provide the best means to this end. The thrust of an abilities-based approach to flight crew performance management is not to treat communication, judgement and decision-making skills as an optional "add on" to which organizations may respond, but to integrate the appropriate capacities in a more holistic approach to flight crew development. The expectations which can be realized from this approach are a greatly enhanced capability at prescribing competency requirements which maximise the transfer of learning from one condition to the next and which integrate the hitherto discrete dimensions of theory and practice, skill and judgement into dynamic specifications of pilot ability.

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"Human Factors Applications To The Training of Flight Crews: The Next Generation of Cockpit Resource Management (CRM) Training"

by

FlightSafety International

Introduction

Human factors training has become the focus of growing attention within the international aviation community. With few exceptions, airlines, military organizations and regulatory agencies throughout the world have become interested in implementing some form of CRM training for flight crews.

Not surprisingly, CRM training activities are occurring at various levels throughout the world. Some operators are actively conducting training programs for their flight crews. Others anticipate doing so; while still others consider their options.

This paper will briefly review three generations of cockpit resource management training. The first generation, which began in the early 1980s, provided an initial pool of experience and has now yielded to the current level of CRM training activity. Second generation CRM, which is rapidly becoming industry standard, will be compared to its first generation counterpart to identify lessons learned from early experiences and to assess paths to follow in future generations of CRM training. Third generation CRM is yet to come. It represents the next stage in CRM development. This paper will suggest a direction for third generation CRM activities.

The Growth Of CRM Training

For many years the civilian aviation community displayed little support for the idea that pilots would benefit from training in communications skills, leadership, decision making and other areas commonly addressed by present day CRM courses. The term pilot error became a "catch-all" phrase in accident investigations that offered little or no insight into the underlying causes of human error.

In the mid to late 1970s, the need to train flight crews in the nuances of crew coordination and skills that would enhance team effectiveness in the cockpit drew more attention. The research community was learning more about how humans, operating in highly technical environments, perform in critical situations. At the same time, they were exploring innovative ideas on how to improve performance of small groups; which is the composition of a flight crew.

Yet, while accident statistics showed a clear trend in the preponderance of human error mishaps, the aviation community continued to resist adding "human factors" training to the regular routine of training provided pilots.

Then, in 1979, a significant event occurred that would thrust the value of CRM training to the forefront of attention. On December 18, a United Air Lines DC-8 crashed while preparing to land in Portland, Oregon. The flight had experienced a landing gear malfunction, distracting the attention of the crew and adding to the normal workload intensity of approach and landing. The captain, concerned about the potential for a post crash fire on landing and for adequate preparation of the passengers and cabin, delayed landing as long a possible.

Despite remarks from both the first and second officers suggesting a critical fuel state, the delayed landing resulted in fuel starvation to all four engines just prior to reaching the airport.

This untimely event led United to take a close look at how their flight crews worked together in the cockpit. They determined a need to improve the quality of "teamwork" among their pilots. With the assistance of NASA researchers, United Air Lines became the first to initiate cockpit resource management training for flight crews. The significance of this step is noteworthy. This was a new and innovative concept in pilot training. The courage and innovation displayed in their decision to initiate this new program opened the door for an entire industry to re-evaluate expectations of flight crew performance. CRM training has come a long way since then, but that first step is always the most difficult. To their credit, United took it.

Other programs followed; but, only a few. CRM training was considered time consuming, expensive, and different from what pilots and providers of flight crew training were accustomed to. This resistance to change coincided with a new sense of fiscal responsibility among U.S. air carriers created by the onset of deregulation. None the less, from this beginning, cockpit resource management training would continue to grow, and eventually flourish.

First Generation CRM

First generation cockpit resource management training is generally characterized by two features: concepts and awareness. Participants are introduced to basic concepts relating to cockpit resource management and then sensitized to the role the concepts play in the cockpit. This is a useful and necessary part of any CRM training program. Typical among concepts introduced are communications, assertiveness, advocacy, inquiry, command and leadership.

Along with these features, first generation CRM courses had a strong foundation in psychology. Participants were often challenged to examine their own personalities, and to varying degrees, the personalities of others. The purpose of these activities was to create self-awareness among pilots of how they interact with other crew members, and how other crew members interact with them. First generation training was intended to break down the barriers of personality that might inhibit effective crew performance.

Second Generation CRM Training

Those carriers and operators who participated in first generation CRM training activities unknowingly created the framework for current generation CRM training programs. Two overwhelming lessons where learned. First, pilots seemed uncomfortable with the "psychology and personality" features of courses. Perhaps they were threatened by the sensitivity of issues raised, or perhaps the approach was too esoteric. In any case, it became clear that a more practical approach to cockpit resource management was in order.

The second lesson learned was that it was not enough to simply introduce concepts and then develop an awareness of their application to the flight deck. A bridge to practical use was needed: specific skills that pilots might use in the cockpit to improve the effectiveness of the flight crew as an operating team.

Second generation CRM, then, is the result of a natural process of maturation that followed first generation CRM training. These courses tend to be less dependent on the underlying psychology of individual personalities and more concerned with addressing attitudes that crew members bring to the cockpit. This emphasis is appropriate in light of the fact that it is unlikely that CRM, or any other course, can change personalities. However, attitudes, which have a great deal to do with behavior, can be profoundly affected by the activities typically included in CRM training.

Second generation courses also tend to be far more practical in their approach to CRM. In addition to the "concept" and "awareness" phases of training accomplished in predecessor courses, they expose participants to specific skills which can be practiced, perfected and put to use in the cockpit. *To illustrate this difference,* consider a first generation CRM course which might introduce the concept of advocacy, an assertive form of communication. Participants learn to understand the concept and its role in the cockpit. But, they will not have learned how to advocate. In contrast, a second generation program will teach how to advocate, by describing the skill, providing examples and a means to put it to practice.

Other pertinent CRM skills are taught and perfected in a similar manner. Typical among them are communications, listening, team building, leadership, conflict resolution and decision making.

FlightSafety International's Experience

FlightSafety has been conducting cockpit resource management training for several years. Over ten thousand pilot have completed some part or all of our two-day workshop. This program is typical of second generation CRM programs. Instructors function as facilitators of learning rather than in the traditional role of instructor. Lecture is limited to an absolute minimum, replaced instead by an experiential approach to learning marked by group discussions, skill practice sessions, problems solving and role playing exercises, and accident case studies.

The program focuses on two primary goals: _team building_ and _achieving operational goals._ The focus on team building is to present skills that crew members can use to develop the flight crew into the most effective operating unit it can be.

The second emphasis is on achieving operational goals. Consider that when an airplane crashes, it's flight crew has *failed to achieve a goal: that of arriving safely at* destination. There are, in fact, a variety of sub-goals relating to the safe, efficient, scheduled operation of a flight. The course addresses how to maintain a focus on goals and assure that they are achieved.

This dual focus is supported by five basic elements, each of which constitutes a section of the two-day workshop. They are situational awareness and error chains; communication skills; teaming building (which includes a discussion of command, leadership and leadership styles); decision making; and stress management.

The program is a practical approach to maximizing flight crew performance. *It offers specific skills that flight crews can* use to meet designated objectives in a timely and safe manner. A sense of "ownership" in the course is fostered among participants. The absence of grading and reporting creates a non-threatening environment that encourages participation, and application and sharing of experiences among participants.

Third Generation CRM

However effective second generation CRM training is, it lacks one important element: that of measurable, objective performance standards. This is the yet to be realized role of third generation CRM.

As industry develops higher expectations of flight crew performance, it is necessary to develop corresponding measures of assessment. To date however, we continue to use individual performance criteria which measures one's flying skills in terms of prescribed standards of performance relating to control dexterity. Such parameters include altitude, plus or minus one hundred feet; airspeed, plus or minus ten knots; etc. It is ironic that at a time when we are looking ever more closely at crew performance, it is still possible for one crew member to fail a check ride while the others pass. Yet, it is not possible for only one member of a crew to crash: the entire crew succeeds or fails as a team.

In essence, the role of the pilot has changed from that of a control manipulator, to that of an information processor and system manager . The performance measures we employ must keep pace with this changing role.

Measurable crew performance standards will provide:

1. self-assessment targets for pilots;
2. specific behavioral targets for CRM training programs;
3. assessment criteria for crew performance;

This author would suggest that it will be two to five years before measurable CRM related performance criteria are defined in such a manner as to be useable.

A crude, yet formidable, example of a crew-based performance criteria is illustrated by a feature of the cockpit resource management training workshop conducted by FlightSafety. This is called the "Error Chain".

The error chain is a concept that describes human error accidents as the result of a sequence of events that culminate in mishap. There is seldom one overpowering cause, but rather a number of contributing factors or errors, hence the term "error chain". The links of these so called error chains are identifiable by means of eleven clues. Breaking any one link in the chain might potentially break an error chain and prevent a mishap.

Hence, we are suggesting that flight crews, <u>unknowingly</u> progressing toward mishap, might interrupt that sequence of events and avoid mishap.

More than thirty accidents or incidents have been examined in testing the concept of error chains. Each was considered from the following perspective: "If this flight crew had been trained to recognize links in error chains and been proficient in doing so, were links present which, if found, might have caused a different response and outcome?"

In each event considered, the answer was "yes". The fewest links discovered in any one accident was four; the average seven. Yet, recognizing and responding to only one link is all that is necessary to change an outcome. The presence of more than one serves to enhance the potential for timely recognition of an error chain.

While an error chain might be relatively easy to reconstruct during accident investigation, the presence of one may be difficult for a flight crew to detect as it occurs. Familiarizing flight crews with the concept of the error chain corrects this.

These are the eleven clues to identifying links in an error chain. The presence of any one, or more, does not mean that an accident will occur. Rather, it indicates rising risk in the operation of an aircraft and that the flight crew must maintain control through proper management of resources.

*AMBIGUITY
Ambiguity exists any time two or more independent sources of information do not agree. This can include instruments, gauges, people, manuals, senses, controls that do not correspond with associated indicators and so on.

*FIXATION OR PREOCCUPATION
The focus of attention on any one item or event to the exclusion of all others. These may include any number of distractions that can draw attention away from the progress of a flight. Distractions can be the result of high workload brought about by the demands of flight within high density traffic areas, inclement weather, or abnormal and emergency conditions. Distraction can also be the result of personal problems, inattention, complacency and fatigue.

*CONFUSION OR AN EMPTY FEELING
A sense of uncertainty, anxiety or bafflement about a particular situation. It may be the result of falling behind the aircraft, lack of knowledge or experience. Perhaps it is being pushed to the limit of one's ability or experience. It is often evidenced by physiological symptoms such as a throbbing temple, headache, stomach discomfort or nervous habit. Researchers suggest that these signals are symptomatic of uneasiness and should be trusted as indicators that all may not be right.

*NO ONE FLYING THE AIRCRAFT
No one monitoring the current state of progress of a flight. Flying the aircraft is the highest priority for the flight crew. If it is not being attended to, perhaps other equally important priorities are being overlooked.

*NO ONE LOOKING OUT THE WINDOW
Again a matter of priority. At a time when one of the greatest hazards to flight safety is the threat of midair collision in the terminal area, it is easy to be tempted to keep ones head in the cockpit rather than maintaining a careful eye outside. If this priority is lost, are any others?

*USE OF AN UNDOCUMENTED PROCEDURE
The use of procedure or procedures to deal with abnormal or emergency conditions that are not prescribed in approved flight manuals or checklists. Does the flight crew have a thorough understanding of the problem? Have all resources been used to their fullest potential?

*VIOLATING LIMITATIONS OR MINIMUM OPERATING STANDARDS
Intent to or violation of defined minimum operating conditions or specifications, either intentionally or unintentionally, as prescribed by regulations or more restrictive flight operations manuals or directives. These include weather conditions, operating limitations, crew rest or duty limitations, systems limitations, airspeed restrictions and so on.

*UNRESOLVED DISCREPANCIES
Failure to resolve conflicts of opinion, information, changes in conditions.

*FAILURE TO MEET TARGETS
Failure of the flight or flight crew to attain and/or maintain identified targets. Targets include ETAs, airspeeds, approach minimums, altitudes and heading, configuration requirements, plans, procedures or any other goals established by or for the flight crew.

*DEPARTURE FROM STANDARD OPERATING PROCEDURE

Intent to or inadvertent departure from prescribed standard operating procedure. Well defined SOPs are the result of a synergistic approach to problem solving with the influence of time removed. As a result, in difficult situations, standard operating procedures represent an effective means of problem resolution without the sacrifice of time, which is often not available.

This is not to suggest that SOPs will resolve all problems. However, they are an effective starting point. Failure to follow SOP constitutes a link in the error chain and is an appropriate indicator of rising risk.

*INCOMPLETE COMMUNICATIONS

Incomplete communications are the result of withheld information, ideas, opinions, suggestions or questions; and failure to seek resolution of misunderstandings confusion or disagreements. For example, if a crew member withholds information, or fails to question another crew member about an area of concern, a link in the error chain exists. Likewise, if a crew member believes another crew member to be withholding communications, this too constitutes a link in the error chain.

The presence of one or more of these clues means that an error chain <u>might</u> be in progress and that appropriate caution is advised. Recognition of the presence of error chain links provides a flight crew with the tools to appropriately manage risks associated with flight.

It is important to point out that identifying the presence of an error chain does not in and of itself eliminate the risk of mishap. Instead, it serves as a warning to the crew that they must take appropriate action to manage the progress of the flight in the face of rising risk.

Air Florida Flight 90

To illustrate the application of the error chain, consider events surrounding Air Florida flight 90 (Palm 90) in January of 1982. The Boeing 737, scheduled to fly from Washington National Airport to Tampa, Florida, encountered lengthy departure delays while on the ground in Washington due to severe winter weather conditions in the Washington, D.C. area and at the airport.

After takeoff, the crew had difficulty maintaining a positive rate of climb and the aircraft crashed into a bridge, spanning the Potomac River just north of the airport. Among the findings of the National Transportation Safety Board were that the crew had failed to activate the aircraft's engine anti-ice system during ground operations. As a result, the Pt2 probe, which serves as a ram air pressure source for EPR indications, became blocked by ice accumulation, thus providing EPR instrument readings higher than actual engine thrust output. The engines, which normally would be expected to produce 98% or more turbine power at takeoff, were actually generating between 78% and 82% turbine power. This was inadequate to maintain a positive rate of climb in the existing conditions.

Were links in the error chain present during this flight? If the crew had been trained to recognize and react to the presence of these error chain links, might they have performed differently? Let us consider what happened.

There were clearly visible links in the chain that the crew might have identified.

Ambiguity existed in the cockpit. While EPR was set in accordance with charted power settings for the takeoff, turbine tachs, EGT gauges and fuel flow indications would not have supported what the crew thought to be correct takeoff power. This link in the error chain provided the crew an opportunity to break the chain.

Fixation or preoccupation may have been present. It has been suggested by some that the captain was preoccupied with concerns for the financial condition of his company which may have caused him to press on rather than expose his passengers to further delays. There is no factual evidence to indicate that this occurred. In fact, Air Florida was financially sound at the time. Nonetheless, if concerns for schedule distracted the captain from the primary goal of the operational safety of the flight, it represented another link in the error chain.

Confusion was present. On three separate occasions, the first officer observed that he did not believe the takeoff to be proceeding normally. These concerns were neither addressed or rectified by the crew. In fact, the captain offered no response to any of the three comments of the first officer who said , "...that's not right."

The use of an undocumented procedure was evident. According to the cockpit voice recorder tape, the captain expressed concern about the accumulation of airframe ice. In an attempt to mitigate the effect of potential ice buildup he parked the aircraft closely behind another jet waiting in line for takeoff, perhaps expecting the hot jet blast from ahead to melt the ice from his aircraft. This procedure is not contained within any known documentation relative to the Boeing 737.

Unresolved discrepancies existed in the form of the concerns raised by the first officer that were not reconciled. In fact, he voices his concerns on three separate occasions, none of which were addressed to a satisfactory conclusion.

The crew also failed to meet targets. Climb performance targets were not met. They failed to correctly set power for takeoff. Acceleration down the runway during takeoff roll was hindered by the absence of full power, weight of ice on the airframe and contaminated runway surfaces. Each provided an opportunity to break the chain.

The crew departed from standard operating procedures by failing to operate the engine anti-ice system while on the ground.

It should be noted that inadvertent departure from SOP is very difficult for a crew to identify because it occurs by accidental omission rather than by intent. However, rigorous use of checklists and accurate understanding of related conditions provide some protection from this. Furthermore, crews that knowingly depart from SOP have introduced a link in an error chain.

Finally, a communications breakdown occurred. The concerns of the first officer were not explored and were not addressed to his satisfaction. Nonetheless, the flight proceeded.

Eight of the eleven links in the error chain were present and could have been recognized by this flight crew had they been trained in its use. Only one link is needed to break the chain: and there were eight.

Are we suggesting that the accident would have not happened? No! However, this author is suggesting that recognition of the links in the error chain would have provided the flight crew with ample opportunity to react differently to events, perhaps in such a way as to have changed the outcome.

Putting Error Chains To Use

The concept of error chains has been put to practice in two ways at FlightSafety. Participants in cockpit resource management training workshops are taught the error chain and challenged to use it during a series of case studies and role playing exercises. We have also begun to use the concept as part of simulator training. Posters, listing the links in the error chain, are placed in briefing rooms where flight crews are challenged to perform error chains analyses of their own performance during debriefing sessions.

Conclusion

The error chain concept represents an objective behavioral target in that training scenarios can be constructed to include one or more links. Flight crews can then be evaluated on their success in identifying and responding to them.

As mentioned, we believe the error chain to be a crude beginning. For example, how should a crew respond to the presence of an error chain link? Can it be addressed procedurally, and if so how? We have yet to answer these questions, but we are working to do so.

None the less, the error chain concept has the potential to make a significant contribution to flight safety now, and provide a platform toward a more refined approach to measurable crew oriented performance assessment criteria for the future.

LA PSICOLOGIA EN LA AVIACION CIVIL DE CUBA. SU CAMPO DE TRABAJO EN EL ESTUDIO DE LOS FACTORES HUMANOS

Licenciada en Psicología
María del Carmen Pico Penabad

Licenciado en Psicología
Pedro Cabrera Daniel

El término "factores humanos", se ha utilizado de muchas maneras que abarcan muchos temas diferentes. En la siguiente exposición abordaremos las líneas de trabajo de la psicología en la Aviación Civil de Cuba; cuyo campo de estudio está dirigido fundamentalmente "al hombre" y su interrelación en el sistema: hombre - máquina - medio ambiente.

En el concepto "factor humano", se entiende que forman parte de él las características psicológicas del píloto, o sea las posibilidades y las limitaciones que son características para todos los pilotos al surgir dificultades objetivas.

La introducción del concepto "factor humano", dá la posibilidad de separar la culpa real cometida por el piloto de la culpa que está relacionada con la técnica, o más exactamente de la imperfección ergonómica de los instrumentos y las limitaciones de las posibilidades humanas.

Como resultado del progreso científico técnico en la esfera de la técnica de Aviación, se perfeccionan constantemente los aviones, y actualmente los mismos son equipos altamente complicados, con dispositivos técnicos muy modernos, pero el papel fundamental de este sistema: hombre-máquina-medio ambiente lo ocupa el "hombre", ya que el trabajo de pilotaje de una aeronave es catalogado fundamentalmente como una actividad mental, donde el nivel funcional de los procesos cognoscitivos y la estabilidad emocional del piloto deben ser óptimos para el buen desempeño de su actividad, pues su eficiencia no depende unicamente de sus habilidades técnicas, entrenamientos, y salud física.

La alta seguridad y efectividad del funcionamiento de este sistema, puede garantizarce solamente cuando las características técnicas de los elementos de la máquina y su nivel de seguridad se encuentren en correspondencia con las posibilidades psicofisiológicas del hombre, y que los factores del medio ambiente no ocasionen una capacidad de trabajo desfavorable.

En los últimos años se ha producido un despertar gradual frente al hecho de que el "factor humano" es tán importante como el factor técnico, como consecuencia que han disminuído el número de accidentes causados por la máquina, mientras que los causados por el hombre han aumentado en proporción.

Frecuentemente la causa fundamental de errores en el vuelo es la inexactitud de las acciones a ejecutar por parte del piloto en el mando del avión, o sea, la técnica de pilotaje y los factores psicológicos puros, o como también se le ha dado en llamar: "el error humano", como pueden ser: la no correcta valoración de la información

Como resultado de la recepción errónea de la situación; la no correspondencia de un momento dado con la distribución y concentración del proceso de atención; deficiencias sensoperceptivas, rasgos de personalidad que pueden ejercer influencia en la toma de decisiones del hombre, y todos aquellos estados psicofisiológicos no favorables del Piloto.

Es importante aceptar que el "Error Humano" es inevitable, pues el Piloto no actuará a la perfección en todo momento, lo que podría señalarse como actuación perfecta en ciertas circunstancias podría ser inaceptables en otras; por lo cual es necesario la atención al hombre el cual está sometido a una amplia gama de variables y de situaciones y circunstancias muy diferentes, las cuales no pueden preverse fácilmente en su totalidad.

Al analizar los problemas de la Seguridad de los Vuelos, siempre debemos partir de la afirmación de que la Aviación es un Sistema, donde "el todo" está compuesto por 3 aspectos : El Hombre- el Avión y el Medio. Un análisis de las distintas esferas sirve de interés a la seguridad de los vuelos y de esta forma se hace posible el estudio de las relaciones recíprocas complejas dentro del sistema.

Se sobre entiende que en éste Sistema la capacidad humana debe estar constantemente "reasegurada"; es necesario estudiar y chequear regularmente las propiedades de la Psiquis del hombre, por lo cual la Psicología Aeronáutica en Cuba comprende diferentes funciones como son : La selección profesional, Psicología Clínica, Profiláxis y la Prevención e Investigación de Accidentes.

La Selección Profesional de los aspirantes a Piloto o a puestos de trabajos relacionados con la Seguridad de los Vuelos como: Controladores del Tránsito Aéreo, Aeromozas y Sobrecargos, Ingenieros de Vuelo, Navegantes y Técnicos de Tierra; según los índices psicofisiológicos determinados, constituye un sistema de medidas encaminadas a detectar a las personas que por sus cualidades individuales son más útiles para la instrucción y para la futura actividad de vuelo o de tierra.

En los exámenes Psicológicos el sistema de exigencia para los aspirantes a Carreras de Aviación es rígido, se investigan todas aquellas funciones psíquicas que tienen importacia especial en los distintos perfiles profesionales de la Aviación Civil, como por ejemplo: Las funciones sensomotoras; los distintos componentes del proceso de atención como: La concentración, la distribución, el volúmen y las variaciones y la estabilidad de la misma; valoración de las cualidades del pensamiento, como: capacidad para el análisis y la comparación, habilidad para hacer conclusiones lógicas; facilidad del surgimiento de relaciones asociativas: establecimiento de identidad; diferencia y rapidéz de la conmutación de un modo de operación mental a otro; estudio de la memoria: memoria operativa y memoria mediata o inmediata; determinación del coeficiente de inteligencia; exploración de la existencia de elementos orgánicos y las características de personalidad que puedan influir en las relaciones-sociales, laborales y personales.

Es importante que en los exámenes psicológicos, el psicólogo identifique la motivación por la profesión, y si es necesario la dirija hacia un sentido de salud, porque la disminución de la motivación tarde o temprano puede constituir una premisa - de accidente.

La Psicología Clínica en la Aviación Civil de nuestro país comprende el estudio --- clínico psicológico orientado a la evaluación, diagnóstico, psicoprofiláxis y rehabilitación de las tripulaciones de vuelo y controladores de tránsito áereo.

Los exámenes psicológicos se realizan anualmente; las entrevistas psicológicas y -- psicométricas se realizan en un ciclo de 4 años; las entrevistas se mantienen todos los años y los psicométricos se desglosan parcialmente entre los 4 años, de la ---- siguiente manera :

1er Año

Evaluación del nivel funcional de los procesos cognoscitivos como: atención, memoria, pensamiento, capacidad para operar con representaciones espaciales y capacidades psicomotoras.

2do Año

Control más específico y minucioso de los procesos funcionales.

3er Año

Estudio de la personalidad

4to Año

Comprobación y re-estudio general de todas las funciones psíquicas y la personalidad.

La metodología expuesta anteriormente fué una propuesta de la Comisión permanente-- del CAME para la Aviación Civil en el año 1986.

Esta concepción metodológica fue aprobada, ya que se sustenta sobre resultados científicos y se encuentra en aplicación actualmente.

El orden integral de los exámenes asegura la posibilidad de una comprobación permanente de todas las funciones psicológicas y de la acción efectiva en caso de anomalías que influyen en la seguridad de los vuelos.

Al mismo tiempo consideramos como un factor importante el hecho de que con éste --- método el Psicólogo se encuentra en una constante y estrecha relación con el personal aeronáutico, fortaleciéndose la relación abierta y sincera entre el psicólogo y los tripulantes, ya que las Tripulaciones de Vuelo, Controladores del Tránsito Aéreo y Técnicos, tratan de no mostrar sus debilidades y problemas por temor a la --- ineptitud en su puesto de trabajo.

De esta manera se realiza el estudio clínico-psicológico conjuntamente con otras -- medidas psicoprofilácticas que se llevan a cabo, como son

1. La participación del Psicólogo en las reuniones mensuales del cuerpo de instructores, con el objetivo de conocer y contribuir en el análisis de aquellos tripulantes o controladores de tránsito aéreo con dificultades en el desempeño de la técnica, al igual que los tripulantes que se proponen para la trancisión a Capitanes de Aeronaves o Técnicas superiores, estableciéndose de ésta forma un estudio psicológico del caso por parte del psicólogo y por parte del instructor el- estudio de la técnica.

2. Preparación psicológica de las tripulaciones para el vuelo de acuerdo a su perfil ocupacional y muy en especial a los Capitanes de Aeronaves, mediante cursos docentes programados periódicamente.

La Profiláxis constituye el objetivo fundamental de la Comisión Médica de la Aviación Civil, por lo cual el estudio clínico-psicológico está orientado fundamentalmente a detectar y valorar a tiempo cualquier tipo de afección psicógena que pueda- existir en nuestro personal.

En caso de que existiera alguna afección psíquica en el hombre, la psicoprofiláxis- se lleva a cabo mediante consultas preventivas, en la cual se le realiza al trabajador, ya sea tripulante de vuelo, ATC o técnico de tierra, una entrevista psicológica para llegar a un diagnóstico clínico, y de esta forma indicar el tratamiento a - seguir según la patología que presente; si con el tratamiento el caso no es recuperable se discute el mismo en Comisión Médica y se determina su no aptitud para el-- puesto de trabajo.

Especificamente las Tripulaciones de Vuelo pueden tener diferentes particularidades psicológicas individuales que le invaliden su aptitud para el vuelo o le entorpezcan en un momento determinado la asimilación exitosa de su actividad.

Entre estas particularidades psicológicas, las cuales denominaremos categorías, se hallan las siguientes :

- Ausencia o pérdida de la motivación por el vuelo.
- Desadaptación al vuelo.
- Miedo al vuelo.
- Y bajo nivel funcional de los procesos cognoscitivos.

Estas categorías psíquicas mencionadas anteriormente pueden ser no solo particularidades psíquicas individuales del hombre, sino, que pueden ser síntomas que inicien determinadas patologías psiquiátricas o puede darse el caso que surja una patología psiquiátrica por sí misma, la cual incapacita al tripulante para continuar siendo apto personal de vuelo, teniendo en cuenta los requisitos médicos de la OACI, como son :

- Psicosis
- Alcoholismo
- Dependencia a fármacos.
- Desordenes de la personalidad, en particular cuando son lo suficientemente graves como para haberse manifestado repetidamente mediante acciones evidentes.
- Y Anomalías mentales o neurosis.

En nuestro trabajo diario existe además una estrecha relación de la Psicología con otras especialidades de la Comisión Médica, como : Psiquiatria, Medicina Interna, Otorrinolaringología, etc; ya que la actividad de los Tripulantes y Controladores de Tránsito Aéreo, transcurre sobre una elevada tensión psíquica y la influencia sobre su organismo de factores desfavorables del medio exterior.

En estas condiciones adquiere un especial interés la valoración no solo de su estado fisiológico, sino también psicológico, ya que muchas patologías orgánicas tienen como etiología un origen psíquico, siendo frecuente los casos con sintomatología de ansiedad latente.

Ante la presencia de estos casos, se realiza un trabajo terapéutico conjunto con el médico asistente y el psicólogo sobre la base de un programa de rehabilitación, utilizando fundamentalmente técnicas que se engloban en los principios de las técnicas de relajación , como son : El entrenamiento autógeno, ejercicios respiratorios espe-

Para llevar a cabo dicha terapia se realizan consultas sistemáticas para la aplicación de la técnica de relajación, y seguir la evolución del caso.

De esta forma el hombre aprende los métodos de autocontrol y autorrelajación para-- ponerlos en práctica en su actividad de trabajo, y su realización sistemática implica la disminución paulatina de los altos niveles de ansiedad, hasta obtener una --- curación total y ser dado de alta.

La Comisión Médica de la Aviación Civil, realiza la profiláxis y rehabilitación del personal de vuelo en dos direcciones, las cuales están en correspondencia con el nivel funcional de la capacidad psíquica de trabajo de este personal: Una que se realiza en el Centro de Medicina de Aviación, la cual explicamos anteriormente, y otra que se lleva a cabo en el Profilactorio de Topes de Collantes.

El Profilactorio es una Institución Médica de carácter eminentemente profiláctico,- con algunos rasgos asistenciales, se destina para el fortalecimiento del estado de- salud del personal de vuelo a través de entrenamiento físico programado bajo control médico.

Al Profilactorio acuden todos los años personal de vuelo, siendo remitidos algunos- casos con orientaciones específicas por los psicólogos u otra especialidad del Centro de Medicina de Aviación.

Los objetivos generales de esta Institución son :

- Valorar el estado físico y psíquico del personal, y estudiar la capacidad física y mental del hombre para prolongar su servicio activo en la aviación.

Esperamos que con el tiempo ésta actividad para la conservación de la salud mental, no solamente reduzca el porciento de accidentes, sino que también aumente la cantidad de especialistas que se mantienen en la actividad aérea al igual que se reduzca la proporción de las distintas enfermedades incapacitantes en la Aviación Civil.

En el campo de la Prevención e Investigación de Accidentes, la Psicología trabaja-- fundamentalmente en la investigación de los aspectos psicosociales que constutuyan- premisas de incidentes o accidentes.

Las investigaciones psicológicas en los accidentes de aviación, deben penetrar más- profundamente en la causalidad y en las condiciones en que se dá el accidente, ---- detectando las desviaciones en el microsistema Avión-Tripulación-Medio Ambiente.

En esta línea de trabajo se investigan :

Las características individuales, psicológicas y sociales del sujeto del accidente.

Aquí se estudia :

El nivel de la carga psicofisiológica del hombre (sentimientos, emociones, fatiga, elevada tensión emocional y nivel funcional de sus procesos cognoscitivos), más el grado de transformación social de los mismos (orientación volitiva, equilibrio volitivo emocional) y el grado de responsabilidad profesional del sujeto del accidente.

Los accidentes de Aviación son causados generalmente por situaciones en las cuales la capacidad del individuo es insuficiente o puede suceder que el individuo no pueda sobreponerse a una situación adversa del medio ambiente. Al considerarse la actuación de la persona en un accidente o incidente, se evalúan las decisiones y las acciones del individuo en un momento dado, teniendo en cuenta la sobrevaloración que existe por parte de algunos pilotos en cuanto a sus posibilidades, conocimientos y experiencia.

En consecuencia debe prestarse suma atención a todos los factores que pueden ejercer influencia sobre el personal participante.

En otras palabras no solo debe prestarse atención al error humano, sino también a las razones que condicionaron ese error, las cuales pueden ser múltiples; para mayor simplicidad éstas causas se han dividido en tres grupos: Humanos, Mecánicos y Ambientales.

En la investigación del factor humano el Psicólogo se debe cuestionar muchas interrogantes, como por ejemplo :

- ¿Se encontraba el hombre en plena capacidad física y mental para responder correctamente?. En caso negativo, ¿Por qué no?.

- ¿La situación era consecuencia de un estado de fatiga debido a su régimen de trabajo y descanso?.

- ¿Tenía ese hombre algún problema que lo afectara emocionalmente, ya fuera familiar, social o laboral?.

- ¿La persona había sido debidamente adiestrada para enfrentar la situación?.
  Si así fuera:

- ¿Quién era el responsable de un adiestramiento insuficiente?. Y ¿Por qué?.
- ¿La aeronave presentó algún desperfecto técnico que imposibilitó el buen desempeño de la actividad de vuelo?. En caso afirmativo. ¿Cúal?

Estas son solo unas pocas de las muchas preguntas a indagar durante la investigación de accidentes.

La Prevención de Accidentes requiere de un trabajo ininterrumpido psicoprofiláctico-de atención al hombre, con el objetivo de prevenir accidentes o incidentes, y de ésta fòrma preservar la Seguridad de los Vuelos.

Referente a las investigaciones científicas realizadas por la Comisión Médica de la-Aviación Civil de Cuba, éstas se han encaminado al estudio del factor humano en los-diferentes perfiles y puesto de trabajo de la Aviación Civil.

Haremos alusión muy breve de algunas investigaciones realizadas en nuestro país y --expondremos como primer ejemplo un trabajo realizado en el año 1988, referente al --"Estudio de la Ansiedad en Controladores de Tránsito Aéreo".

Los objetivos fundamentales de dicho trabajo fueron los siguientes :

1.- Demostrar que las características de trabajo de los Controladores de Tránsito--Aéreo generan estados psíquicos de ansiedad.

2.- Valorar la influencia de los factores psicosociales en el Sistema ATC.

Después de un análisis de los resultados obtenidos mediante diferentes técnicas psicológicas aplicadas en los distintos turnos de trabajo de este personal, llegamos a-la conclusión que :

1.- Las características sui géneris de la actividad de Control de Tránsito Aéreo, -producen de por sí altos niveles de ansiedad, como estado o situacional en ese-personal.

2.- Los factores psicosociales recogidos en nuestro trabajo, que incluían la exploración de las esferas: laboral, familiar y personal, en caso de que existieran-afectaciones en alguna de éstas esferas, contribuirán a criterio de los encuestados influencias negativas para el trabajo de los mismos, y por consiguiente--facilitan a incrementar los estados de ansiedad.

En dicho trabajo se orientaron las medidas psicoprofilácticas a seguir con los ATC-- en función de los resultados obtenidos.

En el año 1986, realizamos un trabajo con los pilotos de la Aviación Agrícola para-- valorar la Incidencia de Hiperlipidemias y otros factores de riesgo vascular en pilotos de dicha Empresa.

Los objetivos de trabajo del psicólogo en esta investigación fueron los siguientes:

1.- Valorar las alteraciones de la capacidad de trabajo en los diferentes vuelos de- fumigación, al igual que en los vuelos de distribución de publicaciones periódicas en las zonas rurales del país.

2.- Valorar sentimientos de inadecuación, temor y ansiedad en los pilotos que realizan los vuelos mencionados para demostrar si las afectaciones cardiovasculares y y las alteraciones lipídicas que se pudieran encontrar, podrían tener como base- un orígen psíquico.

Los resultados se obtuvieron a través de mediciones psicofisiológicas realizadas --- antes - durante y después del vuelo, arrojando que un porciento alto de pilotos presentaron alteraciones en la capacidad de trabajo post-vuelo, observándose déficit -- con fatiga manifiesta en el vuelo de la prensa, y un alto grado de ansiedad como estado, al igual que sentimientos de inadecuación y temor durante los vuelos de fumigación.

Dichas alteraciones psicológicas tienen como causales el gran temor que sienten los- Pilotos en los vuelos de fumigación, por la manipulación de los productos tóxicos,-- siendo más marcado con los productos líquidos que con los sólidos.

En los Vuelos de la Prensa, el factor causal era el tiempo prolongado de vuelo, y -- las condiciones meteorológicas complejas de la zona estudiada.

Además se encontró relación en algunos casos, entre alteraciones lipídicas y electrocardiográficas en pilotos con altos niveles de ansiedad latente.

En función de los resultados obtenidos se recomendaron sugerencias para los Pilotos- de la Aviación Agrícola, como por ejemplo :

1.- Se modificó el vuelo de la Prensa, realizando más escalas en el transcurso del-- vuelo con cambios de tripulación.

2.- Chequeo sistemático y riguroso a los Tripulantes de la Aviación Agrícola, debido a la manipulación de los productos tóxicos.

Actualmente un Grupo de Especialistas de la Comisión Médica de la Aviación Civil, entre ellos Psicólogos; se encuentran en la primera fase de estudio y conclusiones --- acerca de un trabajo investigativo referente a la "Influencia del cambio de los usos horarios en las funciones psicofísicas del personal tripulante en vuelos trasatlánticos.

Consideramos que éste trabajo preliminar, abre un amplio campo de investigaciones -- referente al estudio del Factor Humano; el cual se continuará con una muestra de --- grupos mayores, para llegar a resultados y conclusiones finales más definitivas.

LA FRECUENCIA CRITICA DE FUSION.
UNA EXPERIENCIA CONCRETA EN EL MEDIO AERONAUTICO

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Introducción:

En sentido general, tanto por los investigadores, especialistas y demás profesionales, los cuales se desempeñan en el marco de la salud ocupacional, consideran el trabajo de vuelo una de las más complejas y difíciles actividades del ser humano, dado por la serie de particularidades principales que lo identifican; las cuales comienzan desde las tareas que preceden la preparación de las naves aéreas para el despegue, su rápido desplazamiento en el espacio, el elevado ritmo de trabajo y precisión, la elevada tensión emocional que trae aparejada y que aumenta ante situaciones inesperadas, etc., hasta su culminación con el aterrizaje. Todo lo cual exige un adecuado estado de salud físico y psíquico, acorde con las exigencias de la mencionada actividad de vuelo.

Es precisamente, una de las tareas principales del Centro Nacional de Medicina de Aviación de Cuba, la de perfeccionar el Examen Médico de Control de Salud (EMCS) del personal de vuelo, lo cual se puede traducir en la elevación de la calidad del estudio de la capacidad de trabajo del ya nombrado personal.

La capacidad de trabajo, como es conocido, constituye una propiedad integral del organismo del hombre y esté condicionada por muchos factores fisiológicos, psicológicos y sociales (1) y aunque en el sentido empírico se entiende como la capacidad del hombre, para realizar con efectividad la actividad práctica en base al logro de un objetivo, en un tiempo dado; existen innumerables definiciones de capacidad de trabajo, condicionadas a la forma de analizar y medir la capacidad de trabajo por sus autores.

En nuestro centro, como en sus homólogos de otros países; las tripulaciones de vuelo son estudiadas por las diferentes especialidades médicas, las cuales reflejan criterios de aptitud pa re el vuelo; ellos constituyen indicadores indirectos del nivel de la capacidad de trabajo del mencionado personal de vuelo, ya que este examen tiene la limitante de realizarse fuera del marco o del proceso de la propia actividad de vuelo, pero posibilita detectar cambios duraderos y referirse al nivel general del estado funcional del organismo del hombre.

El presente trabajo responde a las investigaciones psico fisiológicas, que se realizan en nuestro centro, durante el EMCS a las tripulaciones de vuelos; siendo el objetivo general de esta investigación, el perfeccionamiento de un sistema de evaluación del estado funcional de los pilotos de aviación, a través de indicadores psicológicos y psico fisiológicos; siendo el objetivo específico el establecimiento de criterios normativos, para el análisis de la dinámica cortical del referido personal.

Para el establecimiento de las normas, hemos tomado como indicador psico fisiológico, la Frecuencia Crítica de Fusión (FCF), que obtiene a través del instrumento Flicker.

La evaluación de la FCF a partir del Flicker, ha sido utilizada para el diagnóstico de la fatiga, ya que es considerado como un indicador válido y confiable del nivel de vigilancia, activación cortical, así como indicador precoz de procesos patológicos (2).

Importantes fueron los hallazgos de Grümberg (3), al encontrar una correlación significativamente positiva entre la FCF y la actividad psicomotora, así como Holmerg (4), Lapierre (5) y Hindmarch (6), los cuales, en investigaciones independientes demostraron, que por medio de la evaluación de la FCF, se evidencia el efecto de las drogas en la dinámica de la corteza cerebral.

Hoy día, es difícil la ausencia de la evaluación de la FCF, en aquellos investigadores que explican la dinámica cortical y la capacidad general del funcionamiento de la misma.

Material y Método.

Para el presente estudio, se escogió la población de pilotos, que pasaron el EMCS en el primer semestre del año 1989, en el Centro Nacional de Medicina de Aviación de Cuba. De ellos se excluyeron los pilotos que tuvieron accidentes y premisas por su responsabilidad (técnica de pilotaje), en un período de doce (12) meses antes de la evaluación y aquellos los cuales se les detectaron patologías o afecciones de la salud en el referido EMCS; en total fueron procesados los resultados de 130 pilotos.

Las especialidades de los pilotos sometidos a la investigación, las constituyen las concernientes a las tripulaciones de aviones, monomotores (Zlin y AN-2), turbohélices (AN-24,26 y 30), turbo-reactores (Yak-40, TU-154 e Il-62).

El instrumento utilizado, el referido Flicker, permite el registro de la FCF y se define como la frecuencia en la que el centelleo de una luz desaparece a la vista del ojo humano (2).

El método utilizado corresponde a los límites, consistentes en promediar umbrales instantáneos.

Se aplicaron dos de sus variantes:

1º Forma ascendente, comienza con una frecuencia de 10 Hz y va incrementándose hasta el punto de fusión, cuando el sujeto deja de ver el centelleo.

2º Forma descendente, parte en tal sentido de una frecuencia de 60 Hz, la luz aparece fija para el sujeto y en la frecuencia donde el sujeto percibe que comienza a centellear, se determina el valor umbral del centelleo.

La forma de aplicación es individual y en condiciones de laboratorio.

El análisis estadístico se basó en la media aritmética y en la desviación standar, siendo procesados los datos en una computadora ACER 1100 IBM compatible.

Resultados y Discusión.

Observando los resultados de los pilotos en la forma ascendente de presentación del estímulo (ver Tabla Nº 1), se aprecia una $\bar{X} = 36,61$ Hz y una $S = 4,58$ para los pilotos de aviones mono-motores; una $\bar{X} = 36,51$ Hz y la $S = 3,76$ para los pilotos de aviones turbo-hélices; los pilotos de aviones turbo-reactores reflejan una $\bar{X} = 36,34$ Hz y la $S = 4,81$.

Estos resultados reflejados en el Gráfico Nº 1, nos permiten apreciar que no existen diferencias significativas entre los re sultados de las diferentes técnicas de pilotos, lo cual se avala con los valores de las desviaciones standars (Tabla Nº 1).

Al evaluar los resultados de los pilotos investigados en la forma descendente de presentación del estímulo (Tabla Nº 2), nos muestra que los pilotos de aviones monomotores su $\bar{X}$ = 33,04 Hz y la S = 2,66; para los pilotos de aviones turbo-hélices, la $\bar{X}$ = 32,30 Hz y la σ = 3,25; siendo la $\bar{X}$ = 32,47 Hz y la S =3,67 para los pilotos de aviones turbo-reactores.

Dichos resultados reflejados en el gráfico Nº 2, nos permiten apreciar diferencias no significativas, en esta forma de presentación del estímulo (descendente), en los pilotos investigados, lo cual se avala además, por los valores muy similares de las desviaciones standars.

El primer análisis que se infiere de los resultados alcanzados, es el referido a que ambas formas de presentación del estímulo, (ascendente y descendente) no reflejan diferencias significativas, en su proyección individual, para decidir la utilización preferente de uno de ellos con vista a la obtención de elementos, que indiquen cómo transcurre el proceso de la dinámica cortical en los pilotos de aviación, de los tipos de técnicas evaluados.

El segundo está referido a que los datos procesados en esta investigación, permiten establecer criterios evaluativos para esta población de pilotos, para cada una de las dos formas de presentación de estímulo (ascendente y descendente).

Si además, estos resultados, los referidos a las medias obtenidas en cada una de las formas de presentación del estímulo, la comparamos con resultados frutos de investigaciones llevadas a cabo en el Instituto de Medicina del Trabajo de Cuba (2), en operadores que su actividad laboral difieren de las particularidades del trabajo de vuelo y que se obtuvieron $\bar{X}$ = 30 Hz, nos está confirmando lo ya planteado por otros autores (1), (7); sobre la influencia del trabajo de vuelo en la actividad del sistema Nervioso Central del piloto y nos alerta directamente de cierta proyección en el transcurrir de la dinámica cortical en este personal.

Conclusiones.

Basado en el análisis de los resultados, referidos a la población estudiada, consideramos que:

1/ Es provechoso cuando evaluamos el proceso en que, transcurre la dinámica cortical de los pilotos de aviación, utilizan el método de los límites, en su faena ascendente y/o -- descendente.

2/ Los criterios de normalidad del proceso de la dinámica cortical, evaluados a través del instrumento Flicker para los sujetos de la técnica de aviones mono-motores es la $\bar{X}=36{,}61$ Hz, con una $S=4{,}58$; para los pilotos de aviones turbo-hélices, la $\bar{X}=36{,}51$ Hz y la $S=3{,}76$; siendo para los pilotos de aviones turbo-reactores la $\bar{X}=36{,}34$ Hz y la $S=4{,}81$.

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TABLA Nº 1

FORMA ASCENDENTE

Pilotos de Aviones Mono-motores $\bar{X}$ = 36,61 Hz S = 4,58

Pilotos de Aviones Turbo-hélices $\bar{X}$ = 36,51 Hz S = 3,76

Pilotos de Aviones Turbo-reactores $\bar{X}$ = 36,34 Hz S = 4,81

TABLA Nº 2

FORMA DESCENDENTE

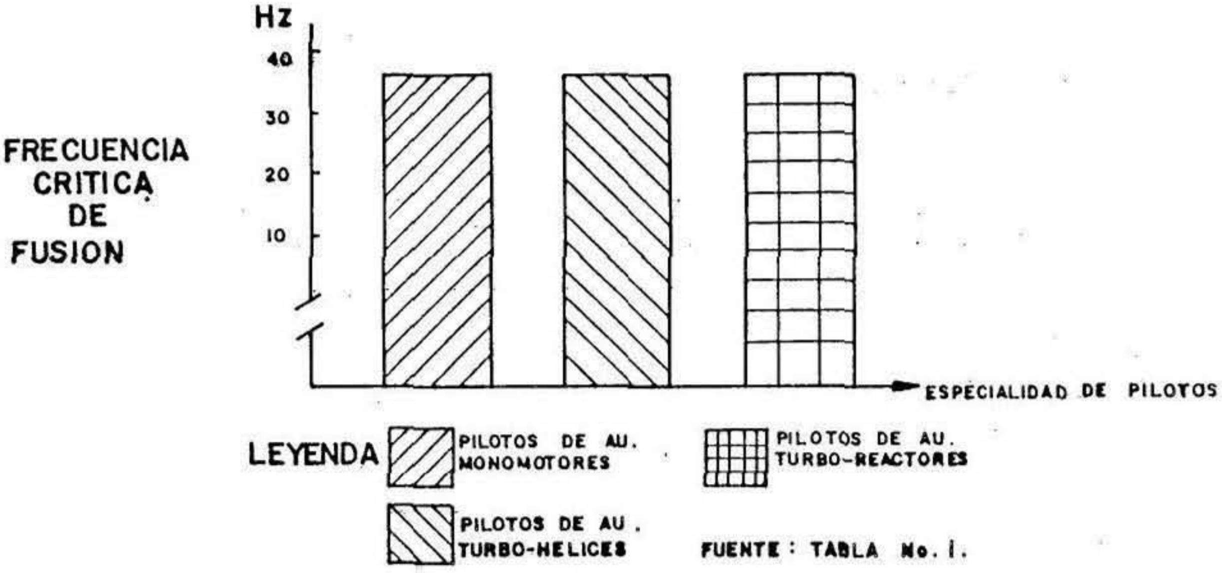
Pilotos de Aviones Mono-motores $\bar{X}$ = 33,04 Hz S = 2,66

Pilotos de Aviones Turbo-hélices $\bar{X}$ = 32,30 Hz S = 3,25

Pilotos de Aviones Turbo-reactores $\bar{X}$ = 32,47 Hz S = 3,67

GRAFICO N°1

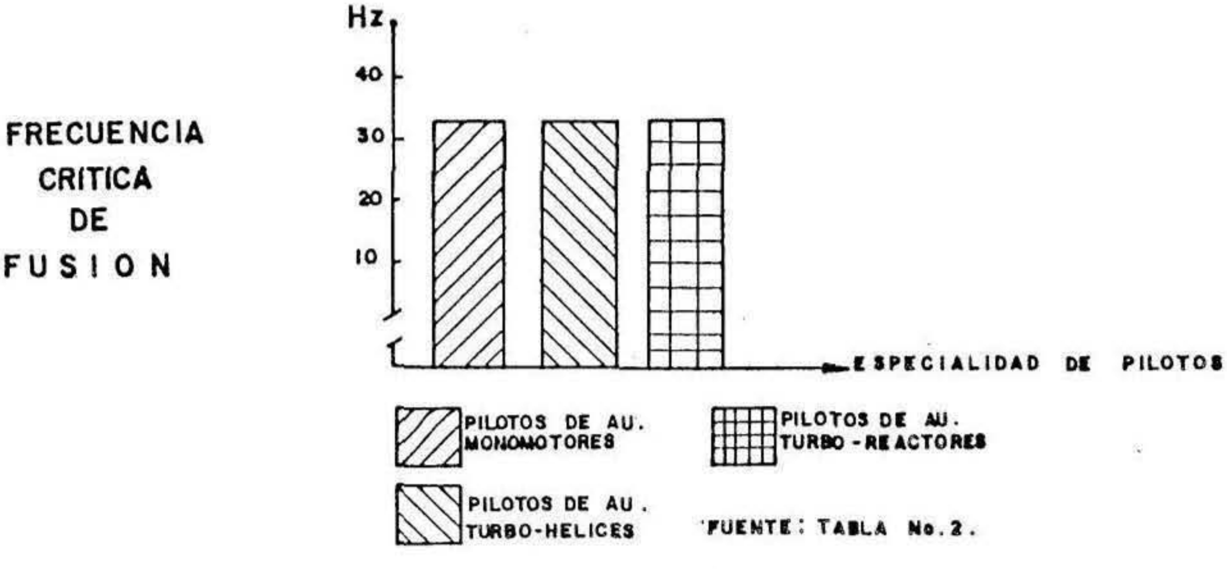
METODOS DE LOS LIMITES. FORMA ASCENDENTE



FUENTE : TABLA No. 1.

GRAFICO N°2

METODOS DE LOS LIMITES. FORMA DESCENDENTE .



FUENTE : TABLA No. 2.

VARIABLES PSICOLOGICAS Y LINGUISTICAS EN LA INSTRUCCION DE TRIPULACIONES ACERCA DE "FACTORES HUMANOS"

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ETUDE DE LA VIGILANCE DES PILOTES AU COURS DE VOLS LONG COURRIERS

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RESUME

Les variations du niveau d'éveil au cours d'activités monotones ont été montrées par de nombreux auteurs. Dans le domaine aéronautique au cours de vols long-courriers, ces variations du niveau d'éveil peuvent avoir des répercussions directes sur la performance de l'équipage. Afin d'étudier les variations de vigilance des pilotes et leurs conséquences sur leurs activités au cours de vols long-courriers, une recherche sur le terrain a été entreprise. La méthode repose sur l'utilisation de techniques ambulatoires permettant de recueillir l'EEG, l'EOG, la fréquence cardiaque et l'activité motrice des pilotes au cours du vol et des escales. Simultanément, une observation de la tâche est réalisée. Les résultats de la première phase sont présentés.

AVANT-PROPOS

Convaincue de l'influence des facteurs humains dans les accidents d'avions, la DGAC a demandé diverses études dans le but d'analyser le plus finement possible les raisons des accidents dûs aux facteurs humains.

Pour cela, il a été retenu l'hypothèse que, si l'on excepte les questions psychologiques et l'aspect formation, les facteurs humains interviennent de trois façons différentes :

- la surcharge de travail à éviter en certification (ergonomie, composition et organisation du travail en équipage,...) qui a mené aux marchés relatifs au modèle de charge de travail en équipage, passés avec Airbus Industrie,
- *les erreurs de présentation mentale dont l'étude Archimède (Phase I) a fait* l'objet d'une présentation lors du Vème symposium sur la psychologie aéronautique à COLOMBUS (OHIO),
- l'hypovigilance au cours des vols long-courriers qui fait l'objet de cette recherche (convention DGAC-LAA n° 88.52007).

INTRODUCTION

L'automatisation des postes de pilotage entraîne une modification de l'activité des pilotes. Dans l'ensemble, ces modifications se traduisent par une fiabilité et une sécurité accrue. Cependant, dans le cas de vols long-courriers, cette automatisation va exagérer la monotonie du vol de croisière notamment en modifiant la répartition des rôles entre le pilote et l'avion. A l'exception des phases d'atterrissage et de décollage le pilote se voit très souvent réduit à un rôle de surveillance.

Ces évolutions considérables dans la gestion du vol et dans l'activité du pilote au cours des vols long-courriers engendrent dans un grand nombre de cas de baisses du niveau de vigilance. Ceci n'est pas spécifique à l'aéronautique, et a pu être montré par plusieurs auteurs notamment dans le domaine ferroviaire, que ce soit sur le terrain (Akerstedt et Torsvall, 1985 ; Torsvall et Akerstedt, 1987) ou dans des études de laboratoires utilisant une tâche de conduite simplifiée (Coblentz et coll., 1988, 1989).

Outre les évolutions de la nature de la tâche, les pilotes de vols long-courriers sont soumis aux horaires alternants et aux décalages horaires dans le cas de vols transméridiens. Cette situation peut accroître les baisses de vigilance par les perturbations qu'elle occasionne sur le rythme veille-sommeil (Nicholson et coll., 1984 ; Graeber et coll., 1986 ; Nicholson et coll., 1986) avec notamment une diminution de la qualité et de la durée du sommeil.

La plupart des études menées sur le terrain utilisent des techniques de monitoring ambulatoire qui permettent de recueillir des paramètres physiologiques. Ces études ont permis notamment de mettre en évidence les perturbations du cycle veille-sommeil consécutives aux vols transméridiens et leurs répercussions sur la performance pour différents tests. Cependant ces études demeurent limitées dans leurs conclusions. En effet, en raison des conséquences directes de ces baisses de vigilance sur la performance du pilote, une observation de la tâche plus élaborée semble nécessaire. Cette observation doit permettre d'identifier de manière précise les tâches susceptibles d'être affectées par des baisses de vigilance et de concevoir des moyens de réactivation, en optimisant par exemple la gestion des cycles activité-repos (Stampi, 1988) ou dans la répartition des tâches entre les différents membres de l'équipage et la machine.

Dans le but d'évaluer la variabilité du niveau d'éveil des pilotes et d'étudier des possibilités de réactivation ou d'assistance en vol, une recherche a été entreprise pour des conditions réelles de vol.

Au cours de la première phase de cette recherche il s'agissait essentiellement de mettre au point une méthode d'étude utilisant simultanément le monitoring physiologique et l'observation de la tâche et de l'environnement du pilote (Coblentz et coll., 1989).

La méthode mise en place ainsi que les premiers résultats sont présentés .

METHODE

Vols étudiés et échantillon

Afin de rechercher les conditions favorisant la survenue d'hypovigilance, huit vols long-courriers ont été effectués au cours de cette phase préliminaire en privilégiant pour quatre de ces vols des vols de nuit, caractérisés par des situations monotones sur des vols nord-sud. Ces vols se sont déroulés sur B747 pour des rotations Paris-Libreville-Paris et Paris-Brazzaville-Paris. Les autres vols sont des vols transméridiens, effectués entre Paris-Winnipeg-Paris et Paris-Cayenne-Paris respectivement sur B747 et DC8.

Actuellement, une deuxième série d'expérimentations est en cours sur Airbus pour des vols nord-sud (Bruxelles-Libreville-Bruxelles) et est-ouest (Bruxelles-New York-Bruxelles).

Tous ces vols sont effectués avec des équipages composés de volontaires. Dans le cas des vols effectués sur B747 et DC8, les mesures sont réalisées sur les trois membres de l'équipage (commandant de bord, co-pilote et mécanicien). Pour les vols effectués sur Airbus, le commandant de bord et le co-pilote font l'objet d'enregistrements.

Mesures effectuées

Pour chacun de ces vols, deux types de mesures ont été effectuées :
- des mesures physiologiques,
- une observation de la tâche et de l'environnement.

Les mesures physiologiques suivantes ont été retenues :
- l'éléctro-encéphalogramme (EEG),
- l'électro-oculogramme (EOG) dont est extrait la fréquence des mouvements oculaires,
- l'électrocardiogramme (ECG) et la fréquence cardiaque,
- l'activité motrice du poignet (actométrie).

L'EEG et la fréquence des mouvements oculaires permettent de mesurer en continu des variations fines du niveau d'éveil. Elles constituent des moyens fiables de détecter des périodes de somnolence. L'EEG est recueilli à partir d'une dérivation pariéto-occipitale droite nécessitant la pose de quatre électrodes : une électrode occipitale, une électrode pariétale et deux électrodes de terre placées au vertex. Cette dérivation permet d'étudier notamment la bande de fréquence alpha (8-12 Hz) dont les variations sont assez bien corrélées avec les fluctuations du niveau de vigilance (Akerstedt et coll., 1985 ; Coblentz et coll., 1988 ; Torsvall et coll., 1987).

Pour la fréquence des mouvements oculaires, deux électrodes sont fixées : l'une sur une zone électriquement inactive, la mastoïde, l'autre à un centimètre au dessus de l'oeil. A l'exception de cette dernière, tous les capteurs ont été collés au collodion qui assure une bonne fiabilité aux enregistrements de longues durées.

La fréquence cardiaque a été enregistrée au moyen de deux dérivations de type CM5 (creux axillaire droit, creux axillaire gauche). Nous nous intéressons ici davantage à la variabilité cardiaque dont les fluctuations sont liées aux variations de l'effort mental (Aasman, 1987).

La mesure de l'actométrie est réalisée à partir d'un capteur de mouvements fixé par un bracelet sur le poignet droit des pilotes. Ce capteur comptabilise les déplacements à partir d'une détection d'accélérations. Le paramètre ainsi recueilli permet de suivre sur des enregistrements de longues durées le déroulement des cycles activité-repos.

Deux centrales d'acquisitions miniaturisées différentes ont été utilisées pour l'enregistrement de ces mesures physiologiques. L'utilisation de ces deux systèmes permet de réaliser deux types de traitements :

- l'EEG, l'EOG et l'ECG sont enregistrés sous forme analogique sur une bande magnétique. L'enregistreur utilisé est un MEDILOG (MD4),
- le deuxième enregistreur est une centrale d'acquisition numérique (VITALOG PMS-8) sur laquelle sont enregistrées la fréquence cardiaque et l'actométrie.

Les données analogiques de l'EEG, de l'EOG et de l'ECG sont numérisées afin d'obtenir après traitements :

- une analyse spectrale de l'EEG dans la bande 0,5-30 Hz sur des périodes de 2 à 60 secondes,
- une édition des résultats sous forme graphique, représentant l'évolution des rythmes alpha, bêta, delta et thêta au cours du vol ; cette édition peut être réalisée sous forme de puissance absolue et de puissance relative pour les différentes bandes de fréquence, ou de rapport de spectres,
- une édition de la fréquence et de la durée des clignements des yeux,
- une analyse spectrale de la fréquence cardiaque dans la bande 0,001-0,5 Hz avec une édition sous forme graphique de l'évolution du spectre particulièrement dans les bandes 0,001-0,05 Hz, 0,05-0,15 Hz et 0,2-0,3 Hz.

Une observation de la tâche et de l'environnement est effectuée parallèlement au recueil des mesures physiologiques. Ces observations demeurent le complément indispensable du recueil des paramètres biologiques dans la mesure où elles permettent d'éliminer de l'analyse des segments pour lesquels l'activité physique interfère avec la tâche mais surtout de caractériser l'environnement du pilote, son état et la tâche dans laquelle il est engagé.

Cette observation est réalisée à l'aide d'une grille de codage mise au point lors d'études antérieures (Fouillot, 1989) et adaptée aux besoins particuliers de cette recherche (figure n°1). L'environnement du pilote est défini par l'environnement opérationnel : zone de contrôle radar, surveillance radar, espace libre ainsi que par les conditions météorologiques.

Les différentes phases du vol, les procédures engagées, les événements anormaux éventuels, la répartition des tâches entre le commandant de bord et le co-pilote sont également identifiés dans cette observation. Les codes et le type de communication engagée sont donnés pour l'ensemble de l'équipage. Ceci permet d'écarter les communications individuelles de l'analyse et conduit à privilégier la communication actuelle la plus importante. L'état du pilote (veille, repos ou autre) et la tâche sont par contre identifiés pour chaque membre d'équipage.

L'évaluation de la charge de travail du pilote au moyen d'une échelle subjective de type Cooper-Harper Bedford Scale, SWAT, ou Airbus, ne peut être appliquée dans le cadre d'une étude de la vigilance des pilotes, car toute requête de ce type est susceptible de modifier leur état.

Le modèle de prévision de la charge de travail développé par Airbus Industrie (Blomberg et Coll., 1989) peut, par contre, être utilisé sans inconvénient pour contribuer à la description du contexte de charge de travail. Ce modèle fait appel à des mesures de paramètres de vol et de la variabilité cardiaque des pilotes ; il a été validé au cours de vols de certification en équipage minimal sur Airbus A310 et A320. L'étude a été menée également au cours de vols moyen-courriers de 2 heures -Paris-Athènes- qui ont montré la bonne correspondance entre l'évaluation du pilote et la prévision. La transposition du modèle au cours de vols long-courriers sur A310, en compagnie, nécessite au préalable une adaptation du recueil des paramètres de vol, ceux-ci ayant été acquis jusqu'à présent au moyen d'une installation d'essais de l'Aérospatiale (Système SAMBA) et non sur enregistreur de type DFDR. Une nouvelle validation du modèle dans ces conditions de vol, de routine doit être entreprise prochainement.

Le recueil des paramètres est différent selon que l'on considère le vol ou l'ensemble de la rotation :

- au cours de la rotation, seules la fréquence cardiaque moyenne et l'actométrie sont recueillies au moyen du système Vitalog. Ces résultats sont utilisés afin d'identifier les phases de repos et d'activité de repos des pilotes et de mettre en évidence d'éventuelles situations de privation de sommeil,
- au cours du vol, l'ECG, l'EEG et l'EOG sont enregistrés sur enregistreur magnétique miniaturisé Médilog afin d'étudier les variations de la période cardiaque, le spectre de fréquence de l'EEG, le nombre de clignements des yeux. L'actométrie enregistrée sur système Vitalog est également disponible.

L'ensemble de ces résultats est analysé de deux façons :

- en fonction du temps, ce qui permet une analyse des fluctuations les plus marquantes et une identification de phases d'hypovigilance secondairement rapportée au contexte du vol identifié par l'observation et l'évolution de la charge de travail,

- en fonction des segments temporels identifiés par l'observation et caractérisés par un code de phase de vol, d'activité des pilotes, etc...

Une base de donnée a été développée. Elle va permettre de présenter une typologie des réponses biologiques en fonction du contexte du vol.

PREMIERS RESULTATS

Observation de l'activité de l'équipage

Les premiers résultats obtenus ont permis de mettre en évidence des facteurs prédominants influençant la vigilance des pilotes :

- la période au cours de laquelle se déroule le vol (de nuit ou de jour),
- les activités antérieures du pilote (repos, décalage horaire, rotations nocturnes),
- la région survolée (zone atlantique à faible trafic aérien, zone terrestre à trafic aérien faible ou important).

Sur le plan de l'observation, les tendances suivantes peuvent être dégagées (figure n°2) :

- il existe d'importantes modifications dans la nature et dans la durée des communications selon la phase de vol dans laquelle le pilote est engagé. Le silence tend à augmenter au cours du vol et devient prépondérant lors des phases de croisière. Par ailleurs, les communications entre les membres de l'équipage semblent être plus importantes lors de vols de jour que lors des vols de nuit.

- les périodes de repos yeux ouverts ou yeux fermés sont plus nombreuses lors des phases de vol de croisière. Parallèlement, on voit une diminution assez nette de l'activité lors de ces phases, puis une augmentation lors des phases d'approche et de descente.

Grille de codage des phases de vol et des tâches de pilotage long-courrier

1	2	3	4 à 9 CM1, CM2, CM3		10	11	12	13
Phase de vol	Gestion Vol	Pilote	Etat	Tâche	Communication	Envi.Oper.	Météo	Evènement
0	0	0	0 Veille (Y.O)	0 Aucune	0 Silence	0	0	0 Normal
1 Pre-taxi	1 Pré-Opérat.	1 CM1 PAC Man.	1 lecture	1 Déf.route	1 Equipage	1 Contr.Radar	1 Clair, Calme	1 Anomalie
2 Taxi	2 Bef.Start CL	2 CM2 PAC Man.	2 Repos (Y.O)	2 Chgt.route	2 PNC	2 Surv.Radar	2 Clair, Turb.	2 CL/Anomalie
3 Take-off	3 Engine Start	3 CM1 PAC P.A.	3 Repos (Y.F)	3 Chgt.niveau	3 Passager	3 Espace libre	3 Nuages, Calme	3 Incident
4 Climb	4 Aft.Start CL	4 CM2 PAC P.A.	4 Pause repas	4 Evitement	4 ATC	4	4 Nuages, Turb.	4 CL/Incident
5 Cruise	5 Briefing	5	5 Pause Boisson	5 Proxi.Avion	5 ATIS	5	5 Orages	5 Panne
6 Descent	6 Check-List	6	6 Debout marche	6 Radio Com.	6 C°.Mainten.	6	6 AP, Visit.<<	6 CL/Panne
7 Approach	7 Final CL	7	7	7 Monit.Carb.	7 C°.Commerc.	7	7	7
8 Landing	8 Status	8	8	8 Monit.Tech.	8 Assist.Sol	8	8	8
9 Taxi aft.land	9 Autre	9	9 Autre	9 Autre	9 Autre	9	9 Autre	9 Autre

Etat actuel du codage : - de l'activité des différents membres de l'équipage,
- des conditions du vol et de l'environnement.

Figure n°1

Etude des cycles activité-repos

A l'examen des tracés de la fréquence cardiaque et de l'actométrie au cours du temps, on peut constater que les cycles activités-repos sont aisément identifiables sur la restitution des enregistrements, les périodes de repos étant caractérisées par une baisse très nette, voire une disparition complète pendant le sommeil des mouvements du poignet (figure n°3). Il est possible de cette manière d'objectiver des privations partielles de sommeil, dont on sait par ailleurs qu'elles induisent des somnolences diurnes en situation monotone et des dégradations de la performance. Les oscillations de la fréquence cardiaque moyenne sont observées en liaison avec des phases d'activité physique, du pilotage proprement dit, ainsi que pour les fluctuations à long terme dues aux rythmes circadiens. On constate également une diminution significative de la fréquence cardiaque lors des périodes d'endormissement.

Etude de la vigilance des membres de l'équipage de conduite au cours de vols

Les périodes d'hypovigilance sont détectées à partir de l'analyse spectrale de l'EEG et du dénombrement des clignements palpébraux, à partir des enregistrements d'EOG.

Les critères utilisés pour caractériser ces périodes peuvent être de nature différente :
- une augmentation de la puissance dans la bande alpha (8-12Hz) à l'EEG, corrélée avec une modification de la fréquence des clignements des yeux (augmentation rapide suivie d'une diminution),
- une augmentation de la puissance dans les bandes de fréquences lentes, delta (1-3Hz) et thêta (4-7Hz),
- une augmentation des rapports des rythmes alpha-delta et alpha-thêta,
- une augmentation de la puissance totale du spectre.

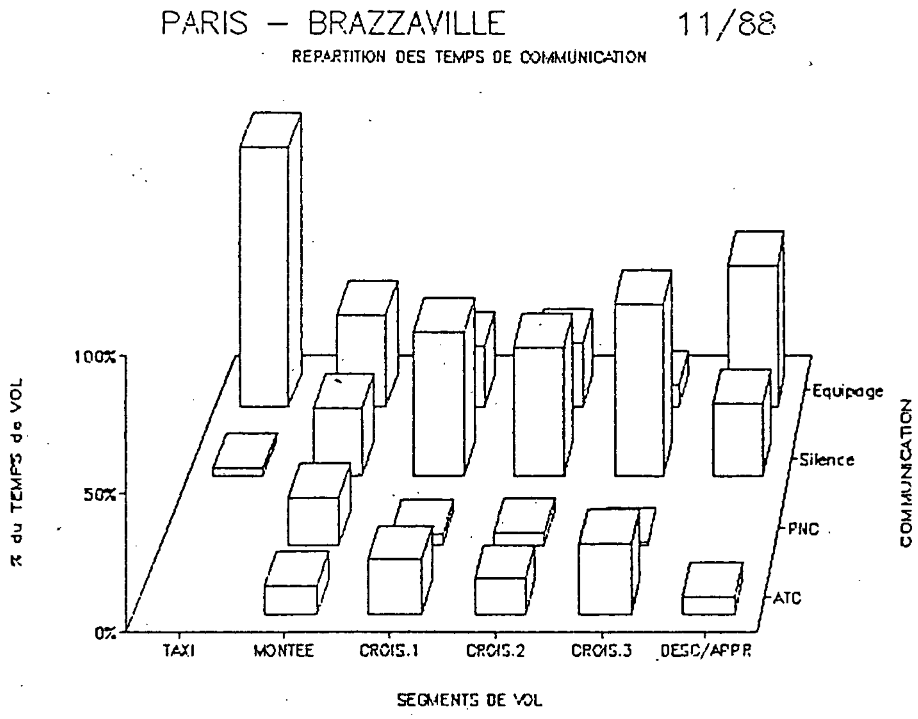
Un exemple est reporté sur la figure n°4 où sont reproduites les variations du spectre EEG pour un pilote au cours de deux vols transméridiens.

Le premier vol a été effectué dans le sens est-ouest, le second dans le sens ouest-est, après une privation de sommeil à l'escale (durée du sommeil réduite à 4 heures). On peut constater pour ce second vol, une augmentation de la bande alpha après 1 heure 30 de vol, sur une durée de 30 minutes environ, puis après 4 heures de vol, pour une période prolongée, de plus de 3 heures. Le pilote se retrouve en état de veille attentive qu'en fin de vol pour la préparation de l'approche.

Pour le premier vol, les périodes d'hypovigilance sont par contre nettement moins marquées, mais on identifie entre 5 heures et 6 heures de vol, une période avec une forte augmentation de la puissance dans la bande alpha qui coincide avec une phase de repos les yeux fermés (sieste-somnolence).

CONCLUSIONS

Cette phase préliminaire a permis d'aborder essentiellement les problèmes de méthodes liés aux enregistrements effectués au cours de vols de longues durées. Cependant, une première analyse montre qu'il existe d'importantes variations dans les spectres EEG quantifiés et dans la fréquence des mouvements


PARIS – BRAZZAVILLE 11/88
REPARTITION DES TEMPS DE COMMUNICATION
100%
50%
0%
% du TEMPS de VOL
TAXI
MONTEE
CROIS.1
CROIS.2
CROIS.3
DESC/APPR
SEGMENTS DE VOL
Equipage
Silence
PNC
ATC
COMMUNICATION

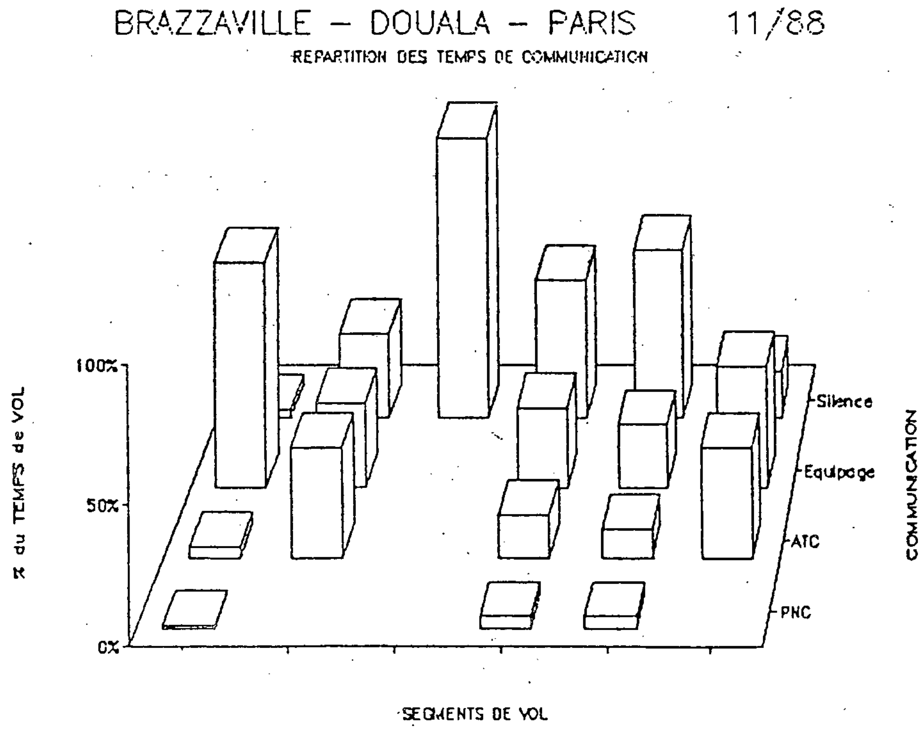
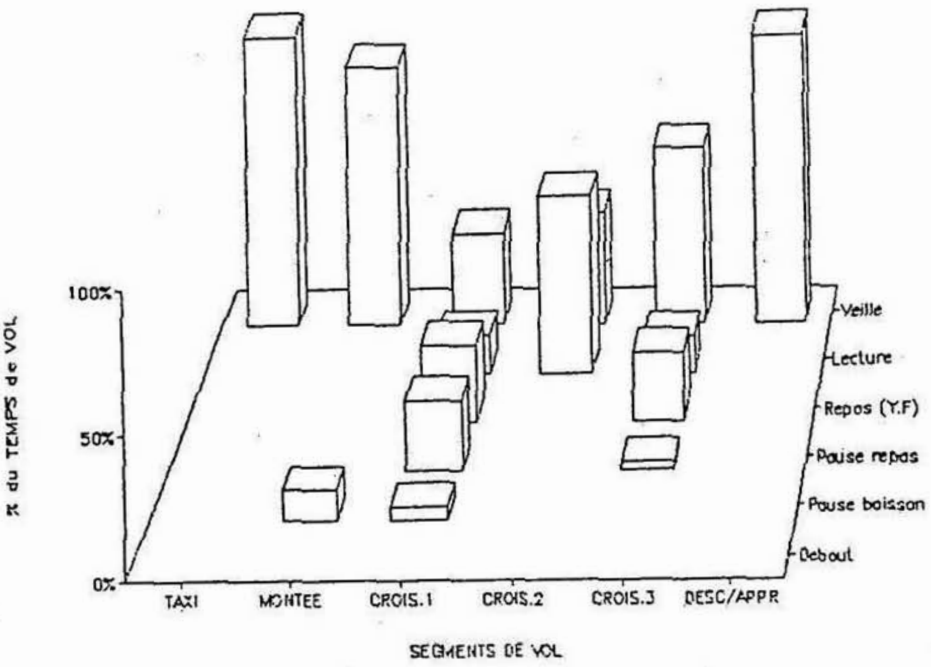

BRAZZAVILLE – DOUALA – PARIS 11/88
REPARTITION DES TEMPS DE COMMUNICATION
100%
50%
0%
% du TEMPS de VOL
SEGMENTS DE VOL
Silence
Equipage
ATC
PNC
COMMUNICATION

Figure n°2a



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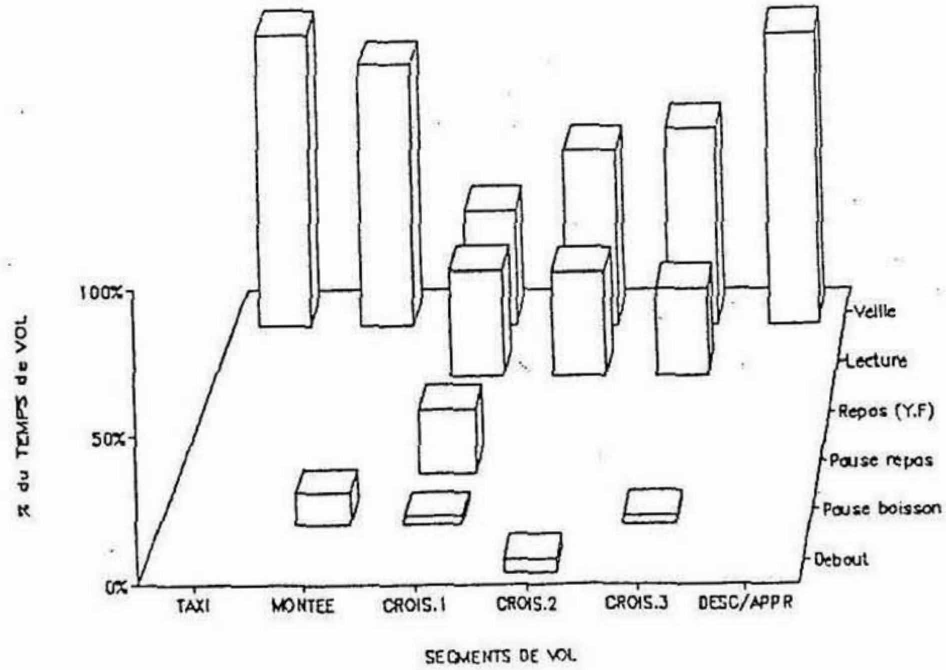
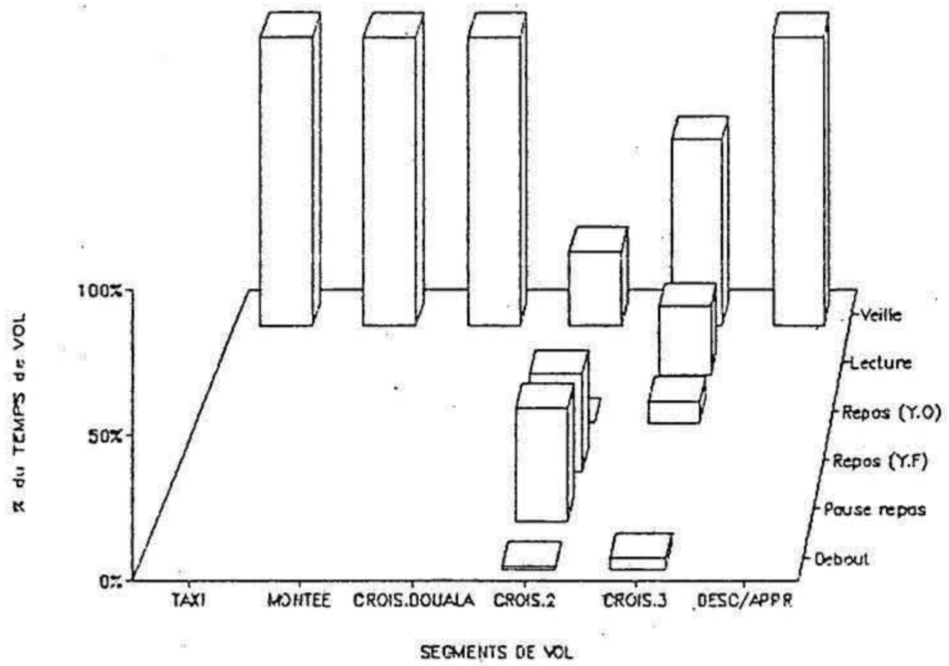
CM1



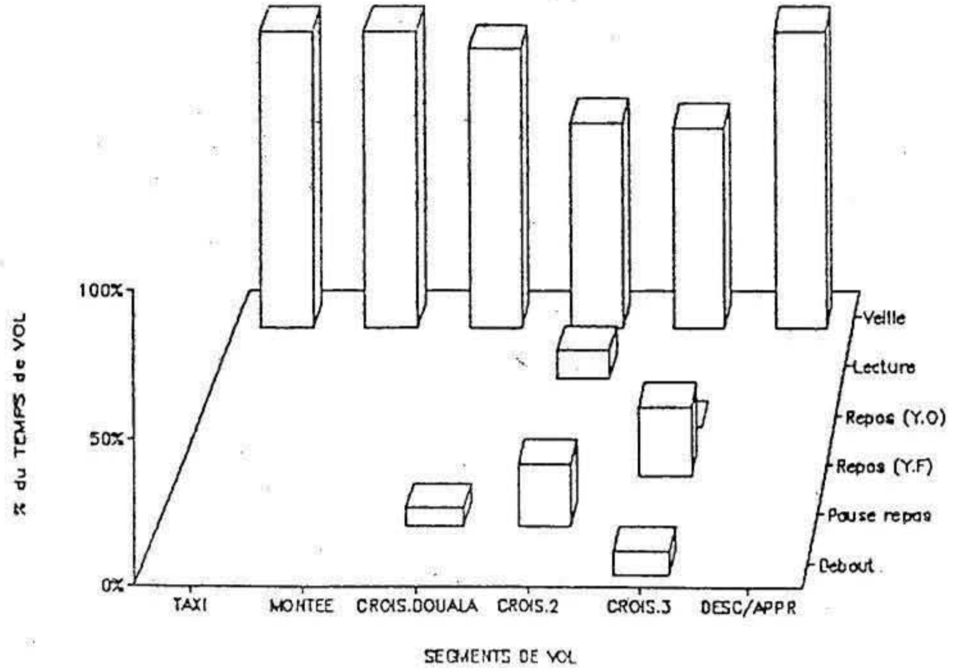
PARIS – BRAZZAVILLE 11/88

CM2



BRAZZAVILLE – DOUALA – PARIS 11/88

CM1



BRAZZAVILLE – DOUALA – PARIS 11/88

CM2

EVOLUTION DE L'ACTOMETRIE ET DE LA FREQUENCE CARDIAQUE MOYENNE AU COURS D'UN VOL TRANSMERIDIEN.

Figure 3a

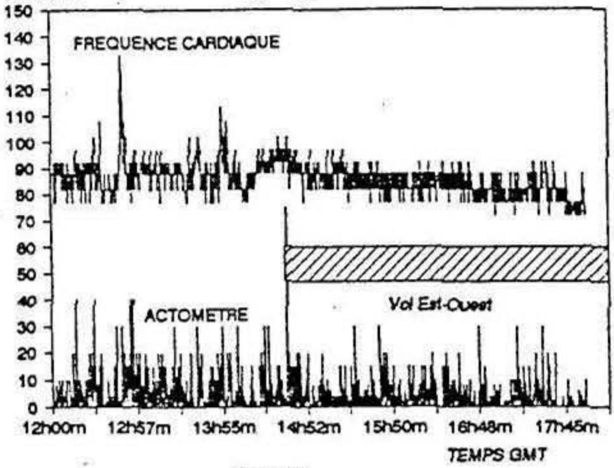


Figure 3b

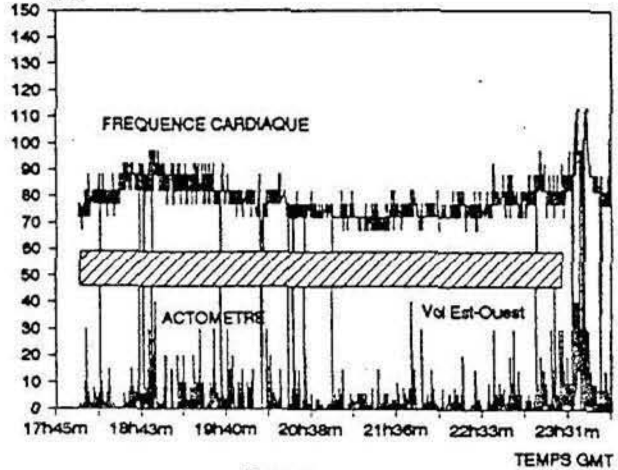
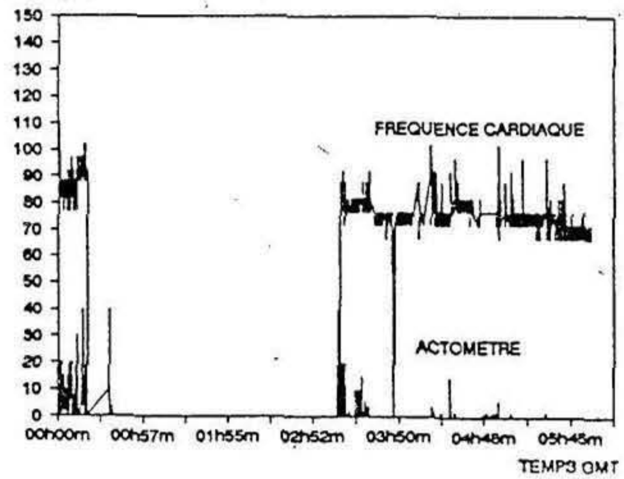


Figure 3c



EVOLUTION DE L'ACTOMETRIE ET DE LA FREQUENCE CARDIAQUE MOYENNE AU COURS D'UN VOL TRANSMERIDIEN.

Figure 3d

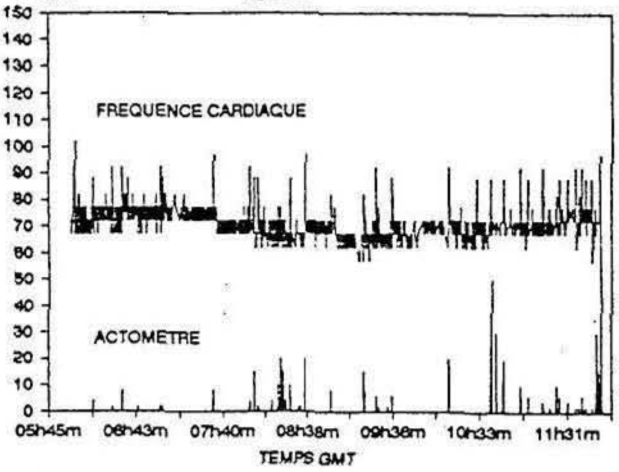


Figure 3e

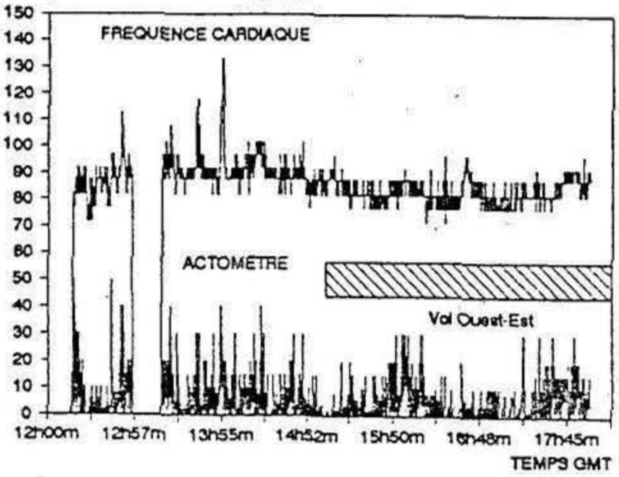
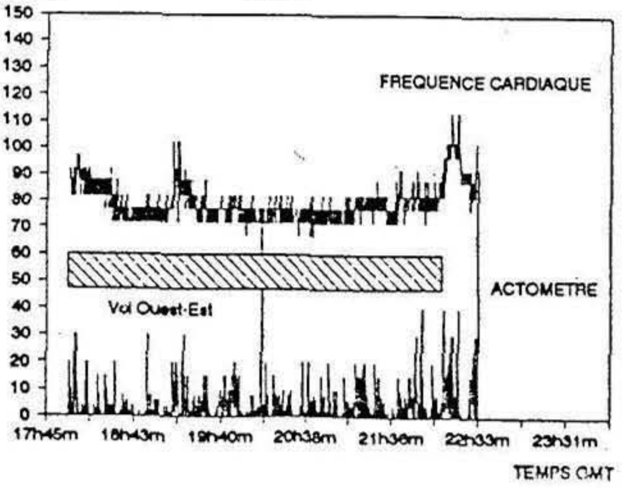
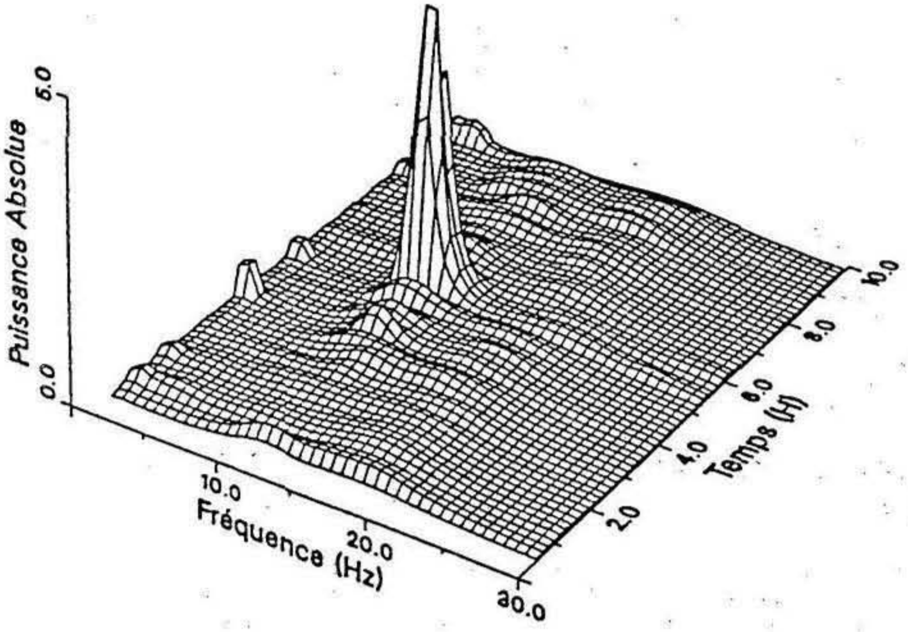


Figure 3f

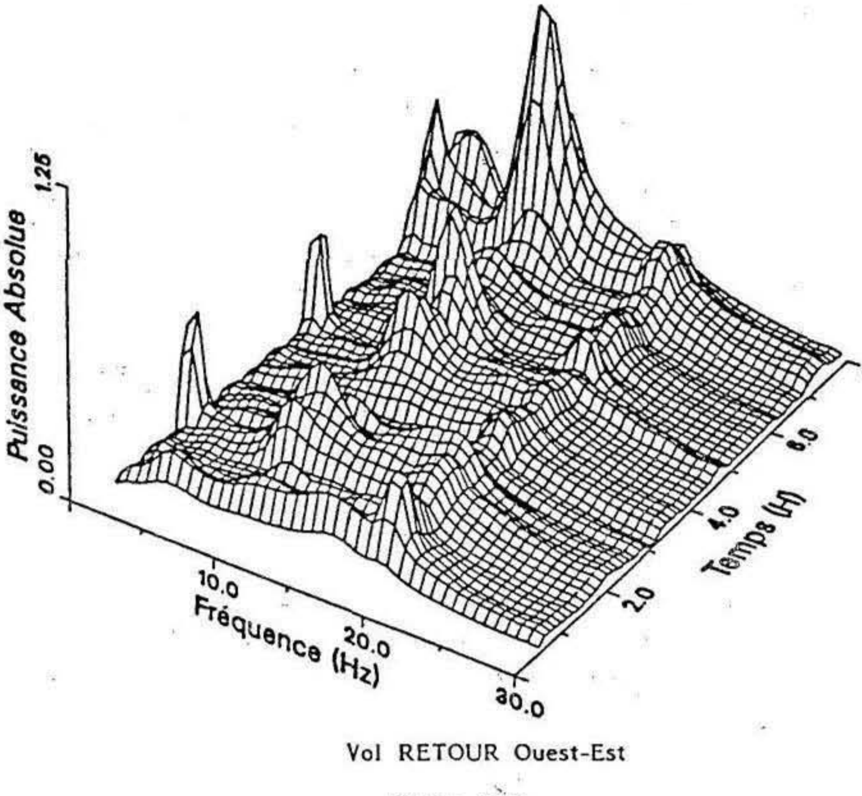


Variations du spectre EEG d'un pilote au cours
d'un vol transméridien.



Vol ALLER Est-Ouest

Figure n°4a



Vol RETOUR Ouest-Est

Figure n°4b

oculaires. Des alternances de phases durant lesquelles les pilotes présentent une vigilance élevée avec des phases de somnolence ont été observées pour chaque membre de l'équipage. Ces phases de baisse de vigilance ont été identifiées pour des séquences d'activité de surveillance au cours des phases de croisière.

Par ailleurs, il a pu être constaté une répercussion des privations de sommeil au cours des escales ou sur le comportement des pilotes au cours du vol. En particulier la baisse de vigilance paraît plus prononcée pour les vols qui suivent une nuit avec privation de sommeil, même si ce vol est effectué durant la journée.

La seconde étape de cette recherche, qui se déroule actuellement, porte sur 50 vols long-courriers. L'analyse des données sera centrée sur l'identification des phases d'hypovigilance, la redondance de ces phases, leur interaction avec les tâches et les activités des pilotes ainsi que sur l'effet cumulatif de la monotonie, du "jet-lag" et de la privation de sommeil.

Airbus Industrie participe à cette seconde étape au cours de laquelle il adapte le modèle statistique de prédiction de la charge de travail sur avion de ligne, l'objectif étant d'étudier une éventuelle application de ce modèle pour les évaluations de la charge de travail des pilotes dans les situations monotones.

Les résultats attendus de ces recherches devraient permettre d'établir des recommandations relatives aux horaires, au contenu et à l'organisation du travail des équipages. Par exemple, des sommeils de courte durée avec une périodicité et une durée à définir pourraient être proposés dans le but de maintenir l'efficience de chaque membre de l'équipage.

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SUPERVISION DE LA APTITUD PSICOFISICA DEL PERSONAL DE VUELO UN MEDIO INSUSTITUIBLE DE PREVENCION DE ACCIDENTES DE AVIACION METODOLOGIA DEL CENTRO NACIONAL DE MEDICINA DE AVIACION DE MEXICO

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SECRETARIA DE COMUNICACIONES Y TRANSPORTE. -MEXICO-

En México al igual que en otros países, los accidentes de tránsito representan un gran problema de salud pública, debido a su frecuencia, magnitud y trascendencia, y a las repercusiones que de ellos se derivan, pérdidas de vidas humanas, lesiones y secuelas físicas y mentales de los individuos involucrados, - además de la destrucción o deterioro de los equipos de transporte, de los bienes encomendados y de las instalaciones correspondientes; por lo que la prevención y control de los referidos riesgos se ha convertido en tarea insoslayable del gobierno mexicano.

En consecuencia y al identificar al factor humano como el principal responsable en los siniestros de referencia la Dirección General de Medicina Preventiva en el Transporte se fijó como objetivo fundamental: "Preservar la salud y - la fuente de trabajo del personal del transporte público federal y servicios - conexos, así como prevenir sus riesgos laborales y enfermedades predisponentes a éstos para elevar paralelamente su seguridad y la de los usuarios de las - vías generales de comunicación y de los bienes transportados e incidir en la - conservación de la infraestructura correspondiente".

Conforme a lo anterior se establece como acción prioritaria: detectar oportunamente padecimientos y por consiguiente prevenir la invalidez parcial o total e incluso la muerte, así como seleccionar al personal idóneo para desarrollar - sus actividades laborales con mayor eficacia, eficiencia y seguridad y como requisito indispensable para la expedición o revalidación de la Licencia Federal para el personal de los diversos modos de transporte.

Esta Institución practica exámenes psicofísicos a los aspirantes a ingresar a las Escuelas Técnicas dependientes de la Secretaría de Comunicaciones y Transportes -de Policía Federal de Caminos y Puertos, Náuticas Mercantes- a los aspirantes a ingresar a laborar en la Secretaría, al personal del transporte carretero, ferroviario, aéreo civil, y al marítimo -que incluye al gremio de pescadores- así como a trabajadores portuarios y de dragado.

Es menester señalar que para la práctica de tales exámenes, la Dirección General de Medicina Preventiva en el Transporte dependiente de la Subsecretaría de Transporte cuenta en la capital del país -Distrito Federal- con el Centro de Diagnóstico e Investigación -unidad central que dispone tanto de personal especializado como de equipo médico de alta tecnología, que permite elaborar los diagnósticos con el sustento clínico, de laboratorio y gabinete, y en consecuencia emitir un dictamen sobre la aptitud psicofísica; además de ser el Centro Nacional de referencia para todos los órganos de trabajo de la propia dependencia-.Dispone asimismo de un Centro Nacional de Medicina de Aviación -que tiene el objetivo específico de atender la demanda de exámenes psicofísicos al personal técnico aeronáutico, la investigación de factores humanos en accidentes e incidentes de aviación, la instrucción aeromédica al personal técnico y el adiestramiento fisiológico en cámara de altitud al personal de vuelo-; una Unidad Médica y ocho Módulos de Exámenes Médicos en Operación ubicados en centrales y terminales de autotransportes y de ferrocarriles; 40 Unidades Médicas distribuidas estratégicamente a lo largo y ancho del territorio mexicano; seis Centros de Medicina de Aviación ubicados en algunos de los principales aeropuertos del país y 52 Módulos de Exámenes Médicos en Operación en las terminales y centrales de autotransporte de pasaje y carga, en estaciones de ferrocarriles y en recintos portuarios de los transbordadores. Adicionalmente cuenta con tres Unidades Médicas Móviles, una en un vagón ferroviario y dos sobre trailer, con las que se llevan los servicios al sitio mismo en el que surge la demanda.

Por otra parte, se impulsa decididamente la investigación sobre los accidentes y otros riesgos de trabajo a fin de emitir medidas encauzadas a su prevención y control, a promover mejoras en el diseño de la maquinaria, equipo y vehículos para que se adecuen a las características antropológicas del operador mexicano y a proponer en su caso, la tipificación de los riesgos citados en la legislación respectiva.

Es de resaltar la prioridad otorgada a tal tarea, toda vez que en el alud evolutivo de los diversos modos de transporte se ha tratado de obtener eficacia y eficiencia en la maquinaria, pero no siempre en las condiciones en las que opera el individuo a quien se ha considerado frecuentemente como una pieza más de la misma -como un medio y no como un fin- obligándolo a utilizar su capacidad de adaptación.

Por eso, colateralmente, se fomenta la humanización en el trabajo del personal del transporte público federal y servicios conexos, para así ampliarle la posibilidad creativa y hacer de su experiencia respeto por su dignidad, ya que seguramente es ésta una de las mejores formas de protección contra los riesgos referidos.

Como complemento a las acciones enunciadas, se desarrollan actividades de promoción para la salud dirigidas al personal del transporte y público en general, tendientes a lograr cambios favorables de actitud en el cuidado de su salud y estilo de vida, así como en el empleo de medidas de prevención de accidentes y otros riesgos de trabajo, apoyándose con la elaboración de audiovisuales, de carteles, de boletines y de folletos, así como la transmisión de impactos por radio y televisión, promoción realizada en todo el territorio mexicano.

Dado que el hombre es y será el elemento más importante e insustituible en la operación de los diversos modos de transporte, habrá que darle la prioridad que le corresponde. En este sentido la Dirección General de Medicina Preventiva en el Transporte se responsabiliza por obligación y convicción, del control de los factores humanos, de todos los aspectos médicos del personal técnico aeronáutico civil en México; considerando las recomendaciones que en la materia emite la Organización de Aviación Civil Internacional, y las experiencias obtenidas en visitas de observación a diversos países, además del análisis de la legislación respectiva de numerosos estados contratantes.

Afortunadamente el hombre continua siendo el eje de todas las actividades aeronáuticas, a pesar de los grandes avances alcanzados por el vigoroso crecimiento de esta industria, por lo que para intervenir en la prevención e investigación de accidentes aéreos, es imprescindible la interacción del hombre con la máquina y el medio ambiente.

El hombre no es perfecto y en condiciones desfavorables puede fallar. La falla humana puede estar presente en el diseño, la producción, el mantenimiento y la operación de la máquina e infraestructura.

El término "factores humanos" se refiere al estudio de las variables psicofisiológicas del personal que participa en la operación del transporte aeronáutico, prestando atención a las acciones que condicionen o puedan condicionar situaciones de riesgo y por tanto estar relacionadas con la génesis de un incidente o accidente de aviación.

Es importante enfatizar que los accidentes son causados generalmente por situaciones en las cuales por diversas circunstancias la capacidad del individuo es insuficiente o a éste le resulte imposible controlar una condición imprevista y adversa. Por lo tanto, al considerar la actitud de la persona en un incidente o accidente, deben evaluarse las decisiones tomadas, teniendo en cuenta la actuación que podría esperarse de otra persona con conocimientos, calificaciones y experiencia equivalentes y con buena capacidad psicofísica.

Para lograr avances significativos en la seguridad de la aviación, es necesario tomar medidas apropiadas y oportunas en el estudio de los factores humanos involucrados en los incidentes o accidentes de aviación; como lo ha recomendado la Organización de Aviación Civil Internacional en su Asamblea de octubre de 1986, que propone a los estados contratantes que "cooperen ampliamente y activen el intercambio de información en lo referente a los problemas vinculados a la influencia de los factores humanos en la seguridad de los vuelos de la Aviación Civil", asimismo encarga al Consejo que "recoja la experiencia de los estados contratantes, a fin de que se utilicen los recursos y procedimientos actuales para llevar a cabo estas tareas con carácter de alta prioridad". Tales objetivos fueron ratificados durante la reunión científica que en mayo de 1989 efectuó la Asociación de Medicina Aeroespacial en particular dentro de las sesiones de la FAA.

La Dirección General de Medicina Preventiva en el Transporte, por tanto a través de su Centro Nacional de Medicina de Aviación realiza acciones tendientes a coadyuvar a la prevención de incidentes o accidentes de aviación, como lo es la supervisión de la aptitud psicofísica al personal que interviene en la operación, conducción o auxilio del transporte aéreo civil.

Para dictaminar sobre la aptitud psicofísica es indispensable establecer una adecuada correlación entre el perfil del hombre y el perfil del puesto, tomando en cuenta los factores presentes en el ámbito laboral.

En México, esta Institución elaboró los perfiles de puesto del personal técnico aeronáutico con la participación de Pilotos y Sobrecargos , con los responsables de Aeronáutica Civil, con Representantes de las Empresas Aéreas Nacionales, así como de las Autoridades encargadas de los Servicios a la Navegación en el Espacio Aéreo Mexicano.

En Medicina Aeronáutica algunos de los factores ambientales, como bien sabemos son variables; tal es el caso de la aceleración, la presión barométrica, la tensión parcial de oxígeno, de zonas de tiempo, del nivel acústico, la humedad, los horarios de trabajo y el stress laboral, entre otros; por lo que en los exámenes psicofísicos deben valorarse oportuna y cuidadosamente todos aquellos estados físicos y psicológicos que se agraven o puedan agravarse durante el vuelo e interferir con la seguridad del mismo.

En el caso de México la metodológia utilizada en el Centro Nacional de Medicina de Aviación para la práctica de exámenes psicofísicos integrales es la siguiente:

- Historia clínica completa con énfasis en antecedentes laborales.

- Examen oftalmológico encauzado a evaluar la agudeza visual lejana, cercana e intermedia, perimetría, campimetría, sentido de profundidad, estudio de fondo de ojo, discriminación a los colores y tonometría.

- Examen otorrinolaringológico que comprende valoración clínica de la especialidad, audiometría tonal, logoaudiometría, timpanometría, pruebas funcionales vestibulares y estudio radiológico de senos paranasales.

- Examen cardiológico: estudio clínico de la especialidad y electrocardiograma de superficie en reposo, en su caso ecocardiografía y prueba de esfuerzo.

- Examen neumológico: estudio clínico especializado, catastro torácico o teleradiografía de tórax y si se requieren, pruebas funcionales respiratorias.

- Exámen odontológico: estudio clínico especializado tendiente a conocer los índices de piezas cariadas, perdidas y obturadas complementando con exámenes radiológicos, periapicales y ortopantograma.

- Exámenes de laboratorio, biometría hemática completa; química sanguínea que incluye glucosa, urea, creatinina, ácido úrico, colesterol, triglicéridos y lipoproteinas; examen general de orina; serología para diagnóstico de sífilis y de SIDA.

- Exámenes de gabinete: estudios radiográficos simples o con medio de contraste que no requieren hospitalización, así como ultrasonográficos.

- Examen psicológico con el fin de detectar trastornos de la personalidad y organicidad cerebral y evaluar coeficiente intelectual.

  Si durante la historia clínica o en los exámenes diversos se sospechan otros padecimientos, se solicitan las interconsultas especializadas que pueden ser de Neurología, Ortopedia, Medicina Interna, Psicología, de Psiquiatría y de Cirugía, que se auxilian de los exámenes de laboratorio y gabinete que se consideren necesarios.

Es importante mencionar que, para otorgar la Constancia de Aptitud Psicofísica -Certificado- al personal técnico aeronáutico de vuelo es indispensable aprobar los cursos de instrucción aeromédica correspondientes, en los que se les dan a conocer los agentes a que están expuestos y cuales son las alteraciones que sufren o pueden sufrir como consecuencia de los mismos, así como las medidas para prevenirlos. También es obligatorio pasar a una sesión de entrena -

miento fisiológico en cámara de altitud, a fin de que los usuarios conozcan en forma práctica y objetiva los diferentes sistemas de oxígeno empleados en la aviación, así como los efectos de la expansión de los gases que se encuentran en cavidades orgánicas, los efectos de la hipoxia y de una descompresión súbita en cabina, todo ello con la máxima seguridad y bajo estricta vigilancia médica especializada.

Una vez concluídos los exámenes se elaboran los diagnósticos y se dictamina sobre la Aptitud o No Aptitud Psicofísica, correlacionando los resultados obtenidos -perfil del hombre- con el perfil del puesto, extendiendo en consecuencia la Constancia de Aptitud Psicofísica correspondiente.

Se incide de esta manera en la prevención de accidentes de aviación sobre uno de los elementos causales, el factor humano.

En síntesis debe enfatizarse que aún cuando los avances tecnológicos, nos permitan disponer de los más sofisticados equipos y técnicas para el diagnóstico y tratamiento de la mayoría de los padecimientos -sobresaliendo implantes de prótesis y trasplantes de órganos- jamás serán ni en apariencia ni en funcionamiento como aquellos con los que nace el individuo.

En resumen, resulta imprescindible reiterar que dada la aplicación universal, los bajos costos económicos y los beneficios de la Medicina Preventiva en relación con la curativa y de rehabilitación, se hace imperativo su fortalecimiento y consolidación como alternativa de elección a los problemas de salud que enfrenta el transporte aéreo civil.

Ю.П. Дарымов

СИСТЕМНЫЙ ПОДХОД В РЕШЕНИИ ПРОБЛЕМЫ "БЕЗОПАСНОСТЬ ПОЛЕТОВ И ЧЕЛОВЕЧЕСКИЙ ФАКТОР"

В процессе всего периода развития мировой гражданской авиации неизменным и первостепенным вопросом остается проблема обеспечения безопасности полетов. Для этого непрерывно совершенствуется авиационная техника, методы ее эксплуатации, система подготовки персонала и т.д.

Вместе с тем, усложнение техники и процедур ее эксплуатации в совокупности с ростом интенсивности воздушного движения накладывают свой отпечаток на профессиональную деятельность авиационного персонала и прежде всего на членов летных экипажей и специалистов УВД, которые наиболее тесно взаимодействуют в процессе выполнения полетов. Их деятельность претерпевает изменения как по своему внешнему характеру, так и по содержанию, ввиду широкой автоматизации труда и возросшей потребности в нем аналитического мышления.

Неизмеримо возросла и "цена" ошибок человека. Так, например, из-за неправильного принятия решения о взлете и языковых недопониманий между экипажем и диспетчером УВД на аэродроме острова Тенерифе 27 марта 1977 года произошла самая крупная за историю авиации катастрофа (столкновение двух самолетов Боинг-747), унесшая, по официальному сообщению, 583 человеческих жизни.

К большому сожалению, количество подобных происшествий, связанных с ошибками в деятельности людей при исправной авиационной технике, не уменьшается, а их доля в общем числе происшествий составляет от 70 до 80 процентов.

Все это заставило специалистов более пристально взглянуть на проблему, связанную с функциональной надежностью деятельности человека в системах управления, получившую общепризнанное определение "человеческий фактор".

За последнее время в ряде стран активизировалась научная работа по исследованию поведения человека в процессе труда; возобновились научно-исследовательские программы по психологическому отбору специалистов, методам их обучения и действиям в экстремальных условиях и т.п. Особое внимание стало уделяться проектированию и оснащению рабочего места человека-оператора. Ряд международных организаций и авиакомпаний (ИАТА, КЛМ и др.) подготовили и издали Руководства по человеческому фактору. Регулярными стали симпозиумы по этой проблеме, а число публикуемых статей по данной теме неизменно возрастает.

Иначе говоря, с одной стороны, мы имеем острую проблему, требующую своего решения, а с другой – широкий фронт различного рода разработок, имеющих тот или иной эффект.

Каким же образом добиться того, чтобы этот эффект был максимальным и ощутимым для эксплуатантов?

Очевидно, что механическое сложение опыта и научных разработок различных ученых не будет столь результативным, если не будет принята общая методология исследования проблемы в целом. Решение же такой сложной проблемы, какой является влияние человеческого фактора на безопасность полетов, может быть успешным только при системном подходе и ее рассмотрении на макро- и микроуровнях. Иначе говоря, сегодня в большей степени необходим синтез как метод исследования и организация внедрения его результатов.

С точки зрения макроподхода проблема человеческого фактора включает в себя выработку общей концепции ее решения с реализацией в виде обобщающих нормативов и рекомендаций для той или иной деятельности: летной, диспетчерской, технической и др.

Как показала практика многих стран, в том числе и Советского Союза, в настоящее время вырисовались определенные направления исследований в этой области. К ним относятся: отбор и обучение авиационного персонала, эргономика рабочего места, структура деятельности, режим труда и отдыха, расследование авиационных происшествий.

Естественно, данная классификация не претендует на исчерпывающую полноту, однако она может служить основой для выработки по ней национальных и ведомственных программ исследования и конкретных рабочих документов с нормативами, рекомендациями, руководствами и программами, что крайне необходимо для авиационных администраций и руководств авиакомпаний.

Реализация на уровне макроподхода может быть осуществлена на основе комплексной программы, способной быть адаптированной к различным местным условиям. Ее типовой вид следующий:

1. Обзор состояния проблемы и определение путей ее решения.

Содержание	Путь решения	Результат
1.1 Возникновение проблемы человеческого фактора и виды ее проявления в гражданской авиации	Выявление доли человеческого фактора в авиационных происшествиях	Обзорный циркуляр о роли человеческого фактора
1.2 Подход к решению проблемы и практические действия в этой области (формы, методы, достигнутые результаты)	Обобщение опыта в области работы по человеческому фактору	Информация эксплуатантов о проблеме человеческого фактора в гражданской авиации
	Проведение семинаров по проблеме в гражданской авиации	Сборники материалов семинара
1.3 Выбор основных направлений, форм и методов работы по проблеме	Создание научно-исследовательских групп по проблеме	Определение целей, задач, программы действий для специалистов в области человеческого фактора. Разработка предложений по изданию соответствующих документов

2. Профессиональный отбор, обучение и переподготовка авиационных специалистов

2.1 Ориентиция и мотивация молодежи к обучению авиационным специальностям	Обобщение опыта в профессиональной ориентации молодежи на авиационные специальности	Издание методики по профориентации и серии видео- и слайдфильмов об авиационных профессиях
2.2 Профессиональный отбор кандидатов на обучение летной и диспетчерской специальностям	Обобщение используемых методик, автоматизация профотбора	Руководство по профотбору на летные и диспетчерские профессии
2.3 Пролонгированный отбор в период обучения и профессиональной деятельности (профрекомендация)	Обобщение опыта по профрекомендациям обучающимся и специалистам	Требования к аппаратуре профотбора. Методика по профрекомендации обучающимся и специалистам
2.4 Разработка эффективных методов обучения специалистов по критериям надежности деятельности	Исследования в области новых методов обучения членов экипажей и диспетчеров УВД	Программы обучения летного и диспетчерского персонала (в том числе CRM, LOFT и др.)
2.5 Разработка программ переподготовки летного состава на новую технику и методы пилотирования	Исследования в области разработки программ по переучиванию на новую технику	Целевые обучающие программы на новую технику (воздушные суда)
2.6 Разработка требований к техническим средствам и тренажерам для обучения	Обобщение опыта по техническим средствам и тренажерам	Обзор по техническим средствам обучения летным и диспетчерским специальностям (в том числе тренажерам).

2.7	Разработка программ сохранения летных навыков и действиям в аварийной обстановке	Исследования в области разработки программ действий в аварийной обстановке	Программы обучения по действиям в аварийной обстановке.

3. Структура деятельности (технология работы) авиационного персонала

3.1	Описание деятельности членов летных экипажей и диспетчеров службы движения (задачи, операции, методы действий)	Исследования в области формализации деятельности членов экипажей и диспетчеров УВД	Информационный материал с освещением подходов и результатов исследований
3.2	Определение критериев оценки деятельности и ее оптимизация	Исследования по оценке деятельности "человека-оператора" и ее оптимизации	Информационный материал с обобщением подходов и результатов исследований
3.3	Проектирование деятельности (разработка технологий работы), включая действия в аварийной обстановке	Обобщение опыта в разработке и использовании технологий работы экипажей и диспетчеров.	Циркуляр по применению технологий работы членов летных экипажей и диспетчеров УВД
3.4	Инструментальная оценка деятельности (методы и технические средства)	Обобщение опыта по инструментальным методам оценки деятельности	Рекомендация по инструментальной оценке деятельности
3.5	Групповая деятельность экипажей и диспетчерских смен (формирование и взаимодействие в работе)	Обобщение опыта по исследованиям в области формирования летных экипажей и диспетчерских смен	Материалы семинаров по исследованию в области группой деятельности. Методические рекомендации (циркуляр) по формированию экипажей.

4. Эргономика рабочего места

4.1	Разработка рекомендаций по оптимальному взаимодействию человека с информационным полем и органами управления	Обобщение опыта международных организаций и авиакомпаний в области взаимодействия человека и авиационной техники	Руководство по организации рабочих мест членов экипажей и диспетчеров УВД: А. Взаимодействие с информационным полем и органами управления
4.2	Разработка рекомендаций по проектированию рабочего места членов экипажей и диспетчеров	Обобщение опыта в области проектирования рабочих мест	Б. Проектирование рабочих мест членов экипажей и диспетчеров
4.3	Рассмотрение перспективных средств и методов управления в автоматизированных системах самолета и УВД	Обобщение опыта в области автоматизации полета и УВД	В. Организация рабочих мест при автоматизации процессов полета и УВД
4.4	Обитаемость на рабочем месте – нормирование условий окружающей среды	Обобщение опыта в области нормирования окружающей среды на рабочем месте	Г. Рекомендации по нормированию показателей окружающей среды на рабочем месте (в кабине самолета и на пункте УВД).

5. Режим труда и отдыха

5.1	Исследование работоспособности членов *экипажа и диспетчеров* (включая стрессовые ситуации)	Исследования в области работоспособности в *процессе полетов и УВД*	Информация по проблеме работоспособности *человека в полете и УВД*
5.2	Выбор оптимальной продолжительности труда в полете и диспетчерского дежурства	Обобщение опыта по нормированию труда летного и диспетчерского состава	Рекомендации по продолжительности труда в полете и УВД членам экипажей и диспетчерам
5.3	Выбор режима труда (формы и методы разгрузки) в период полета и дежурства	Обобщение опыта по режиму труда и отдыха в период полетов и дежурства	Методика по формам и методам разгрузки в период работы и ликвидации последствий стрессовых ситуаций.
5.4	Выработка общей концепции поддержания летного и диспетчерского долголетия	Обобщение опыта по сохранению здоровья членов экипажей и диспетчеров УВД	Рекомендации по контролю за состоянием и профилактике здоровья летного и диспетчерского состава

6. Расследование и предотвращение авиационных происшествий

6.1	Разработка форм учета проявлений человеческого фактора в период происшествий (включая виды ошибочных действий)	Обобщение опыта по формам учета человеческого фактора в автоматизированных системах типа ADREP	Уточнение разделов в автоматизированной системе (ADREP) по учету проявлений человеческого фактора
6.2	Учет и анализ ошибочных действий членов экипажей и диспетчеров в период их деятельности (динамика надежности)	Исследование и обобщение опыта по учету динамики ошибочных действий членов экипажей и диспетчеров УВД	Руководство (методика) учета ошибочных действий персонала и профилактика их проявлений
6.3	Создание автоматизирозированной системы учета ошибочных действий в период работы	Исследования в области автоматизации учета ошибочных действий членов экипажей и диспетчеров УВД	Руководство по автоматизированному учету ошибочных действий человека-оператора и выработки профилактических мер
6.4	Разработка методов аль*тернативного поведения* членов экипажа и диспетчеров в период усложнения и аварийной ситуации	Исследования в области *моделирования человече*ской деятельности при экстремальных условиях	Руководство по обучению *поведению в экстремаль*ных условиях. Методика расследования поведения членов экипажей и диспетчеров в период авиационного происшествия
6.5	Совершенствование социально-психологических методов при расследовании авиационных происшествий	Обобщение опыта по участию в расследовании авиационных происшествий специалистов в области психологии и социологии	Рекомендации по составу лиц, привлекаемых к расследованию авиационных происшествий

6.6	Информация эксплуатантов о наиболее типичных причинах авиационных происшествий, связанных с проявлением человеческого фактора	Выбор и обобщение наиболее типичных происшествий, связанных с человеческим фактором	Издание циркуляров с освещением характера и причин происшествий, связанных с человеческим фактором

Данная типовая комплексная программа позволит скоординировать деятельность соответствующих специалистов в области человеческого фактора в широком его понимании с целью выработки общих подходов и решения проблемы в целом.

Вместе с тем, как бы тщательно ни был проработан общий подход, процесс производства полетов складывается из функционирования широкого круга конкретных человеко-технических подсистем, таких как: "пилот-самолет", "экипаж-воздушное судно", "диспетчер УВД – воздушные суда" и они требуют своего особого подхода для достижения их высокой надежности. При этом все эти подсистемы имеют помимо взаимосвязи между собой еще и достаточную степень автономности и тесного, специфического взаимодействия человека с техникой Этот, так называемый микроподход характеризуется детальной проработкой с позиций человеческого фактора каждой из подсистем на всех стадиях ее создания и функционирования.

Данная проработка будет содержать в себе ряд этапов, которые, будучи терминологически позаимствованы из технической области, обозначаются этапами: проектирования, производства и эксплуатации.

На этапе проектирования техники должны решаться такие вопросы, как определение функций техники, организация рабочего места человека и внешней среды, выбор режимов работы средств, а в конечном итоге, разработка комплекса тактико-технических данных всей технической стороны системы. На этапе производства осуществится разработка опытного образца, проведение соответствующих испытаний, опытная эксплуатация и серийное производство. На этапе эксплуатации составными частями будут: монтаж оборудования, подготовку к эксплуатации, профилактику и регламентные работы в процессе применения технических средств по назначению (будь то самолет или система УВД). Данная этапность, практическая конкретизация в виде перечисленных операций позволяют не только организовать получение требуемой техники, но и добиться ее высокой надежности на этапе ее будущей эксплуатации.

Несомненно, что организация обеспечения надежной работы человека-оператора основываться реализовываться в тесном взаимодействии с техникой по тем же этапам. На этапе проектирования должны решаться такие вопросы, как назначение его функций, выбор режима труда и отдыха, разработка структуры деятельности и требований как к специалисту будущей конкретной системы с учетом всех ее особенностей. На этапе производства необходимо решить задачи: профориентацию и профагитации кандидатов на обучение или же их переподготовку к освоению новой техники. В этап эксплуатации наряду с выполнением полетов, или УВД должны входить такие составные элементы, как мотивационные установки, тренировки и поддержание устойчивых навыков специалиста на требуемом уровне.

Указанные этапы, как технические, так и по человеческим составляющим, не должны быть изолированы друг от друга, а взаимосвязаны единым организационным воздействием. Более того, организация должна выступать на этих же этапах со своей целенаправленной функцией для обеспечения надлежащего эффективного функционирования создаваемой человеко-технической системы. Тогда на этапе проектирования организационными составляющими будут: определение целей и назначение будущей системы, определение ее ресурсов (людских, технических, финансовых), выработка технического задания на проектирование и разработка комплексного плана обеспечения дальнейших этапов создания системы. На этапе производства *организационно должны быть решены вопросы:* по созданию необходимых условий для функционирования людей и материально-технической базы системы в целом, комплектование трудовых коллективов (экипажей/дежурных смен) и осуществление освоения новой техники. В процессе же эксплуатации необходимы организация контроля состояния человека и техники в период их взаимодействия по решению поставленных задач, анализ возникающих ошибок человека и отказов техники, разработка мер по предупреждению ошибок и отказов, а также осуществление профилактики в деятельности человека и эксплуатации техники.

При всей своей традиционности, организация процессов создания техники и подготовка для ее функционирования людей в настоящее время наполняется новым содержанием, что выражается, в конечном итоге, в совместной сертификации как технического, так и человеческого компонентов системы. При этом сертификационной оценке должны подлежать основные функции человека-оператора, а также поливариантная компоновка его рабочего места в сравнении с той рабочей нагрузкой, которая при этом возникает.

Все это требует и организации разработки новых методов инструментальной оценки рабочей нагрузки как в период летных испытаний, так и на комплексных тренажерах. Последние, при данном подходе, становятся подлинными испытательными лабораториями.

Достигнутый сегодня прогресс в решении данной организационной задачи весьма значителен, о чем свидетельствует успешное внедрение авиационной техники нового поколения с высокой степенью автоматизации процессов управления ("Эрбас индастри", "Боинг", "Макдоннелл-Дуглас").

Подобный подход к созданию и эксплуатации сложных систем позволит добиться не только высокой надежности каждого из входящих в нее элементов, но и требуемой безопасности полетов.

Эффективность реализации всего комплекса описанных задач с входящими в них взаимосвязанными этапами и элементами немыслима без научного подхода к каждому вопросу. Отсюда встает новый круг задач, связанных с осуществлением исследования проблемы надежности на упомянутых этапах создания человеко-технических систем. Это исследование должно быть направлено на вскрытие и изучение всех механизмов поведения как человека, так и техники в направлении их надежного функционирования в системе с учетом научных достижений в области техники, биологии, физиологии, психологии и социологии. Безусловно, общими для всех этапов должны стать: моделирование происходящих на этих этапах процессов; определение предельно допустимых значений происходящих процессов; выбор метода оценки надежности функционирования системы.

Практика также показывает, что область исследований должна распространяться также и на организационные функции, используя достижения научных методов управления.

Реализация научных исследований на упомянутых выше этапах с общей методологией оценки надежности позволит решить следующие задачи. На этапе проектирования - анализ существующих человеко-технических систем управления, выбор перспективных технических средств, моделирование деятельности человека и функционирования техники, разработка оптимальных рекомендаций по проектированию системы. На этапе производства исследования распространяются на выявление степени согласованности человека с техникой и адаптации человека к ней, а также закономерности формирования знаний и навыков в период испытаний; здесь же потребуется обоснование выбора методов и средств обучения специалиста.

Что касается методов оценки деятельности человека-оператора, то здесь разработаны и применяются: методы статического и динамического анализа рабочей нагрузки (Франция), обобщенный структурный метод (СССР), метод анализа циклограмм (США) и др.

В период эксплуатации должны быть продолжены исследования по изучению поведения человека (в социальном и психологическом планах), сохранению и разрушению приобретенных навыков управления, обоснованию и выбору форм и методов контроля состояния и, безусловно, по исследованию необходимых параметров функционирования системы в целом (см. рисунок).

Таким образом, с позиций системного анализа мы прийдем не только к целостному рассмотрению столь сложной проблемы, которой является влияние человеческого фактора на безопасность полетов (макроподход), но и, опираясь на совокупность научных дисциплин, сможем осуществить поэтапное решение этой проблемы (микроподход) на стадиях проектирования, производства и эксплуатации для конкретных человеко-технических систем, участвующих в процессе производства полетов.

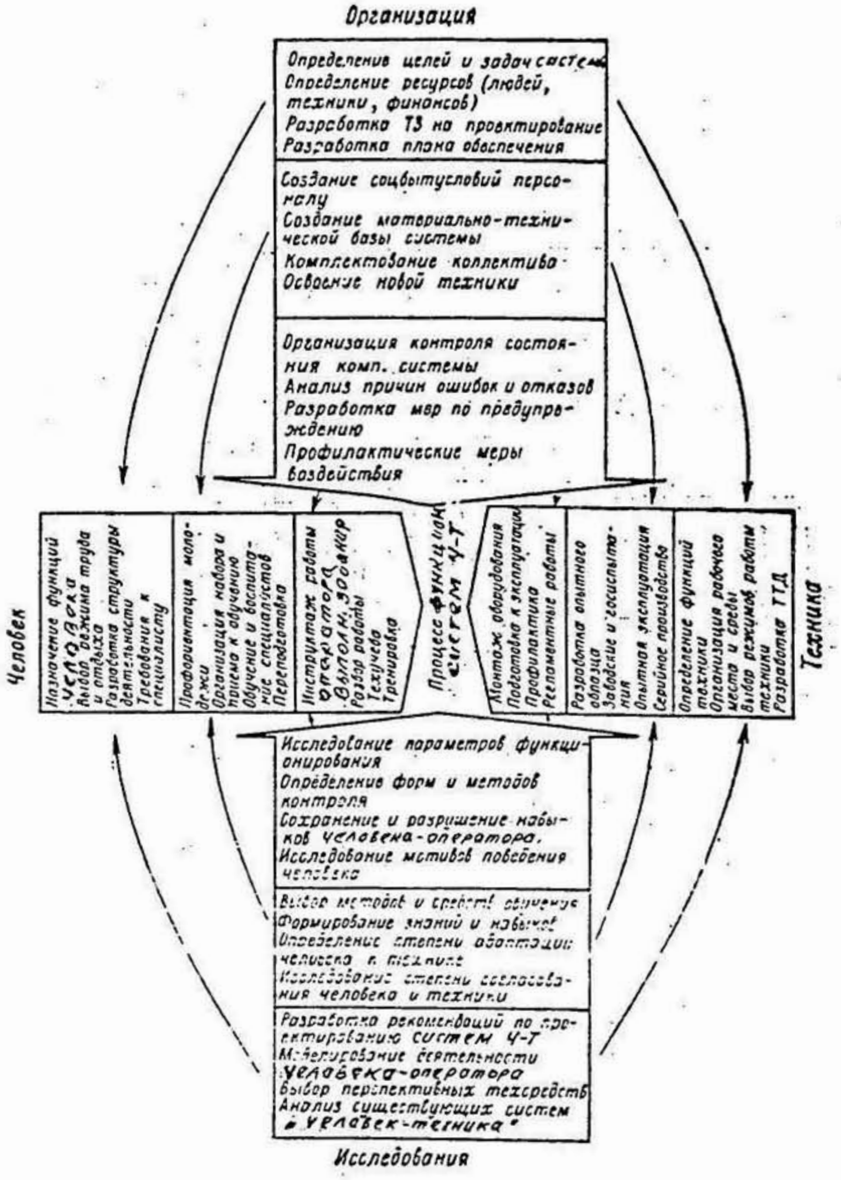

Рис.

A NEW METHODICAL APPROACH OF FLIGHT FITNESS: CONTINUOUS IN-FLIGHT EEG ECG AND INFRARED TELEVISION RECORDING

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Paper presented at the ICAO HUMAN FACTORS SEMINAR,
Leningrad, USSR, 3-7 April 1990.

Going into the human factor in aviation, it means to reduce the accident rate, because the human behavior and performance are cited as well-known the causal factors in the majority of aircraft accidents. To limit the human error, one must first understand its nature.To this attitude to human error, furthermore to live ware, it is essential to change the concepts of aviation medicine doctors.About this question - Contemporary trends in international civil aviation medicine - has published dr.Silvio Finkelstein a very demanding study in ICAO Bulletin (dec.1988).

The object of our presentation, to introduce for the seminar our quite new possibilities for evaluation of flight fitness, moreover the reserve psychophysiological capacity.

But draw up the plans for our investigation first we have studied some characteristic points of aircraft accidents. On this field we got a very important aid from ICAO Headquarters, namely from dr.Silvio Finkelstein and from Mr.Olof Fritsch. We got an ADREP request based on some 14500 reports now stored in the computer. These comprise some 12000 Accident Data Reports and 2500 Preliminary Reports representing accidents to aircraft above 2250 kg reported to ICAO between 1970-1988.

The computer was asked for occurrences involving fatigue factor, and we got information from 147 accidents (fig.1).

The yearly distribution did not shows any remarkable peculiarity, howbeit in 87 and in 88 only one case was reported.

The monthly occurrence shows on the whole equal distribution. Only in april was significant less accidents then the average value. Perhaps it would be interesting to know what is in the background (fig.2).On the stacked-bar graphic the lower part represent accidents in the night time (21.00-09.00) and the upper part shows the number of accidents in daytime (09.00-21.00).

The ratio of this two parts: 2:1.
Investigating the daily occurrence of this 147 accidents,we may observe a sharp difference between the day (09.00-21.00) and the night (21.00-09.00) period (fig.3).
The hourly average of accidents: 6.13. It is remarkable that all the values during the day are more favorable then the average value. On the other hand the number of accidents in the night period greater, it means unfavorable circumstances. Similarly is a significant difference between the average values during the day and night period.

If we keep one's eye on our graph we must observe it has of phasic character, more precise sine curve type (fig.4).
In the following let us transform this curve. Now we see the a graph: n (average) - n.
So the favorable values are positive and the unfavorable are negative. Our graph shows the 24-hour rhythm, where the accident frequency much higher during the night period.

It calls for an explanation.

To explore the background of this observation is one of the most important task of aviation physiology.
In the following let us clarify some characteristic of human body rhythms. The most common of the body's rhythms is the circadian or 24-hour rhythm, which can be related to the earth's rotations time. This periodicity is not quite true, however, because experiments carried out in temporal isolation, that is, where all time cues have been removed, have demonstrated that what 24 hours. This varies between individuals and is usually in the range 24 to 27 hours.
A tipical example of a rhythmic system is oral temperature (fig.5).
This temperature rises during the day to reach a peak during the evening, with extroverts and evening types tending to reach a peak a little later than introverts and morning types. It will be seen that sleep normally occurs when the temperature is falling and waking occurs when it is rising.
Numerous experimental programmes have now been carried out which show this to be the case. The actual form of the curve is task-dependent, meaning that is will vary according to the task (fig.6).
It is important to understand that this reduction in performance during certain parts of the 24-hours is not the result of sleep

deprivation, but is an entirely separate performance-reducing factor. While this is a natural rhythm this is not to say that it is immune from external influence.

Practice will raise and flatten the curve, as will heightened motivation or increased effort. Personality differences of introversion and extroversion will shift the curve to the left or right (fig.7).

The range of oscillation, that is, the difference between the maximum and the minimum performance scores within a cycle, is also task dependent. In tests with certain shiftworkers, it has been shown to be as high as 30-50%. It tends to be greater with complex than with simple tasks.

The loss of performance arising from this natural rhythm, may be greater than can testify that on a long flight which encompasses the normal night's sleeping period, a task may be done more efficiently after the normal 'waking' day period begins than during the previous 'sleeping' night phase. This is experienced is spite of sleep deficit which is accumulating.

To evaluate the effect this physiological circumstances the best method is the continuously multichannel walkman recording.

For multichannel EEG, ECG and other parameters works well the Medilog 9000 system, produced by Oxford Inc./England.

Our data were registered during the night flight on the board the aircrafts types Boeing 737-200 and TU-154.

Fig.8. present the very moment when the captain enters to sleep mixed frequency and decreasing alpha waves, at the time 3:49.01 in GMT on the route Tel-Aviv - Budapest at flight level 310. During the next 25 min. we registrated a nap which covers the all stages of sleep.

For those whose normal nigh's sleep is necessarily broken, the ability to nap would see to be an asset. The nap is not simply a miniature version of a normal sleeping period; the stages of sleep which occur during naps depend on several factors, one of which is the time of day at which the nap is taken.

It appears that the restorative effect of a nap varies between individuals with those who habitually take naps appearing to obtain more benefit than nonhabitual nappers, who sometimes perform worse after a nap.

The application of naps to the life of the long-distance air traveller is important. Before a long night flight many will try to obtain some sleep, though the success achieved varies widely between individuals.

Microsleeps are very short periods of sleep lasting from a fraction of a second up to two or three seconds. Although their existence can be confirmed by EEG recording, the person is not generally aware of them. This makes the phenomenon particularly dangerous. They have been shown in tests to correlate with periods of low performance and they occur mos frequently during conditions of fatigue. Microsleeps are not helpful in reducing sleepiness. A nap of not less than ten minutes appears to be necessary for sleep to be restorative.

Howbeit a nap could be restorative, nevertheless this registrated situation has had a remarkably danger. When our captain awoked the second pilot began descending and the flight level was 200 (fig.9)

It is self-evident, in that situation was reduced the reserve capacity of the crew.

Fig.10 present pulse profile of a flight engineer. The first curve shows the diurnal pulse profile of a normal daytime activity and night sleep. The second curve present also a diurnal pulse profile but after a normal daytime wakefulness, he performed night flight on the route Budapest - Cairo - Budapest. The nature of both curves are the same, like a sine wave.

The pulse profile during the night flight is remarkable shifted upward, but the significant bradycardia which is characteristic for the night period occurs during the flight time too.

I think it is enough persuasive that the duty and the pre- and post flight relaxing time need a special attention.

THERMOGARPHY

The infrared thermography is an absolute non-invasive pinvestigation method. It helps to register the infrared radiation of a given territory continuously. The infared radiation of the skin is a refined index of the vegetative status. The vegetative nervous system governs the functions of the organism through the smooth-muscle innervating of the blood vessels and the glands.

The thermograms were made from the monitor of an AGA 750 thermovision. The pictures analysis were made from point of view of lateral differences, thermal intervals and integrograms by AGA thermocomputer.

After some experience we can conclude that the best part of the human body, to demonstrate psychic load is the face, because no significant muscle work alternates the infrared radiation.

We started our infratelevision measurements on a very important field of the training of pilots. Namely at the TU-154 flight simulator at Ferihegy Airport.

Before simulator flights, we carried out medical examinations to eliminate actual intercurrent illnesses, which can perhaps be accompanied by fever. We could make our measurements without the least disturbing the pilot. We put the camera outside the cockpit and we took our pictures through the open window from a distance about 3 meters.

We made the evaluation with the help of integrograms, using AGA thermocomputer. We should like to demonstrate this method that seems advisable to use and work out in details.

On the lower part of the slide we can see the color distribution of the marked area. The hot colors are on the right side.

The thermovision pictures of a 38-year-old pilot - who has a great experience in flight, about 7000 flying hours- were made in the following order:

Slide 1: before the task
Slide 2: after the 4th turning of the 2nd traffic pattern
Slide 3: after the landing from the 2nd traffic pattern
Slide 4: after the 4th turning of the 3nd traffic pattern
Slide 5: after an overshoot
Slide 6: after landing from the 4th traffic pattern.

A detailed analysis of this pictures, can clarify the increase of sympaticotone in optimal case is proportionally with the difficulty of the task.

Picture 5. was taken after an exceptionally difficult flight situation when the landing had to be interrupted because too many disturbing factors and the flight could be continued with overshooting. After the flight was finished the stress in the organism starts melting and normalising of the infrared radiation on all parts of the face.

On the other hand, and extremely exciting stress, meaning actually overloading the pilot, cause decreasing of infraradiation and a left shift on the integrograms.

Finally

I think, in the civil aviation we must attach more importance to the human factors, but we must is emphasize as well in our surroundings.

For example, I am slightly unhappy looking on the symbol of our seminar. Our artist made a conceptional design error. She/he had given a sharp and ruling color to the aircraft and a meaningless grey color to the man, on spite of that aviation is by the man - for the human.

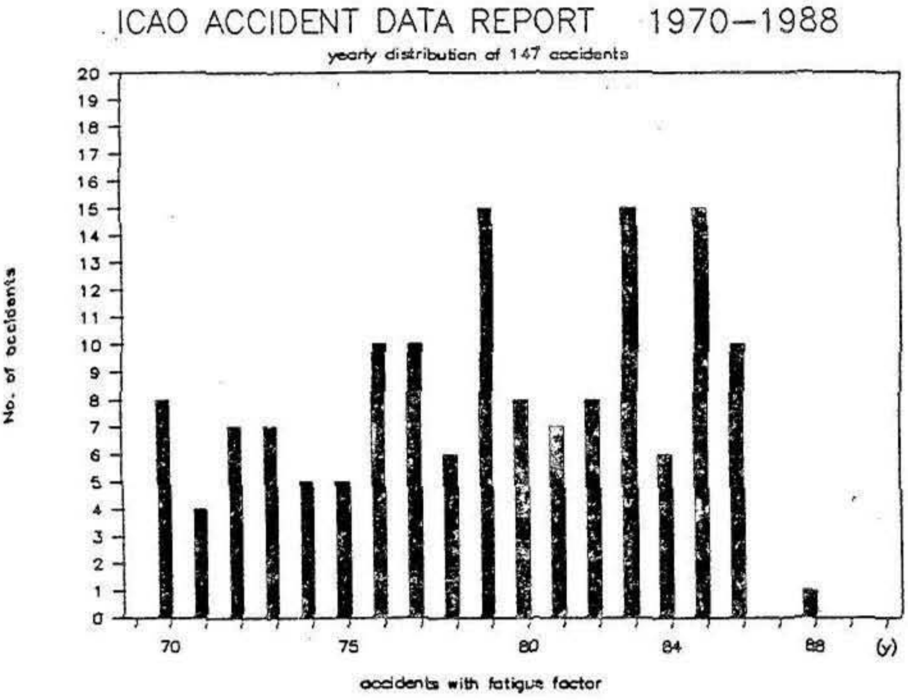

ICAO ACCIDENT DATA REPORT 1970–1988
yearly distribution of 147 accidents
No. of accidents
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
70
75
80
84
88
(y)
accidents with fatigue factor

fig.1.

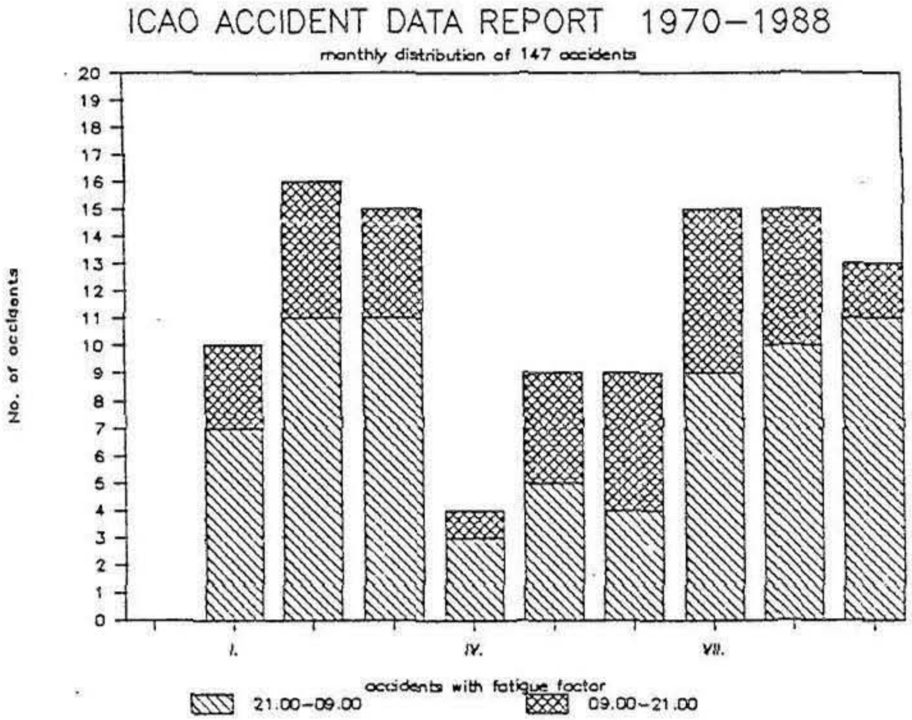
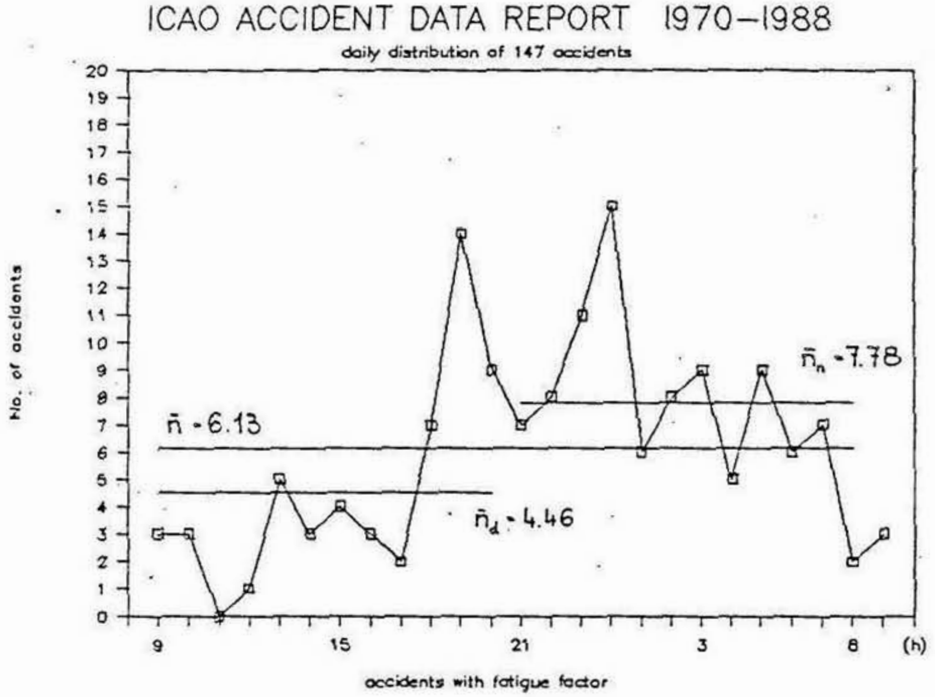

ICAO ACCIDENT DATA REPORT 1970–1988
monthly distribution of 147 accidents
No. of accidents
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
I.
IV.
VII.
accidents with fatigue factor
21.00–09.00
09.00–21.00

fig. 2.



$\bar{n}_d$: 09⁰⁰ – <21⁰⁰ $\bar{n}_n$: 21⁰⁰ – <09⁰⁰

fig. 3

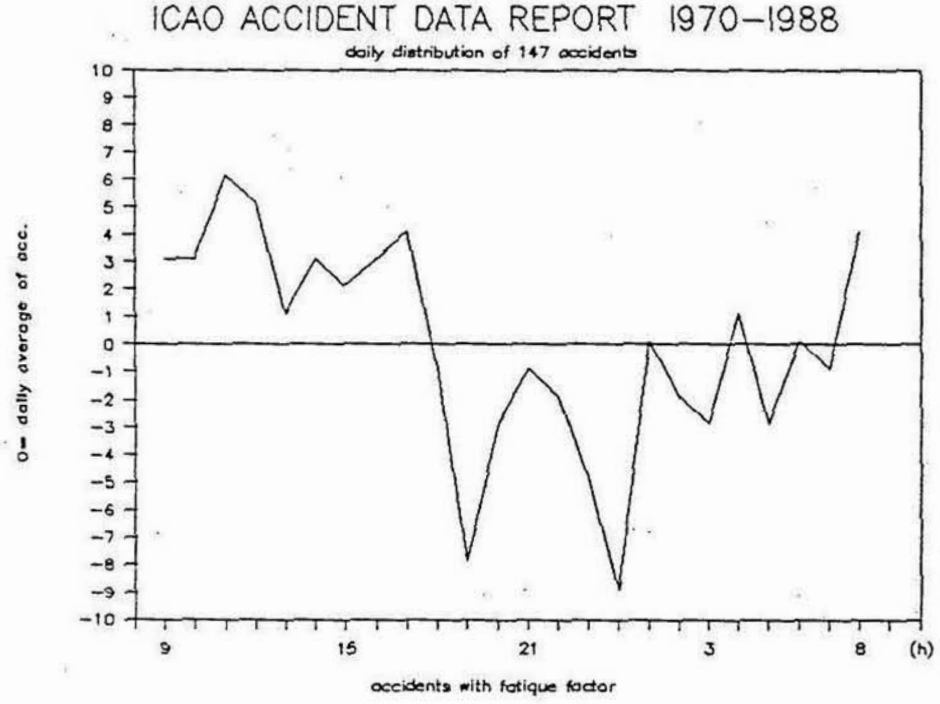


fig.4.

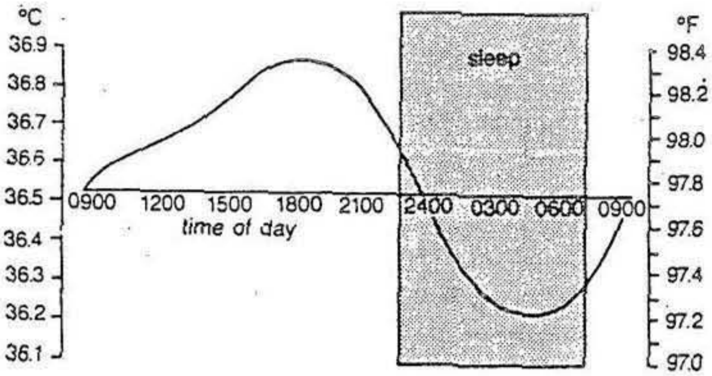


Fig. 5 The circadian rhythm of oral temperature.

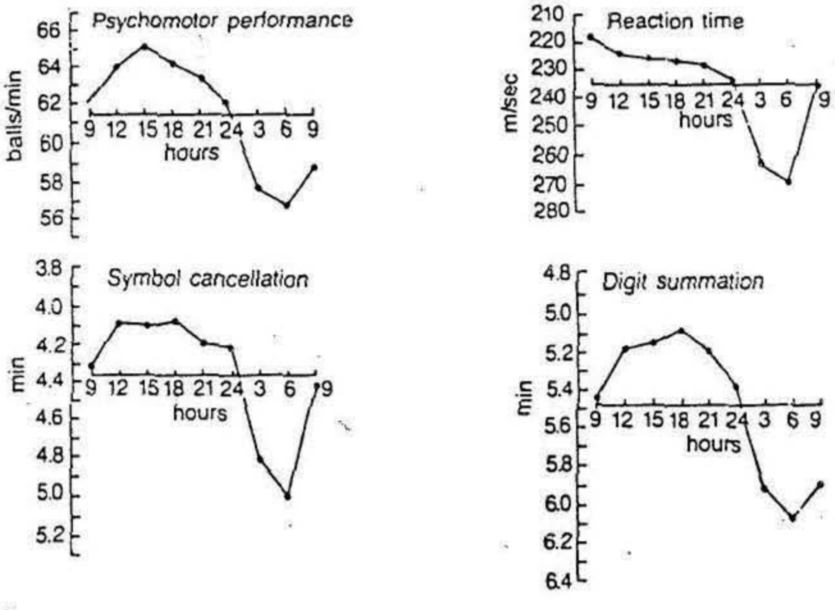
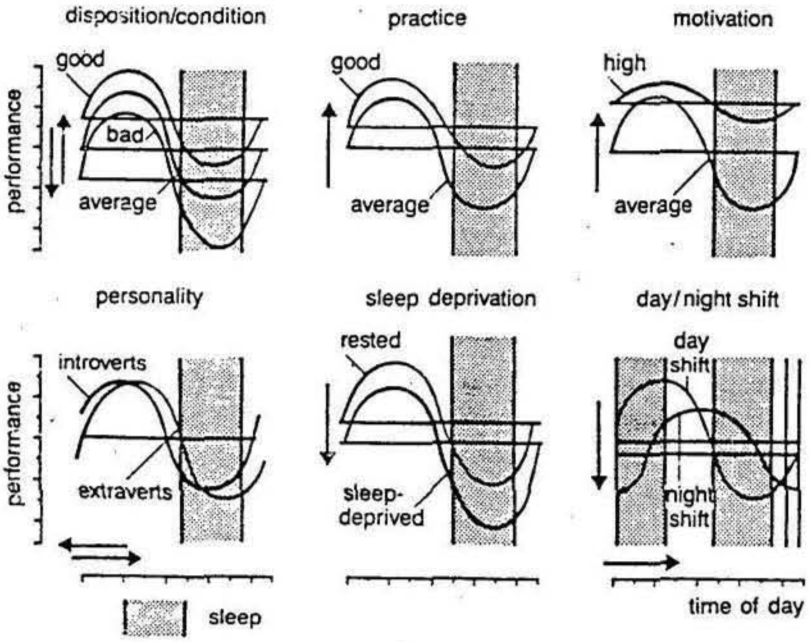


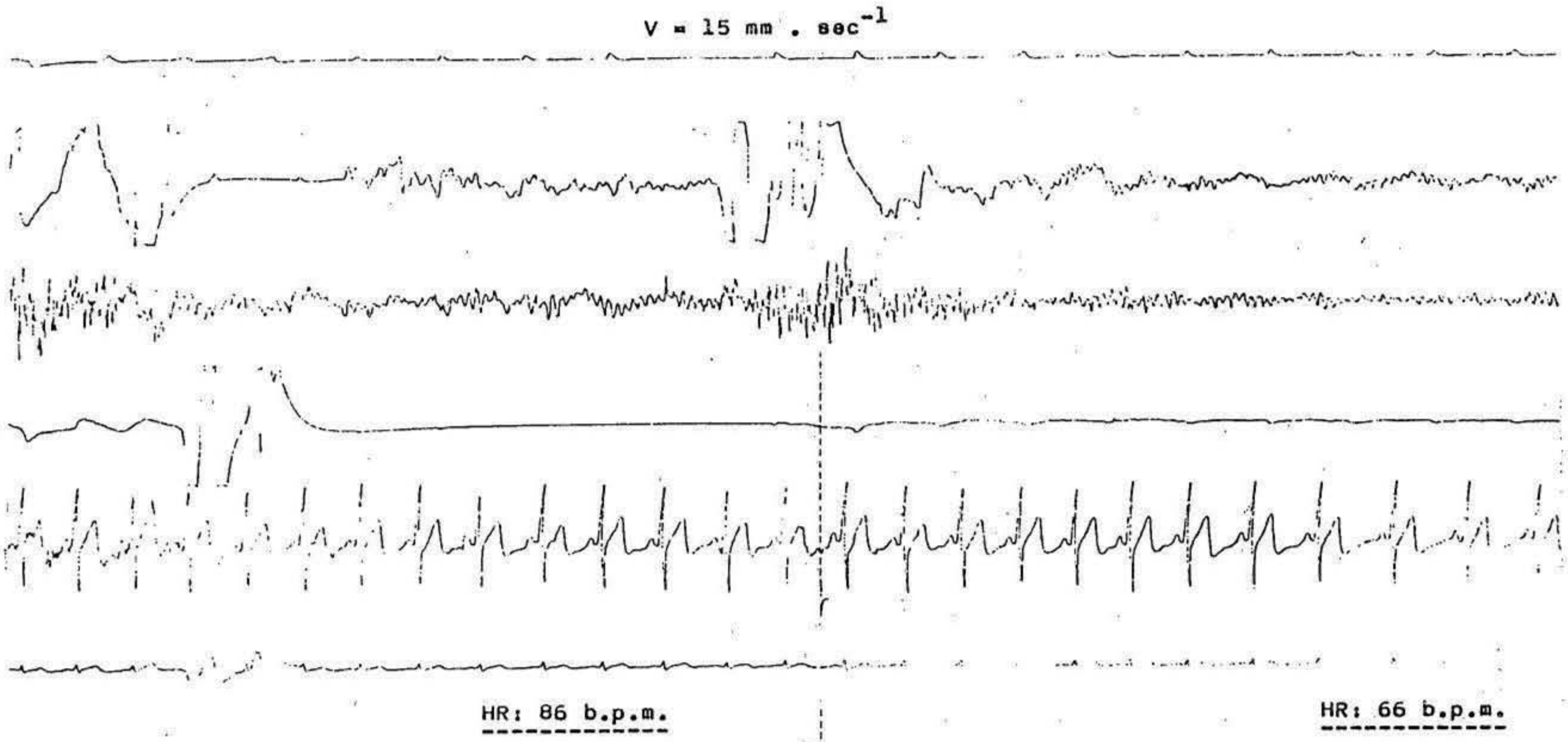
Fig. 6. Human performance of various tasks varies during the day with a rhythm that often tends to correspond with that of body temperature (Fig. 3.1). This variation is in addition to any effect from sleep deprivation (Klein *et al.*, 1972).

Fatigue, Body Rhythms and Sleep



Behavioural performance rhythms can be modified through various factors (Klein *et al.*, 976).

Fig.7



time: 03:49:01 GMT Flight from Tel-Aviv to Budapest

TU-154 cpt.

Fig 8

fig.9.

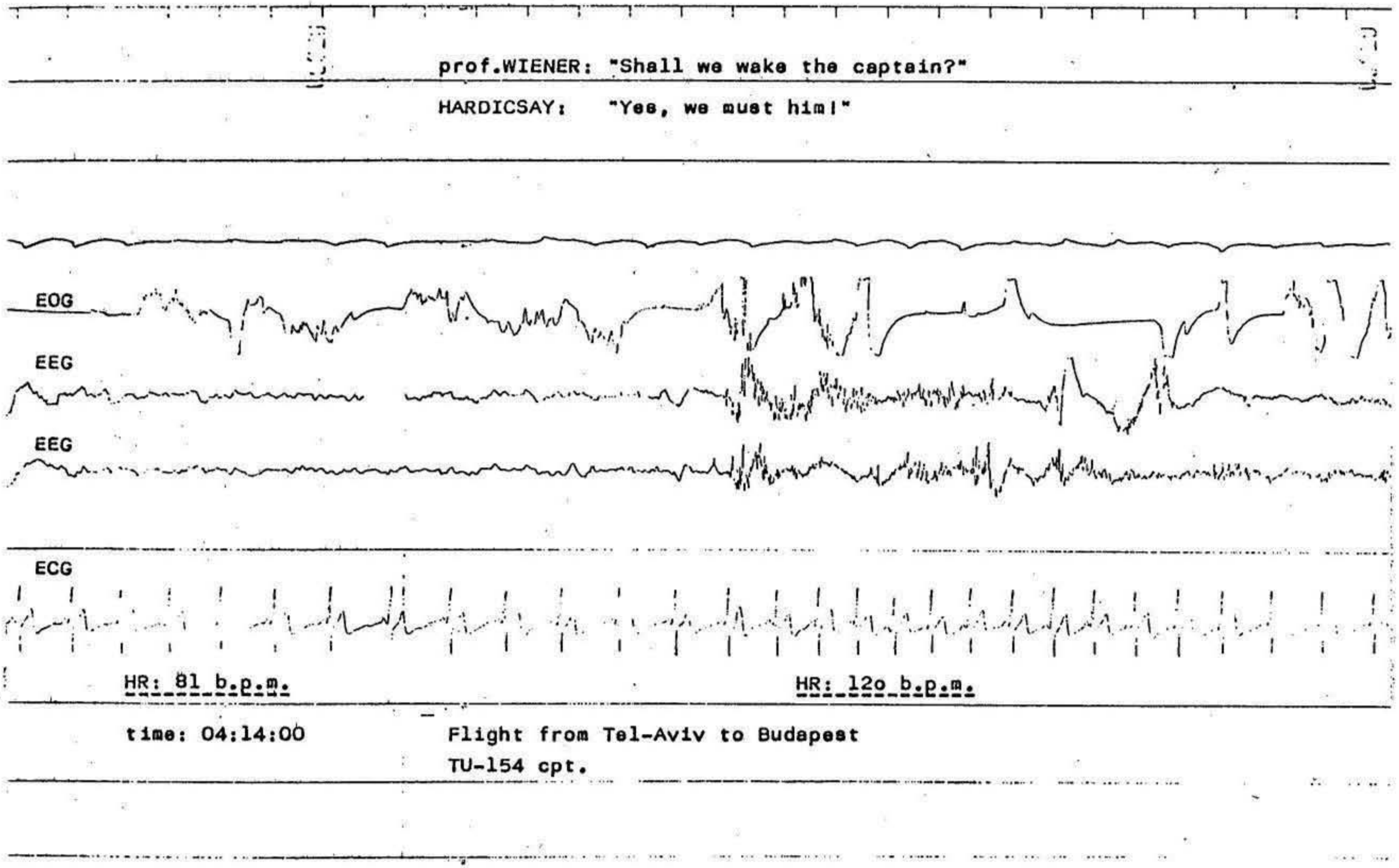
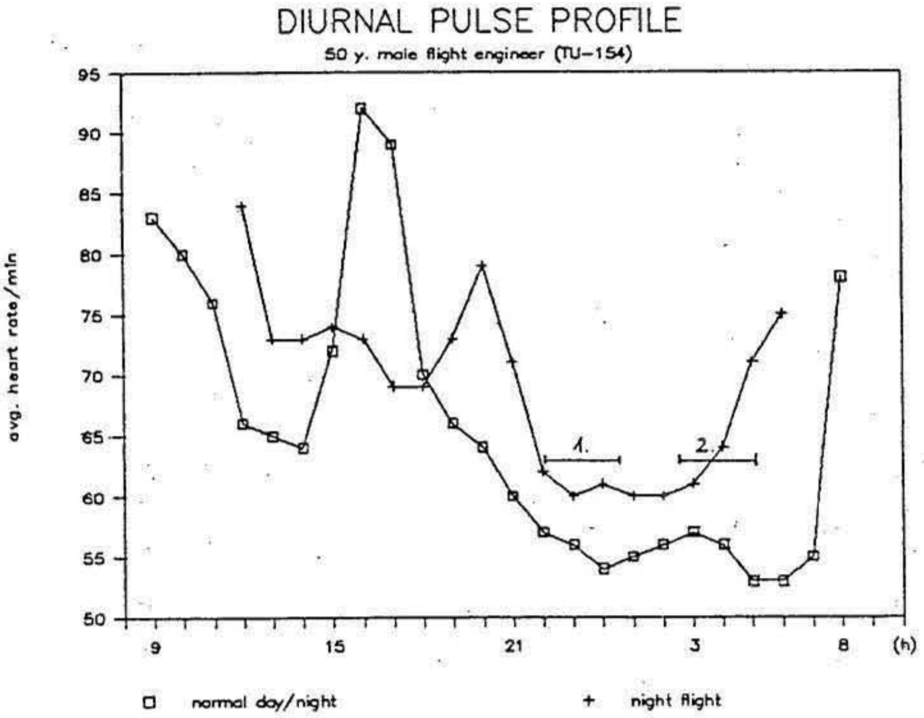

prof.WIENER: "Shall we wake the captain?"
HARDICSAY: "Yes, we must him!"
EOG
EEG
EEG
ECG
HR: 81 b.p.m.
HR: 12o b.p.m.
time: 04:14:00
Flight from Tel-Aviv to Budapest
TU-154 cpt.

Fig.9

fig. 10.



1. Bud. - Cairo - Bud. 2.

Towards design-induced error tolerance

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Airbus Industrie, Blagnac, France

1. System-induced errors : human factors

Current aircraft control and monitoring systems have reached unparalleled levels of reliability and redundancy. The success of the integration and evolution process achieved through systems' interfacing and advances in technology suggested the human operator in the safety loop, a goal long sought in suggest the eventual inclusion of the profession (1).

Emphasising the necessity to consider human factor issues in a broader systemic context was an early paper by Wiener in 1977, titled "Controlled Flight into Terrain : System-Induced Errors" (2). The contradiction suggested in this title aims to indicate the difficulty of integrating two levels of system management : aircraft control (inner loop) and aircraft monitoring (outer loop).

In the aviation transport area alone, some 75% of accidents are catalogued as pilot error, the remainder being evenly split between purely technical and environmental causes. Wiener makes the point that a majority of these accidents are design-induced, referring to human engineering concepts (2), air traffic control (3) and automation (4).

Stressing the failure of the human factors profession to play a more significant role in the design process, he addresses the following interface aspects :

- vigilance problems and crew overload/underload
- inadequate workplace design and extra-cockpit communication
- faulty pilot-controller communication and crew coordination
- unadapted, excessive or wrong automation
- unheard or cancelled warning devices and visual illusion
- confusing terminology and charts.

Politics aside, this author, also a pilot and management scientist, took a critical view of the systems design of air traffic control and, considering the long-debated issue of collision avoidance systems, confined himself throughout a series of papers to the topic of cockpit automation, its promises and problems (4).

The central issue was taken to be that it is highly questionnable whether system safety was going to be enhanced by automating tasks and functions normally performed by the pilot.

To illustrate their qualms, Wiener and Curry examined a number of aviation accidents and incidents and the role of automation in the causal chain towards breakdown :

- failure of automatic equipment
- automation-induced error compounded by crew error
- crew error in equipment set-up
- crew response to a false alarm
- failure to pay attention to an automatic alarm
- failure to monitor
- ensuing loss of proficiency.

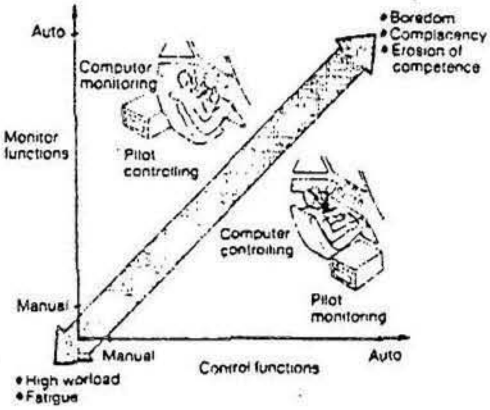


FIGURE 1 - MONITORING VERSUS CONTROLLING

Table 1

Wiener and Curry recommendations on automation

Control Tasks

1) System understandability to facilitate operation and malfunction diagnosis.
2) Automatic system to perform functions in the way the operator wants them to be done.
3) Task demands to remain at reasonable levels to ensure available time for monitoring.
4) Training so as to use automation as an additional resource.
5) Operations to allow more or less automation according to operator style, desires and needs.
6) Overall system insensitivity to different options and styles of operation.
7) Independent set-up and error-checking equipment/procedures to be available when appropriate.
8) Extensive training to ensure proper operation, set-up, anomaly detection, diagnosis and treatment.

Monitoring Tasks

9) Operator training, motivation and evaluation of monitoring activity.
10) Operator involvement should be managed to resist distraction by providing meaningful primary tasks.
11) Alarm rates to be kept within acceptable limits.
12) Alarms to indicate conditions responsible for their display.
13) Provision of ways and means to diagnose the automatic system and warning system operation and alarm validities when automatic response time is not critical.
14) Degree of emergency to be indicated by level of urgency of alarm.
15) Understandability of alerts and combinations of alerts through training techniques and hardware.

This is the controlling versus monitoring issue again, the distinction between automation of control and automation of monitoring being represented by two orthogonal dimensions as illustrated in Figure 1.

Should the pilot monitor the machine or should the machine monitor the pilot ?

A recurrent theme, the implications with regard to design philosophy for control and monitoring system being (4) :

- that the designer must ask to what extent the human should be included in the inner and outer control loops and to what extent automation should assist him in multi-attribute decisions,
- that the designer must consider the single channel behaviour of the human and the integration of the numerous devices, alerting and warning systems and conditions to be monitored.

Said Don Engen, former FAA administrator, at the SAE in 1985 (5) :"Human tolerance to poor design can be high until routine operation commences, then the tolerance level will decline in a random fashion, usually when least expected, and always when not wanted ... The answer for the best system lies with highly competent test pilots and design engineers who provide systems free from error".

The classic misnomer "pilot error" is giving way to a more cautious consideration of the underlying factors in pilot behaviour (6) (7).

2. Design guidelines : rules and philosophies

Few fundamental guidelines are available in the scientific field of human factors. They all appear to come "a posteriori" illustrating that this activity is an art in infancy.

Except the general guidelines of Wiener, Curry and Wanner, we are still short of standards sought by the industry (8) (9) (10) since it is still evolving at a rapid pace.

Wiener and Curry conclude their survey of cockpit automation by proposing 15 recommendations for designing and using automated systems (Table 1). In need of a philosophy regarding automation, Wiener has persistently advocated the respect of at least three (4) (11) :

. to allow the crew more freedom to fly the plane and use automation in the manner it wishes, but surrounded by a multidimensional warning and alerting system that informs the crew if they are approaching some limit ; as long as within the limits, the crew would have freedom to conduct the flight according to its style ; this concept of an "electronic cocoon" is called flight **management by exception**,

. to use forecasting models and trend warnings to predict a penetration of the cocoon rather than waiting for it to happen and alarms to be activated when the system reaches a critical point ; in order for the crew to have maximum control of the situation, values for the forecasting parameters could be selected by the crew ; this concept is called **exceptions by forecasting**,

. to allow the crew to inform the machine of its strategic goal or intention which would allow the computer to check crew inputs and system outputs to determine if they are logically consistent with the overall goal ; if not, an exception message would be issued ; this concept is called **goal sharing**.

Table 2

Wanner's pilotability rules

1) Useful information is necessarily pertaining to the functioning point and its position relative to corresponding limits.

2) Information difficult to interpret or implying the execution of complex mental processes must be avoided.

3) All useful information needs to be provided, excessive or useless information must be avoided, redundant information must only be used to perform reasonableness checks.

4) Information allowing forecasting/extrapolation of functioning point movements needs to be provided, particularly with regard to longer-term process control and strategic anticipation.

5) Vigilance retrieving and meaningful state information must be provided even with stable/routine control and management conditions.

6) Visible, audible and understandable alarms need to be provided so as not to remain unattended by the operator ; their number should be limited to those strictly necessary using logical hierarchisation, caution and warning of limit exceedances and proper selection of threshold limits.

7) The number of actions should be limited but close-looped for feedback since open-loop tasks are innately if not exceedingly difficult to monitor ; actions should always prepare tactics and strategies depending on the understanding of system state and evolution.

8) The use and usefulness of levers must be addressed carefully.

Developing his argumentation with regard to human factors and flight safety, Wanner (12) considers three classes of incident that may be playing a causal role in aircraft incidents or accidents :

. **pilotability incidents** whereby the crew erroneously allowed the functioning point to stray outside the authorized envelope with difficult or impossible reversion,

. **perturbation-sensitivity** incidents whereby external perturbations (windshear) or internal perturbations (failures or fire) let the displaced functioning point go beyond limits, whether limits after perturbations are new or unchanged,

. **manoeuvrability incidents** whereby the execution of a procedure (to modify trajectory or avoid obstacle) and the displacement of the functioning point as a result of incidents of the two preceding types brings the resulting functioning point close to or past its limits.

The goal of safety rules is precisely to lower the probabilities of occurrence of these three types of incident.

Wanner identifies five basic human attributes that allow him to derive a set of proposed design rules mainly covering pilotability incidents :

. single channel behaviour or functioning by the operator implying sequential work procedures,

. need for information input and drive for forecasting and extrapolation of events and situations,

. possibility of performance compensation by increasing workload to cope with higher task difficulty,

. use of mental representation model whether still learning or experienced,

. inability to estimate risks reliably in any given situation.

Wanner proposes eight pilotability rules to alleviate incidents of that type (Table 2). Perturbation-sensivity and manoeuvrability rules are, in his view, easier to establish since they do not implicate the human operator as such but rather system redundancy and integrity and operational knowledge of mission and environment.

As will be seen in the following paragraphs, these "a posteriori" rules and philosophies are finally not too far from the operational orientation that has inspired the functional layout and organisation of our new cockpits and associated systems. Design being an inextricable exercise of compromise, art and science, any "à la lettre" correspondance should however not be expected "a priori".

3. New technology : pilots and facts

In fairness to all, Wiener admits in a later paper (13) that the negative side of automation should not be overstated. The number of automation- or design-induced incidents brought about by new technology aircraft has been very limited and their consequences very small. In 1982, Gannet (14) stated that "the final report card on the results of the most recent application of digital technology and human performance principles to air transports will not be available for several years. It is firmly believed that, in the long run, the benefits far outweigh the costs".

In 1986, Caesar (15) stated that, with 8,000 big jets built so far, the average loss percentage since 1959 was 3.8%. Among these, was not a single of the so-called electronic cockpits like the A300FF, A300-600,, A310, 757, 767 or MD-80, then numbering 800 since being gradually introduced from late 1979.

Most automation works with extremely high reliability and pilots are very satisfied with new control and monitoring interfaces (16, 17, 18, 19) when compared to former equipment. The "good old days" fallacy is even repeatedly discredited with recent incidents and accidents having occurred on earlier technology aircraft (20, 21, 22, 23).

Most crews interviewed in field studies expressed high praise for the new "glass cockpits" which provide "a more dynamic source of information and greater awareness of the aircraft with respect to the operating environment, making conventional electromechanical cockpits obsolete" (19).

- According to Wienner and others, incompatibility with the air traffic control system limits the usefulness of modern flight management computers. The ATC system, designed for the slow climbs and fast descents of older aircraft, forces new ones to routinely use speedbrakes for descents and prevents effective use of the flight management computers for vertical navigation.

- Although this tends to disappear with experience, some pilots have the impression that higher monitoring and programming demands associated with the flight management and guidance systems may force them towards more head in the cockpit time and less availability for extra-cockpit scanning in terminal areas. Some others may, in turn, be concerned about losing their classic monitoring scan and manual flying skill from over-reliance on the automated cockpit and resist this "complacency tendency" by self-imposed flying programs and training exercises to maintain proficiency.

- All 17 pilots and observers that participated to the A310 crew complement certification (18) volunteered to answer an anonymous questionnaire on the quality of the man-machine interface. As a group, these pilots appeared to cover an experience-level corresponding to the operation of almost all commercial jet aircraft introduced to that period.In answering the questionnaire, pilots were asked to compare the A310 with the aircraft they considered most representative of their experience. For each question a scale from 1 to 6 was presented, the 1 showing low appreciation, requesting improvement, the 6 showing high appreciation, recognizing high quality. This questionnaire covered the whole spectrum of aircraft design issues with regard to :

  . functional grouping of instruments/controls
  . general presentation of flight systems information
  . crew comfort
  . overhead panel layout
  . PFD information presentation, speed scale, mode annunciators, etc.

- ND information presentation involving Arc mode, Map mode, Plan mode, Radar...
- ECAM information presentation involving warning display, system display, etc.
- FMS control and display unit, manipulation, pagination, etc.
- AFS flight control unit, autothrottle operation, thrust rating panel, autopilot/flight director procedures, etc.
- checklists and procedures
- outside appearance/mechanical ergonomy
- tasksharing and worksharing
- workload and error-inducing potential
- intelligibility of hardware/procedures/mental ergonomy.

More than 75% of all questions received very high marks in the appreciation scale-range of 4 or rather 5, pilots refraining from making extreme position judgements. Where some improvement was desirable for the future they felt free to rate in this direction.

Examples in this area concern seating, software, procedures, use of space on the overhead panel, FPV-information, attention-getting capability of some alarms on the PFD and on the ECAM, interpretation of error messages on the FMS, homogeneity of abnormal/emergency checklist with ECAM WD.

This provided a tremendous and often too-scarce opportunity for us to do some homework having learnt throughout the years that more contact was going to be necessary to listen to and understand the pilot community. A step in the right direction was prompted by the crew complement issue.

4. Cockpit management : errors and resources

From the observation of errors in our A310 crew complement certification campaign, it was concluded that their mere existence - most having been minor slips, blunders, mishaps and problems in resource management or insufficient familiarity with the aircraft - made possible to establish learning loops (18). Some of the recommended improvements concerned operational procedures and the training syllabus with particular emphasis on system knowledge and insight. Specific operations engineering bulletins were also issued for ECAM, EFIS, FMS and engine monitoring. Special care was devoted to understandable tasksharing in the cockpit smoke or fire procedure.

Analysing newly trained crew's errors revealed that most of these related to procedures/checklists and navigation, with autoflight and tasksharing taking a minor share. No direct relationship could be established between test scenario difficulty and the number or importance of errors. The succession of failures and problems embedded in the simulator and flight scenarios never brought crews to such workload levels that they could but commit errors, one of the underlying verifications in carrying out these tests. Which underlines also the tolerance of the system with regard to various blunders, mistakes, misperceptions and omissions.

Not unrelated to the fact that this area was considered too speculative until recently, a majority of airline accidents in recent years appears to be attributed to human factors communication problems. Most of these seem to be caused by some aspects of inadequate cockpit resource management due to a problem of information transfer or communication - be it man-man or man-machine, system-induced or not (24).

Caesar (15) devides these human failures into the following categories.

- Active failure : 35%
  Non-adherence to rules and SOPs. Lack of discipline or vigilance inadequate flight management - short cuts,
- Passive failures : 30%
  Crew misunderstanding and communication problems
  Distraction - coordination breakdown - fatigue

Judgement errors and decision-making : 30%
Underestimation of actual operational conditions
Bad landing - wrong alternative

. Crew incapacitation : 5%
Subtle or obvious, requiring take-over.

In the aftermath of a landmark study on the interactions of workload with errors, *vigilance and decisions, performed by the late Pat Ruffell Smith (25, 26)*, NASA concluded that these problems can be classified into the following categories :

- social and communication skills
- leadership and management skills
- *planning, problem solving and decision-making skills*
- human and machine characteristics.

Directing an automatic system rather than doing the job manually while coordinating with the other crewmember needs skills different from those required in conventional cockpits. And the changing nature of piloting, the increasing complexity of the environment (ATC congestion, regulations and procedures), the vast number of computer-based devices replacing manual control and mental calculation, jointly demanded the development of a new attitude towards automation.

Any feeling of "being along for the ride", ideas of underload, lack of vigilance, boredom and complacency, any sense of "being out of the loop" needs to be properly addressed by means of cockpit management techniques that help to foster the attitude that automation is just another resource to manage (27). While at NASA, John Lauber (28) emphasized that the major impact of the inclusion of microprocessor and display technology in new generation transport aircraft would be the quality and quantity of real-time information available to the crew and the way this information *would be manipulated* and used to conduct a flight. As a result of previous accidents with conventional technology aircraft due to shortcomings in crew communication and coordination, the NTSB recommanded that the FAA urge operators to indoctrinate flight crews in the principles of flight deck resource management.

It is, however, not the manufacturer's responsibility to ensure that the airlines main*tain adequate cockpit resource management standards*. Rather, the *manufacturer* has to offer high quality flight decks and associated procedures that make good communications possible.
In other words the manufacturer is committed to deliver a product that should be, so to speak, immune to information transfer problems (24).

5. Error tolerant systems : monitoring performance, monitoring the operator

Pointing beyond the sterile cockpit, Wiener insists (13) that the long-standing recommendation that humans serve as monitors of automatic devices must be reconsidered. In his view, shared by others, the pilot should be brought back into a more active role in the control loop (29), aided by decision support systems, especially in view of very long range operations. At one airline, crews on these flights may be required to perform routine in-flight tasks and calculations to sustain alertness, with flight management system backup (30). The vast amount of literature on vigilance has indeed shown that the human, after all, is not a very effective monitor, is less likely to detect system fault or wrong set-up, and is more likely to commit large blunders. For this reason, the famous controller versus monitor doctrine - placing the pilot rather as a monitior than as a controller - is being re-examined.

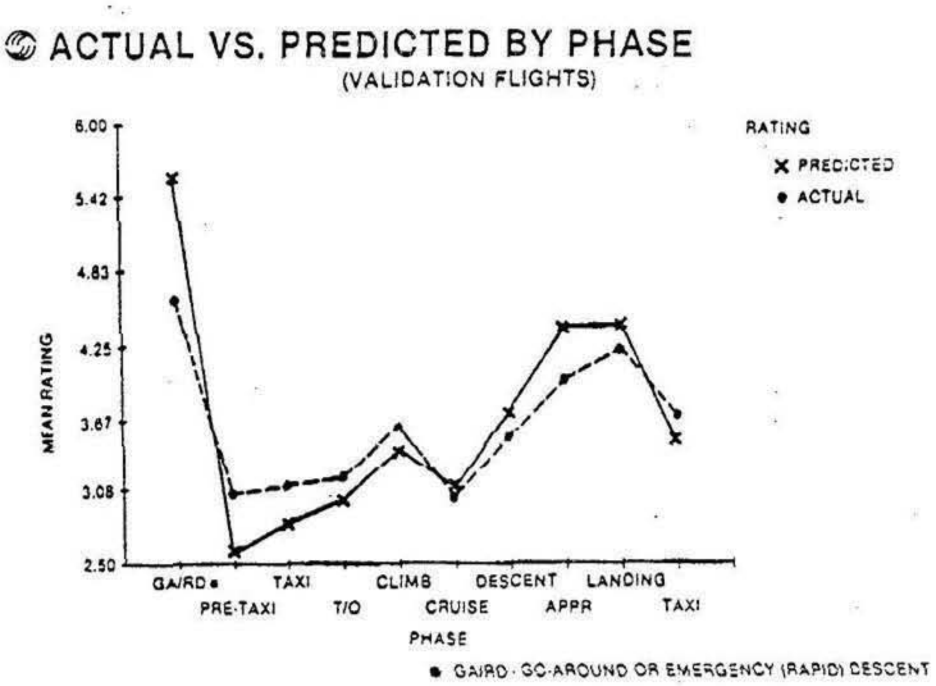


Fig 2

Potentially weak vigilance of the pilot and vulnerable aircraft systems suggested a growing need for the machine to monitor itself and the operator, diagnosing errors performed by the human. The need to develop automatic systems that monitor human operator performance rather than the reverse has also been suggested in the aerospace medical world (31).

Not that familar, Wiener takes a cautious but nevertheless interested view with regard to potential promises in information technologies, decision support systems, expert systems or artificial intelligence. Pelegrin, on the other hand (32), advocates increased automation, using these technologies to include automatic reconfiguration after failure, ongoing maintenance and systems status backdating and updating, pilot assistance in abnormal situations not necessarily resulting from failures and crew error tracking and interrogation systems.

The error-protection capabilities of map displays and fly-by-wire flight control discussed in the following paragraph have somewhat paradoxically been accompanied by a renewed interest in error-tolerant systems as safety nets. Trying to automate error away may merely displace the problem of pilot error, since the human will still prove to be the ultimate cross-check.

Models of human operator behaviour are needed for incorporation of such error-tolerant capability into the automation device itself. Aware of the need for better knowledge of the man-machine relationship, Airbus Industrie has, in cooperation with Dunlop & Associates and Cochin Faculty, developed and validated a predictive crew workload rating mode (33) based on heart rate variability, aircraft performance parameters and situational information (scenario, flight phase conditions etc.) as shown in Figure 2. Further work will, however, be necessary to model crew vigilance, to investigate how automation, workload, vigilance, performance and errors all relate to each other.

Seifert and Brauser have proposed two strategies for future flight deck design (34) equating the pilot's capabilities and needs :

. provision of sufficient feedback to allow the pilot to detect and correct unintentional performance errors before they affect system performance,

. introduction of fail-safe and fail-operational ergonomic design by means of human error detection and correction functions into the man-machine interface intelligence.

Extensive analysis on human errors including preflight and inflight data, physiological and psychological parameters, opinion ratings, environmental factors, mission requirements, organizational and technical factors, proficiency factors, pilot errors and their consequences (35) has revealed that human errors, systematic or random, can be interpreted as a four-dimensional structure : vigilance errors, perception errors, information processing errors and sensory errors. In particular, it has been found that determinants and background variables of human factor incidents and accidents provide a model of basic man-machine system interaction patterns which is useful and predictive of human error occurrence.

The new goaal for cockpit design proposed by Seifert and Brauser may be posed : to provide mutual monitoring of man and technical system.

6. Airbus technology : evolution in design

The pilot's role evolution is inevitably linked to that of the aircraft and its cockpit triggered, as it has been, by economic and technological imperatives.

Whether in technical areas or operational functions, continuity as well as progress elements have been pervasive throughout the A300/A310/A320 family (Table 3).

The forward-facing crew cockpit of the A310 and A300-600 stems from a cascade evolutionary process. Its design proceeds from A300 experience which itself reflected experience with the Caravelle, Trident, BAC I-II and Concorde. It is also the offspring of our customers, traditionally kept involved from the start of the design process through so-called task forces (36, 37). The FFCC concept itself is a direct result of multiple discipline research programmes that included a human factors orientation such as the NASA Terminal Configuration Vehicle Program, the French PERSEPOLIS project and the BAe Advanced Cockpit Design.

Early consideration has been given to making the original A300 a two-pilot crew aircraft. The technology then available did not permit such an approach with the necessary degree of confidence.

The overall design goal being to ensure adherence to the need-to-know and fail-safe principles which the 1970's A300 cockpit did not fully satisfy :

. side panel not fulfilling fail-safe criteria

. number of dials and displays giving unnecessary information during a large part of the flight

. necessity to scan in different places.

The innovations of this first twin wide-body proved a major credit to Airbus :

. automatic throttle from brakes-off to touchdown

. automatic angle of attack protection and speed reference system against windshear incidents

. automatic two and one-engine go-around

. thrust computer linked to autothrottle allowing derated engine operation / increased engine life.

The necessary evolution became possible in the 1980s with the help of technology leaps providing concentration, standardisation and flexibility (38). Design goals of the FFCC were formulated as follows :

AIRBUS TECHNOLOGY : EVOLUTION IN DESIGN

	A 300 FF	A 310	A 320
• PUSHBUTTON TECHNOLOGY AND ADVANCED SYNOPTICS/OVERHEAD PANEL LAYOUT	X	X	X
• ADVANCED SYSTEMS AUTOMATION AND DARK COCKPIT PHILOSOPHY	X	X	X
• DIGITAL AUTOMATIC FLIGHT GUIDANCE SYSTEM (AFS)	X	X	X
• ELECTRONIC CENTRALIZED AIRCRAFT MONITOR (ECAM)		X	X
• ELECTRONIC FLIGHT INSTRUMENTS (EFIS)		X	X
• FLIGHT MANAGEMENT SYSTEM (FMS)		X	X
• FLY BY WIRE FLIGHT CONTROLS AND SIDE-STICKS (FBW)			X
• FULL-AUTHORITY DIGITAL ENGINE CONTROL (FADEC)			X

COCKPIT EVOLUTION

	A 300	A 310 AND A 300 600	A 320
GENERAL ARCHITECTURE	CONVENTIONAL	FFCC/OPTIMISED SYNOPTICS	DESIGN/INTEGRATED UNITS
FLIGHT AND NAVIGATION	• STYLISED ELECTRO MECHANICAL	• CATHODE RAY TUBES EFIS (PFD AND ND) • FMS-IRS ASSOCIATION	• IMPROVED DISPLAY UNITS (ALT, VV....)
SYSTEM INFO PRESENTATION	• SYSTEM PANELS AND ASSOCIATED SYSTEMS	• CATHODE RAY TUBES ECAM (WD AND SD) • PUSHBUTTONS	• IMPROVED DISPLAY UNITS (ENG IND ...)
FLIGHT MANAGEMENT CONTROL	• OPTIMISED AP/FD • COUPLED AP/INS	• PILOT INTERFACE }FCC }FCC • INTEGRATED MODES }AP/FD }ATS • COUPLED AP/FMS	• FBW-SIDESTICK • FMGS INTEGRATING AFS, ATS & FMS • SIMPLIFIED THRUST CONTROL - FADEC
SYSTEMS ARCHITECTURE	• INCREASED REDUNDANCY • EASE OF OPERATION	• DIGITAL TECHNOLOGY • ADAPTED AUTOMATION	• SYSTEMS AND FUNCTIONS INTEGRATION • INCREASED AUTOMATION

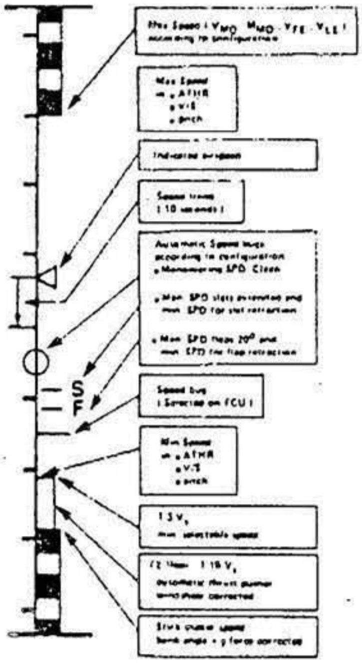
Table 3

- better crew integration and cross-monitoring.
- better man-machine interface
- lower risk of flight / system management error
- automation of routine actions
- simplification of tactic actions in normal, abnormal and emergency procedures
- augmented availability for strategic flight actions
- clear presentation of predigested information for easier and quicker diagnosis and correction
- reduction of crew workload.

These goals were, as we know, effectively reached by :

- pushbuttons combining control, visual feedback and visual malfunction alert

PFD SPD scale schematic



A300-600/A310 EFIS

Fig 3

- systems controls all on an overhead-mounted panel improving visibility, accessibility, use of space for all,
- combining previously separated systems and subsystem panels into synoptic presentations (source to distribution), according to frequency/urgency of use (normal, abnormal, emergency)
- associating all the above with a rigorous dark cockpit philosophy to simplify procedures and understanding of system operations
- introducing basic, transparent system automation to avoid repetitive actions in normal operation or after a single failure (electrical, APU, fuel, pressurization, avionics cooling, air bleed etc.)
- introducing digital flight management (AFS) with preselected functions and reliability enabling less crew intervention, clear and unambigous operation, improved flight envelope protection (FAC, FLC) and automatic landing potential to CAT III.

First to embark on this new lead was the digital A300FF, first wide-body certificated for operation by two pilots embodying all the new goodies except display units for flight and systems monitoring offered on the A310 and A300-600 :

- replacing electromechanical ADIs for short-term flight path control with electronic PFDs allowing a more efficient scan and direct access to predigested information (improved speed scale with critical ranges, margins, trend and speed error, flight path information with path angle and vector, mode annunciation and autoland indications), illustrated in Figure 3.
- replacing electromechanical HSIs for medium-term navigation with electronic NDs allowing a more efficient scan of weather, navigation progress versus constraints, beacons and waypoints monitored by the FMS with several display options available (Rose, Map, Arc and Plan).
- introducing Flight Management Systems with the purpose of :
    - full area navigation and guidance
    - full vertical navigation and guidance with profile optimisation for maximum economy
    - instant prediction and flight planning facility,
- introducing Electronic Centralized Aircraft Monitoring (ECAM) eliminating the need for frequent system scanning in normal operation with :
    - temporarily used systems/functions monitoring
    - routine system monitoring
    - system parameter trend monitoring,

  and simplifying information processing in abnormal/emergency operation through :
    - improved failure analysis
    - orientation of corrective actions
    - minimal need of paper checklists
    - improved understanding of post-failure configuration.

The Flight Warning Computer whose logics have made it possible to provide ECAM operational features is a real breakthrough achieving in addition :

ECAM Warning inhibition

- ensures proper warnings only when necessary.
- avoids warning without interest for a flight phase ; an inhibition logic filters the presentation of warnings according to the flight phase
- allows the crew to cancel warning presentation when the corrective actions have been done (CLEAR functions).

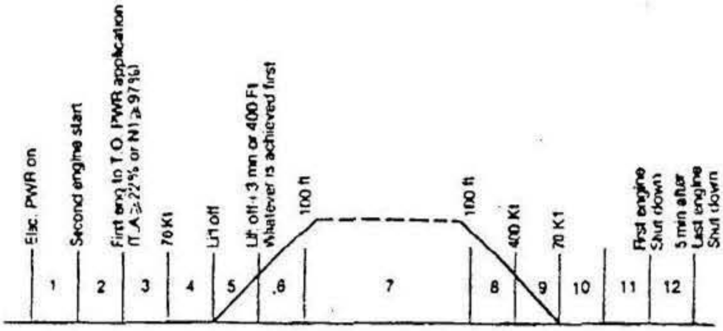


Fig 4

A300 Flight experiment

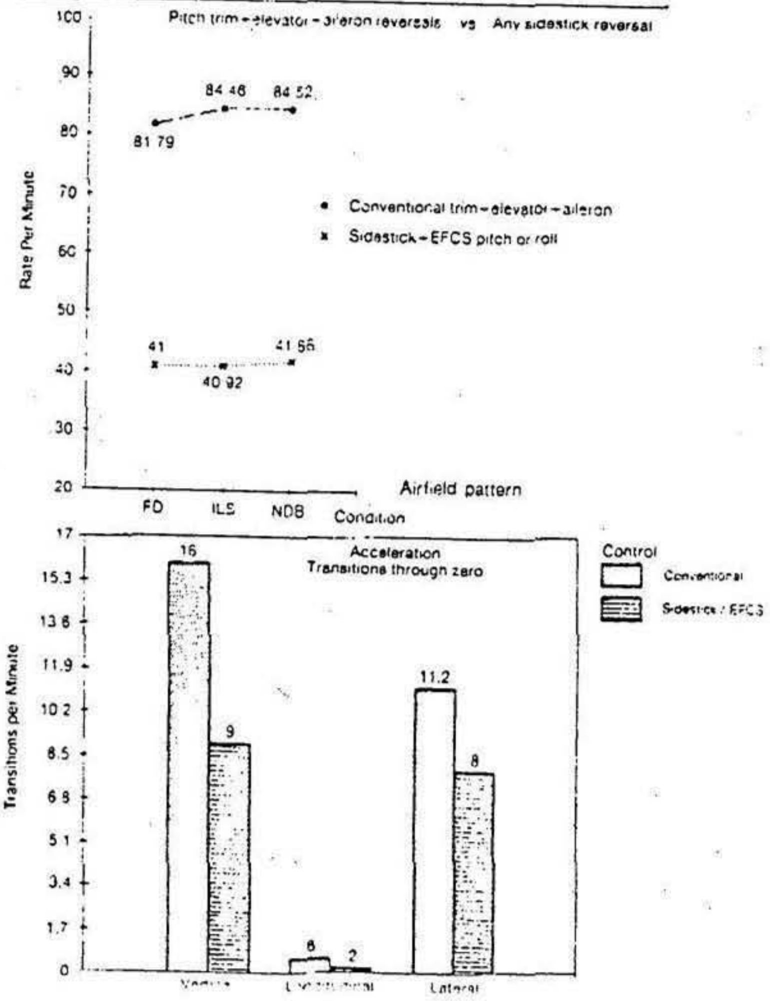


Fig 5

- the reduction of discrete sounds to a bare minimum, basic attention-getters alerting the crew of warning display messages
- the adaptation of the warning to flight phase with inhibitions where safety mandates (Figure 4).

We are convinced that, with selective and tailored information according to the situation, the major contribution is towards protecting the crew against mishaps, blunders or more serious errors. What has been achieved with the A310/A300-600's cockpit is also in the vicinity of Wiener's philosophy on automation (flight management by exception, forecasting and trend possibility, goal sharing or strategic intent) and Wanner's philosophy of human attributes and pilotability incidents.

In the step that was to be taken in the mid-1980s, design aims have essentially been extended to cover more error-tolerance or protection against pilotability, pertubation-sensitivity and manoeuvrability incidents by safeguarding functioning points and envelopes. In this respect a major emphasis was put on windshear (39) as evidenced by Table 4. Continuing developments in digital technology and data transmission have also led to greater possibilities of systems integration. Former breakthroughs with FFCC technology have been refined in several areas but essentially kept as mainstays for the future.

The most prominent innovation on the A320 being to introduce fly-by-wire (FBW) as primary means of flight control in conjunction with sidesticks, (40, 41). A natural decision since it is available on Concorde with an analogue electrical control system in all axes, mechanically backed up, and to a more limited extent on the A310 with digital signalling of the roll spoilers and aileron with no back-up.

For the A320 to become fly-by-wire with minimal mechanical back-up is furthermore based on considerable partner companies' experience with military aircraft. But Airbus Industrie's decision on this hinged upon considerable flight testing work with its R & D testbed. From September 1983 onwards this aircraft went through an evaluation program involving 48 pilots from airworthiness authorities and airlines. It was equipped with a sidestick controller, from which output signals were fed through a black box into the existing AFCS to give primary FBW-control in roll and pitch. The unanimous acceptance of this configuration was quantitatively confirmed by a small test program involving manually flown experimental circuits that posed a variety of operational problems. All performance measurements of smoothness and stability favoured the FBW-system compared to a conventional system by at least 20%, pilot control inputs being reduced by about 50% (Figure 5) to allow better performance and more availability for general cockpit management (42).

Originally derived from NASA studies on self-correcting flight control concepts, a C* law was chosen as the fundamental mode of control in pitch, with roll control based on roll rate. C* provides short-term direct flight path control by modulating the load factor using a blend of pitch rate and load factor at low speed and pitch speed without autotrim below 200 ft normal flare.

Its characteristics feature is to maintain the aircraft at 1g as long as the stick is neutral, which permits a stable trajectory through turbulence without any need for the pilot to interfere. Likewise, this concept automatically eliminates pitch oscillations when performing angle of attack changes, and eliminates the need for pitch trim with thrust or configuration changes.

Airbus Industrie efforts against windshear since 1972

	A300	A310 & A300-600	A320
Angle of attack protection	×	×	×
Speed reference system	×	×	×
Beam deviation on ILS	×	×	×
Stick shaker speed and speed Trend information		×	×
Wind speed and direction info		×	×
Flight path vector		×	×
Visual warning		×	×
Stall protection	Stick shaker	Stick shaker	Full protection against stall
High Angle of Attack Control			×

AIRBUS EVOLUTION : WINDSHEAR PROTECTION

	DETECTION ALERT	GUIDANCE	PROCEDURE
A 300	RAW DATA BEAM DEVIATION AUTOTHROTTLE ACTIVATION	SPEED REFERENCE SYSTEM (PITCH BAR)	MAXIMUM THRUST STAY ABOVE STICKSHACKER SPEED MONITOR GROUND SPEED
A 310	SAME PLUS : SPEED TREND SPEED MARGIN FLIGHT PATH VCTR WARNING IN PFD	SAME	SAME PLUS : VISUAL SPEED CUES FLIGHT PATH VECTOR MONITORING
A 320	SAME	SAME NOTE : PITCH LAW WILL TRY TO MAINTAIN FLIGHT PATH	FULL STICK AFT.

Table 4

Safety features and procedures offered by the A320's FBW/sidestick combination with regard to Wanner's incident scheme are many (40,41) :

- envelope protection - overspeed with marked stability beyond high speed warning
- stall protection so that
  - : below 1.13 Vs the control law changes to an angle of attack control law,
  - : below 1.1 Vs the classic alpha floor (A300, A310) commands full thrust
  - : with maximum angle of attack at full stick at 1.06 Vs resulting in the spectular flight path demonstrations shown by the A300 testbed
- windshear protection by applying full stick with no fear of stalling (Table 4) resulting in a safe escape, and
- manoeuver protection limiting the manoeuvre demand systems to 2.5 g to protect against breaking up at high h in the case of collision avoidance
- attitude protection with automatic recovery in pitch and roll if disturbances take the aircraft beyond its limits
- engine failure compensation after take-off the aircraft rolling to a small (7 degree) bank and taking a mild (1 degree/sec) turn towards the failed engine, hands-off
- electronic sidestick coupling backed by warning lights allowing a training captain to modify a student's flight path without any risk of resistance and helping take-over situations to be handled diligently in case of neighbour pilot's incapacitation or derangement.

Another novelty on the A320 concerning protection of functioning envelope is the Full Authority Digital Engine Control (FADEC) which is deemed to succeed electronic engine control introduced on the A310/A300-600 models.

Offering full engine control and protection under both stabilized and transient conditions of operation, the FADEC provides a wide array of operational functions, some of which were still handled by pilots until recently :

- gas generation control
- engine limit and overshoot protection
- power management and derating
- engine starting (automatic)
- thrust reverser control
- fuel return valve control
- engine condition monitoring.

Similar to sidesticks complementing the FBW-controls, FADEC is associated with a pair of fixed-gate throttle levers. Thrust control through FADEC manages to provide the best power suited to each flight phase either in manual, according to throttle position, or in automatic, associated with throttle detent and in response to ATS/FMGS demands. Engagement of ATS modes (SPD, MACH, THRUST, RETARD) is automatic according to AP/FD mode engagement, the FADEC receiving AFS commands via an ARINC transmission bus.

A320 - AFS - ATS modes

4 MODES :
SPD
MACH
THRUST
RETARD

Engagment of ATS mode is automatic according to AP / FD mode engagement*

AP / FD MODE	ATS MODE
V / S-FPA ALT(ACQ / HOLD)	SPD / Mach
Expedite	Thrust / Retard
Descent / Climb	Retard Thrust / SPD / Mach
SPD / Mach	Thrust / Retard
Approach final descent glide flare	SPD SPD Retard
TO / GA *	ATS Armed

(FADEC control)

*If no AP / FD is engaged ATS can be used in SPD / Mach mode
*In case of excessive angle of attrack configuration ATS Alpha floor mode is engaged. The GA limit thrust is acquired and held

A320 - AFS - Block diagram

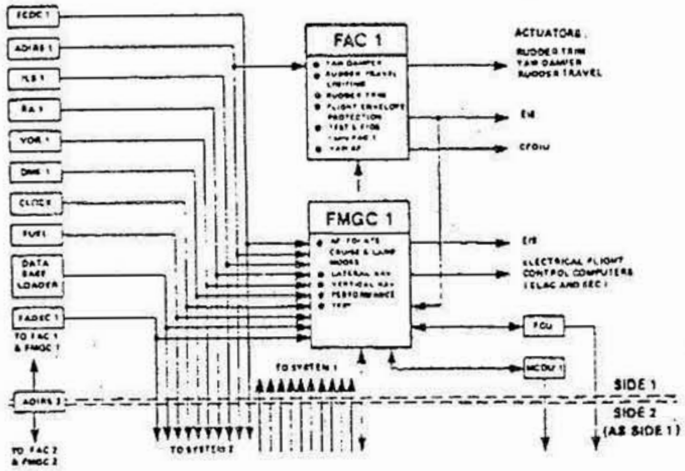


Fig 6

On the A320, the AP/FD and the ATS are fully merged with the FMS into the FMGS, an integration enabled since flight control laws are taken over by ELAC/SEC computers leaving the elaboration of horizontal and vertical guidance to a fully integrated FMGS. Short-term flight control inputs to the FMGS are made through the FCU on the glareshield, longer-term inputs are introduced via the MCDU to select upper navigation and performance modes and advisory functions.

The systems which the FMGS dialogues with (Figure 6), FAC, FADEC, EIS, ELAC/SEC, ADIRS, FCDC etc. - are themselves interfaces with other calculators EIU, EFIS, ECAM etc., branching out towards almost all other aircraft systems. A good knowledge of these systems implies firts of all the understanding of functions and interactions.

Another newcomer to Airbus cockpits, the Radio Management Panel will faultlessly manage the frequency selection for all VH/HF and transponder and radio communications as well as ILS/VOR and DME radio navigation aids in case of FMGS failure.

Apart from the innovations just cited, the experienced observer will note :

- the uncluttered layout (from 35 instruments on the A310 to 12 on the A320)
- the use of six interchangeable display units for EFIS/ECAM, systems whose architecture notes a further trend towards integration (EIS)
- the provision of altitude/vertical speed on the primary flight display, more refined Nav, Rose and Map modes on the navigation display, primary engine pictorials with checklist items on the ECAM upper display, the ECAM lower display presenting refined system or status pages
- the further reduction of pushbutton and overhead system panels through :
  - a radical integration of avionics (from 74 calculators on the A310 to 32 on the A320) and a logical rearrangement of the center row dedicated to engine-related systems and functions (fire controls, hydraulics, fuel, electrical and air conditioning)
  - deletion of several functions switches or levers (no manual temperature and flow control, no fuel manifold valve control etc.),
- the further reduction of system management tasks after single failures presently of three types :
  - no action, disconnection performed automatically (examples : air conditioning temperature overheat, pressurization control)
  - confirmation action to cover the case of automatic disconnection failure (examples : ELAC/ SEC flight control computers, electrical generators)
  - mandatory actions not covered by automatic disconnection (examples : fuel and hydraulic pumps),
- the subsequent simplification of most abnormal procedures mainly consisting of confirmation checks with some confirmation or bakc-up actions but less than on former models.

7. Conclusion

Some years ago, it was anticipated that the 1990's era cockpit (10, 24) can be imagined to be an all-digital, all-electronic flight deck with high-resolution multifunction displays and man-machine interactive systems that will monitor flight operations.

It was anticipated that crews would only be there for aggregate information treatment and strategic decision-making, concentrating solely on mission supervision and management, leaving interactive electronic systems with routine data processing, memory work, control tasks, procedural decision - making and a quasi-human aptitude to monitor, detect and plan.

The high-tech command post of the future with table tops, joysticks and pushbutton controls at fingertips has virtually arrived, yet the A320 pilot will fly as the horseman drove his coach in the not-too-distant past.

Performance and initiative being what he is best at, it is up to man to decide whether he or the machine are to tolerate errors. The best anticipation strategy being to avoid, detect or correct by design. The practical orientation taken by Airbus Industrie in this matter conveys the promise of even smarter intelligence to be in store for the future.

NOMENCLATURE

AP/FD : Autopilot/Flight Director
AFS : Automatic Flight System
AFCS : Automatic Flight Control System
ATS : Automatic Throttle System
ECAM : Electronic Centralized Aircraft Monitor
EIU : Engine Interface Unit
EFIS : Electronic Flight Instruments
ELAC : Elevator and Aileron Computer
EIS : Electronic Instruments
FAC : Flight Augmentation Computer
FADEC : Full-Authority Digital Engine Control
FBW : Fly-By-Wire
FCC : Flight Control Computer
FCU : Flight Control Unit
FFCC : Forward-Facing Crew Concept
FLC : Flight Limitation Computer
FMGS : Flight Management and Guidance System
FMS : Flight Management System
FPV : Flight Path Vector
FWC : Flight Warning Computer
INS : Inertial Navigation System
IRS : Inertial Reference System
MCDU : Multipurpose Control and Display Unit
ND : Navigation Display
PFD : Primary Flight Display
RMP : Radio Management Panel
SEC : Spoiler and Elevator Computer
SPD : Speed mode of AFS-ATS

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BEYOND PILOT ERROR: A PILOT'S PERSPECTIVE

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Introduction

Errors by cockpit crew members account for two-thirds of all aircraft accident causes, according to a study by the Boeing Company covering a 24-year period.[1] Many other observers of aircraft accident statistics report a similar proportion of accident causes attributable to the human crew.[2,3]

The accident statistics of travel show that air travel is one of the safest modes of transportation. Dr. John Lauber,[4] a member of the US National Transportation Safety Board (NTSB), noted that since the introduction of jets in airline service (1959 to 1988), fatalities in commercial jet transportation worldwide have numbered 16,397. In contrast, in only one year (1988), in the US alone, approximately 24,000 fatalities were caused by auto accidents involving alcohol. The crash of an airliner always attracts a remarkable amount of attention by the press. Such media attention is understandable because of the number of lives involved and the public's fascination with tragedy, whether it be an earthquake, a fire, or an aircraft accident. Sometimes the accident becomes a dramatic platform for the politically minded. Government authorities, sensitive to media attention, may feel the need to make immediate changes or even pursue the alleged culprit in the open press, severely hampering the accident investigation process. Investigative authorities must resist the temptation to comment on the cause of the accident and instead appeal for time to gather all the facts necessary to determine the probable cause of the accident. The flight crew is an easy target unless an explanation for the accident can be found quickly.

Purpose of this paper

Our purpose in presenting this paper is not to deny the responsibility of pilots whose errors result in accidents or incidents but rather to demonstrate that accidents usually are the result of a sequence of events, some of which may have occurred over a period of years or which could be the result of a specific method of operation employed by a particular company. The goal is to ensure that the accident investigative process includes a balanced review. Pilots have shouldered the burden of blame for critical errors for many years, but we are finally gratified to hear that others are concerned with tracing the error to the point of initiation, wherever that may be. Sometimes it is in the cockpit, but sometimes it is in the factory where the aircraft was built, or in the office of the manual writer, or in the management of the airline, or in the oversight of the operation by the State authority.

Definition of some terms used in this paper:

Error[5] - An act or condition of often ignorant or imprudent deviation from a code of behavior. An act involving an unintentional deviation from truth or accuracy. An act that through ignorance, deficiency, or accident departs from or fails to achieve what should be done.

Human factors[6] (or ergonomics) - The technology concerned to optimize the relationships between people and their activities by the systematic application of the human sciences, integrated within the framework of system engineering.

Operator error - Those errors which may be ascribed to the person in direct control of a machine.

Pilot error - Those errors which may be ascribed to the person or persons (crew) in direct control of an aircraft.

Sequence (chain) of events - A series of events which precede an accident or incident.

Causal factors - Those predisposing or disposing factors that contribute to an accident or incident.

Human performance - A description of those attributes that may be attributed to a human being or to the study of human characteristics.

Institutional errors - Those errors which are initiated or maintained by the structure, policies, or precedence of a company or organization.

Errors made by pilots

NASA Ames was one of the first scientific groups that attempted to deal with the human equation in errors on the flight deck.[7] The research was based on the use of trained observers who catalogued errors and the interactions of flight crew members during simulator scenarios. While many errors were noted and caught by other members of the crew, communications between crew members appeared to highlight the differences between captains. The more verbal or communicative the captain, the better the crew seemed to operate and deal with the various complexities of the simulator scenarios. This initial work led to the present effort to optimize cockpit communications in what is now called cockpit resource management training, which has become a vital, integral part of training at many airlines throughout the world.

Those who fly realize that the cockpit of a high technology jet transport is a workplace where many errors occur. Outsiders are surprised (and a little alarmed) to hear that, but those of us familiar with the cockpit readily admit it is true. However, we are quick to point out that the redundancy of both the crew (more than one pilot) and the warning systems helps to correct these errors before the flight becomes unsafe.

Typical errors that occur in routine cockpit operations include the misreading of navigation charts because of small size print, poor ambient light, or the need to calculate a reciprocal course; selecting the wrong approach chart because of misunderstanding the automatic terminal information service (ATIS) or the approach controller; and the improper setting of a instrument because of misreading or mis-setting the small digital display. The list could on and on, but many of the mistakes occur because of the heavy workload involved when flying a complicated airliner in a busy terminal area. Pilots must move from one procedure to another in rapid order to accomplish aircraft speed and configuration changes and the course and height changes required by noise abatement or approach procedures.

During the fuel crisis a few years ago, before-takeoff procedures were changed in order to save fuel. One engine was started for taxi and the other engines were started a few minutes before takeoff. While they were taxiing, the crew was expected to start the remaining engines, complete the checklists, ensure that the cabin was prepared for takeoff, and monitor the tower. Some close calls were caused by this intense operation. Management closely monitored the fuel use during this time, heightening the attention paid to fuel use by crews. In addition, the competitive nature of some pilots caused further erosion of normally safe practices.

One of the most common errors is miscommunications with the air traffic controller or other members of the crew. This is often due to a noisy cockpit environment, attention diverted to another task, or inattention to radio traffic. Errors occur when operational requirements deem that a task be delayed yet remembered, e.g., deferred checklist items or altitude crossing restrictions. A simple analogy might be one of an automobile driver who has a number of letters to post, lying beside him in a car. He plans to post these letters at a box in a few short blocks, yet some matter of traffic diverts his attention and he passes the box. Pilots share a similar fate when they receive an altitude crossing restriction. Pilots are aware that the pilot flying can be easily distracted, and therefore additional verbal checks on the altitude crossing restriction are made between crew members to ensure it is remembered.

Speed is another characteristic that changes the complexion of cockpit operations. Increased speed reduces the time required to accomplish a task and imparts an element of urgency to decision making. The multiplicity of task demands during complex operations, such as takeoff, climb, descent, approach, or landing, creates pressure that can result in common errors.

The proliferation of warning systems, in even the most up-to-date jet, is a testament to this continuing problem. Warning systems have most recently been developed for landing gear, flaps, spoilers, terrain avoidance, and parking brakes. Some of the first warning systems developed early in aviation were for simple malfunctions of the powerplant, e.g., oil pressure or quantity, engine fire warning, or loss of hydraulic fluids.

Mistakes in the cockpit are related to the manner in which the complex task of flying is accomplished by pilots, as noted above. It may also be due to weather factors outside the cockpit or methods of aircraft operation recommended by the manufacturer and modified by the individual airline. During the investigation of an accident it is important to judge the complete environment of the cockpit. Task or cognitive saturation must be reviewed in light of the human limitations envelope.

The effect of adverse weather or night operations on the workings of the crew is a factor which few people recognize. Both of these factors limit the visual field both in and out of the cockpit. The number of accidents that occur during night flying and/or adverse weather are higher.[8] Using the instruments of an aircraft to judge position or height is not as natural to a pilot as being able to see outside the aircraft during daylight.

The personality of the crew or its captain may have an influence on the accident/incident. In these cases it important to judge not only the relationships in the cockpit but also the standard performance recommended or acceptable to the company. Institutional errors have occurred in the past and they must be judged carefully by the accident investigation authorities. Many changes in procedures occur as experience in operation of the aircraft continues. Some changes are not consistent with the design of the aircraft. Such an example may be cited in the case of the B767 electronic engine control (EEC) system. In the design and manufacture of the aircraft, the control for the EEC was placed near the fuel shutoff switches. A number of incidents occurred which convinced the government authorities and manufacturer that the EEC controls should be moved to a less accessible location. Misuse of the control by pilots was compounded by changes in procedures (its use as an operating control) that were never predicted by the designer.

<u>What can we learn about errors that occur in accidents?</u>

<u>NWA DC-9-82</u>

On August 16, 1987, a NWA DC-9-82[9] crashed at the Detroit Airport, resulting in the death of 148 passengers and 6 crew members. The NTSB cited the crew for lack of proper use of the taxi checklist during the pre-takeoff preparations. The investigation found that the wing flaps were retracted, which resulted in loss of control of the aircraft after takeoff. The takeoff warning system malfunctioned electrically and did not warn the crew of the flap condition. This malfunction was cited as a contributory factor by the NTSB.
The sequence of events leading up to the accident are notable:

1. Before departing the ramp, the crew discussed with ground personnel the fact that the flight needed to depart the ramp as soon as possible to make the landing curfew window at Orange County airport.

2. Some irrelevant conversation on the flight deck occurred during the taxi to the runway.

3. Due to construction a somewhat complicated taxi route was required.

4. The checklist was interrupted a number of times by the ground controller and the flight attendant.

5. The first officer had to consult a performance manual for takeoff information during taxi-out.

6. The taxi-out occurred during low light conditions after sunset.

7. A cockpit-to-cabin announcement was made to prepare the cabin for takeoff.

In spite of all that has been written about the failure of the cockpit crew and the warning system, were other factors present that contributed to the accident? We will just briefly review these other factors.

1. What role did the need to hurry to make a landing time play in the accident?

2. Under what conditions should a cockpit checklist be accomplished?

It is hard to predict what effect the need to expedite a departure played in the accident, but it certainly was present in the pilots' minds. The accomplishment of critical checklists while being constantly interrupted is an accepted practice, both while taxiing and during inflight operations. In fact, it is a method of operation that has been endorsed by government inspectors and company check pilots. In this case, were there too many distractions caused by cockpit cabin coordination, the need to review takeoff data from a manual, a complex taxi route due to construction, poor ambient light conditions, or the need to make a required FAA announcement just before takeoff? We will never have the answer, but more pertinent questions might be: *Is the crew at fault for allowing the distractions to interrupt the* important function of completing a checklist? Or who approved or expects the accomplishment of checklists during a time of movement of the aircraft? It was not too long ago, in the reciprocating engine era, that the checklist was accomplished after engine runup, while the aircraft was stationary. Who made the decision to accomplish checklists while the aircraft was moving?

Air Florida B737

The Air Florida accident in Washington, DC, on January 13, 1982 should also be noted in this context. Here an inexperienced captain was taxiing out of a congested area, in heavy snow, with poor visibility, while the first officer was accomplishing the taxi checklist. The captain was required to respond to a challenge-response checklist. What was so critical that the checklist needed to be accomplished right at that moment? Can habits become unsafe practices? Are training and check pilots taught to look for habits or procedures that are unsafe? Why did the captain not defer the checklist to a more appropriate time? Do we teach new captains to do this? Surely it is within the purview of the captain to make such a determination. What are the consequences of repeatedly hurrying the preparations for takeoff because a jet engine is almost ready for takeoff after leaving the gate? What habits are created by allowing all manner of interruptions or seemingly important additional duties to be imposed on the flight crew while making important preparations for takeoff? Is not the most important task to prepare the aircraft properly for takeoff? Who teaches new captains the proper order of priority of duties during flight operations?

Can accident investigation authorities look at these kinds of circumstances and place the responsibilities only on the flight crew, or should it go deeper into the actual and accepted institutional methodology of airline operational practices? The practices begin with the manufacturers and their published flight manuals. State authorities and the airline companies themselves make adjustments to fit their needs and oversee the process of integration of the aircraft into operations. Where does the role of management of flight operation begin and end? Can we expect that better training or more professional attention to duties for pilots will eliminate the human error accident? Should we expect acceptable behavior on one day to be altered the next day if circumstances change? What effect do habits have on performance?

"Herald of Free Enterprise"

The accident of the ferry "Herald of Free Enterprise" at Zeebrugge in 1988[10] should stimulate attention among aircraft accident investigators. Setting sail with the bow doors left open and an excessive nosedown trim, the vessel sank immediately with the loss of 180 lives. It was a hurried departure--so familiar to airline pilots--and the communication links within the crew were badly broken. The captain never knew the doors were open as no procedure was established to verify the doors were closed, nor did a warning light exist to warn the crew.

The investigation into the sinking of the "Herald of Free Enterprise" aimed at revealing the so-called "latent pathogens," i.e., those factors that were lurking within the operation. Factors such as organizational decisions and managerial practices were reviewed. The ferry left the dock at high speed because the captain was reminded of the fact that he was running late. Another factor was the failure to have procedures to determine if all the doors were closed and secured before getting under way. Yet another factor was the psychological precursors of crew composition. Only after an analysis of the latent pathogens were the individual unsafe acts and practices approached. As in many other accidents, individual acts or errors followed a whole set of institutional acts or errors.

Efforts to advance the management of errors

Errors will be with us as long we have humans operating equipment or humans designing machines. Rather than succumb to the philosophy of attempting to design the human out of a system, the designer or operator must look to the strengths of the human. The development of error-tolerant systems is one of the advancing philosophies in this regard. A notable effort in human error prevention has been undertaken by the engineering society and a foundation in the US.[11] These organizations have held conferences on human error avoidance that deal with the breadth of the cause of human errors.

Accident investigation techniques to isolate the cause of human errors in aircraft accidents have been slowly evolving over the past 10-15 years. A recent study[12] by the International Federation of Air Line Pilots' Associations (IFALPA) has indicated that just a few of the States surveyed have well-trained and dedicated specialists in human factors. It is essential to have well-trained and academically qualified staff to lead accident investigations. IFALPA believes these teams must be interdisciplinary. Disciplines such as psychology, human and safety engineering, medicine, as well as pilot operational skills, should be teamed together in the accident investigation process. Errors made by crew members are a subject of close scrutiny by accident investigation officials during the investigation of accidents or incidents. During this process it not uncommon to judge all errors as indications of incompetence or unprofessionalism. Pilots feel that errors are commonplace and should be recognized as such by investigators. The difference is that most errors are corrected or are not of sufficient magnitude to cause an accident. During an accident one critical error is usually preceded by a series of errors. The investigator must take a systematic approach to the evaluation of errors.

Flight operations management

Company practices and the corporate culture are starting to receive attention by accident investigation officials. Airlines have their own personalities and many of its pilots adopt these traits. An airline can be a battleground between management and union or, conversely, because their airline may be struggling for survival, pilots may believe that they must do whatever possible to make the airline a success. Usually these conditions are known by the managers, training, and checking personnel, but unless management is sensitive to them, serious erosion of safety standards may take place. During accident investigations these traits must be uncovered and carefully analyzed. The standard of safety begins in the corporate offices.

Organizational conflicts

Beyond those quite obvious examples we should also consider some subtle pressures to which pilots are subjected. In some very busy airports, in the south of Europe, it is an everyday practice to assign a takeoff slot with no more than a five-minute window. The penalty for missing a takeoff slot can be up to several hours of delay. Sometimes it is even necessary to send a planeload of passengers back to a hotel already accepting incoming guests. It is easy to see how a pilot's adrenaline would start to flow when delays are encountered due to baggage loading or a miscount of passengers occurs. Under these circumstances it is not unusual for a pilot to have to explain the problem to his chief pilot. Can we expect careful flight operations under these conditions? An accident that occurred under these circumstances would require careful evaluation of the conditions and possibly criticism by the investigating authorities of their own State's method of air traffic control.

Quality standards

Individual unsafe practices by pilots may be the subject of review during accident investigations. Pilots are critically aware of these unsafe practices and attempt to intervene in certain situations with professional standard committees. Generally, interpersonal relationships between pilots are the problems most often dealt with by these committees, but occasionally these committees deal with the standard of air safety. However, this is a vague and subjective concept certain to lead to many interpretations.

A curious standard is applied in judging cockpit or pilot behavior following an accident. Airline pilots feel the safety standard applied by investigative authorities in post-accident analysis is higher than the standard acceptable in routine practice to the airline or to the licensing authority. Recognizing that a safety standard is very subjective, pilots still need practical, unequivocal guidance from management.

The role of management in the safe practices of aircraft operations is rarely talked about. Accident investigation authorities throughout the world are attempting to understand management practices that influence safety and make airline managements accountable. Some courts already recognize the importance of management's role in accidents. In France, the court did recognize the role of management in the 1985 rail accident at Flaujac.[13] The court retained the concept of "a deficient safety system, since it does not integrate human failure".

Decisions by pilots

The question that haunts pilots following an accident is, "Could this happen to me?" In most cases pilots find themselves in the uncomfortable position of feeling that they could see themselves in the same predicament as the crew of the accident aircraft. When the accident has been caused to some extent by information that was lacking or confusing, other pilots have great sympathy for those who made errors born of lack of information.

Decision making by airline pilots is typified by quick and knowledgeable decisions where information is unambiguous and by purposeful indecision where information is incomplete or ambiguous. The decision to conduct a flight, continue toward a line of weather, or continue an approach to a landing is based on a lack of information that a danger exists rather than information that this is a safe course of action. Pilots will agree that being informed of a thunderstorm in progress at the airport, or being told of significant windshear on final, or seeing a radar return with a sharply defined echo ahead all are definite indications that a significant danger exists that would cause a pilot to alter his course of action.

Recommendations

For many years the aviation industry has been justly proud of its safety record and accident investigation tradition. Nowhere in the field of human technology have such indepth and advanced concepts and methods been used than in aviation accident investigation. However, we must guard against complacency.

The old-fashioned, time-honored, and well-established methodology of tracing *individual* human *faults and errors in* complex sequences called *accidents may* not stand the test of comparison when judged against a complete fault tree analysis such as applied in the investigation of the "Herald of Free Enterprise" accident.

To detect organizational or institutional error potential annual safety audits should be required by all States. The safety audit must reach into all departments that interact with flight operations, including upper level management. The State itself should provide annual audits of its method of *certification, oversight, and* communication.

IFALPA believes it is time to judge the individual act or error only as the trigger that enabled the accident to take place. Business, technical, or organizational decisions may contain the "seed" for characteristic types of failures that lead to unsafe practices and finally unsafe acts. To grow these *seeds, some type of psychological precursors need* to be *present.* All system *precursors (latent pathogens) must be identified. The search for the most* important error detracts from the overall investigation and narrows the investigation process.

If further progress is to be made in aviation safety, we face an enormous educational task that must be centered on issues affecting human factors in flight operations. All of us recognize that we have a monumental task in human performance optimization. But because the influences on human performance are many and subtle, we must guard against limiting our field of view by focusing on the final error. If we are ever to advance the frontier of human factors in accident investigation, we must work in interdisciplinary *groups with little regard for the boundaries of the investigation. If the* precursors of errors can be developed, we have a real opportunity to prevent not one but many accidents. The International Federation of Air Line Pilots' Associations stands ready to cooperate in this endeavor.

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BECOMING A CAPTAIN: PERSONALITY DEVELOPMENT BY NON-TECHNICAL TRAINING AND EDUCATION

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INTRODUCTION

KLM takes in about forty pilots every year from the RLS, the main Dutch flying school, which currently belongs to the Dutch government at the moment but will probably become a KLM flying school in the very near future. On graduation the ab-initio trainees have followed a 200-hour flying course at our school, including:

- 70 hours basic training on the Cessna 152;
- 90 hours advanced training on the Beechcraft B-33 Bonanza (including the IF Rating); and
- 40 hours final training on the Cessna C-500 Citation (including type-rating and route-training).

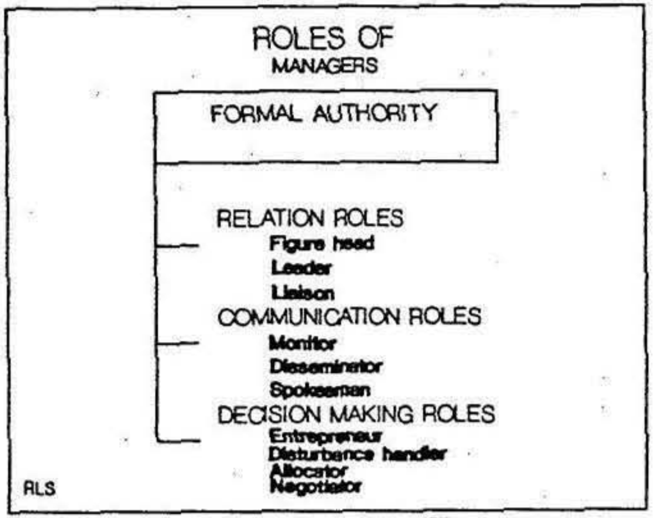
All flying training is supported by simulator training; since 1988 the school has had a glass-cockpit C-500 Citation simulator.

The crew training starts in the advanced phase with mutual flights and continues from then on. The RLS has a non-technical programme to support the crew-cooperation training, to enhance safety awareness and to stimulate personality development. This programme pays attention to communication, team building, decision making and leadership. Within both KLM and RLS there is concern to further develop non-technical training programmes and integrate these in the total flight training package.

TRAINING OBJECTIVE

Training and education, when successful, lead from the initial situation to the desired final situation. The initial situation is that ab-initio trainees of between 18 and 25 years of age enter the school after selection. Their capacities and personality growth potential have been assessed and they have been found medically fit for becoming pilots. The desired final situation is a position and career as an airline captain with KLM or another Dutch airline. What is an airline captain? He can be seen as a team leader in the cockpit environment, a special kind of "manager" with a specialized set of roles and tasks.

Mintzberg (1973) investigated the roles of many kinds of managers and reported the general scheme of managerial tasks as follows.



As a **figure head** the manager takes part in ceremonial activities because of his formal status.

The **leader** integrates unit objectives and personal needs of people. The leader keeps his people alert and motivates.

In his role of **liaison** the manager gathers useful information.

As a **monitor** he monitors his own unit and the environment, detects problems, risks and chances.

As **disseminator** he gives information (facts, preferences, values) to the people within his unit.

As a **spokesman** he gives information (results, explanations) to people outside his own unit e.g. higher management or the public.

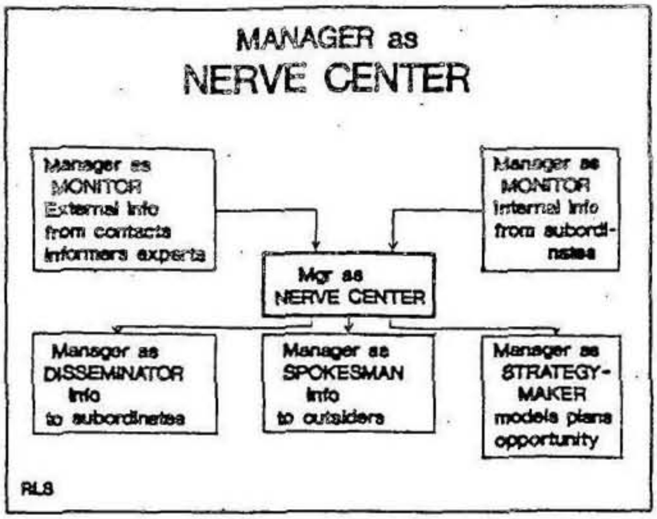
The **entrepreneur** initiates and designs change, sets goals.

As a **disturbance handler** the manager diagnoses a situation and threatening stimuli (internal conflicts, environmental threat, expected loss of resources). He solves problems and takes measures.

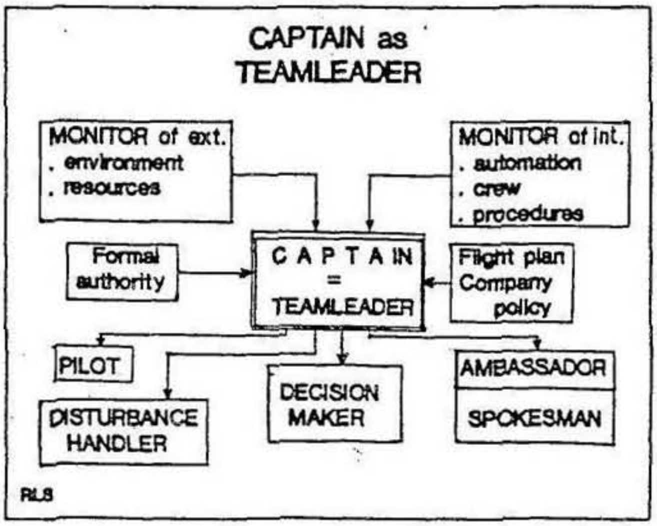
When a **resource allocator** he allocates time, people, and money to tasks; he chooses priorities, aligns and times decisions (=coordination).

As a **negotiator** the manager negotiates with other units or organizations

The manager is the nerve center of his unit.



In analogy to the above, the airline captain is the nerve center in the cockpit. His roles are as shown below (Droog, 1986).



Flight training, theoretical training and non-technical training are aimed at the preparation of the modern pilot for this set of roles and tasks. The captain leads his system (aircraft, crew, passengers) towards its destination in a safe, efficient and comfortable way. Training programmes are set up to increase his effectiveness, and consequently the effectiveness of the organization. Enhancing competence and effectiveness is the objective of every training. Under what conditions act organizations and individuals most effectively?

INDIVIDUAL COMPETENCE AND ORGANIZATIONAL EFFECTIVENESS

The core activities of any system are (1) to achieve its objectives, (2) to maintain control over its internal environment, and (3) to adapt to, and maintain control over, the relevant external environment. How well the system accomplishes these core activities over time, under different conditions, and in any given situation, indicates its competence and effectiveness (Argyris, 1973).

Argyris (1973) mentions a number of criteria that may be used to evaluate the effectiveness of a system. For example problems that are solved and decisions made without recurring when within the control of the system.He also identifies **conditions** causing individuals and groups to behave most competently. The more these conditions are approximated, the greater the probability that the individuals or groups will meet the competence criteria. The conditions for the individual are: self-acceptance, confirmation and essentiality.

Self-acceptance is the degree to which a person has confidence in himself and regards himself. The higher the self-acceptance, the more he values himself. The more he values himself, the more he will value others.

A person experiences **confirmation** when others experience him as he experiences his self. Confirmation is needed to validate one's view of one's self. Everyone experiences the world through his own set of biases and will tend to see only what his own self permits or encourages him to see. The possibility of error is therefore always present and this built-in potential for error creates a basic posture of uncertainty and self doubt and a tendency to inquire into the accuracy of one's perception or sense of reality. Hence the need for confirmation. The more frequent the confirmation, the greater the confidence in one's potential to behave competently.

Essentiality means that, the more the individual is able to use his central abilities and express his central needs, the greater will be his feelings of essentiality to himself and the system. The more essential he feels, the more committed he will tend to be to the system and to its effectiveness.

One of the most effective ways to help individuals increase their self-acceptance, confirmation, and essentiality is to create conditions for **psychological success**. Psychological success occurs when:

a) the individual is able to define his own goals;
b) these goals are related to his central needs, abilities and values;
c) the person defines the path to these goals; and
d) the achievement of the goals represents a realistic level of aspiration, which means a challenge or a risk that requires hitherto unused, untested abilities.

Behaviours contributing to interpersonal and technical competence are:

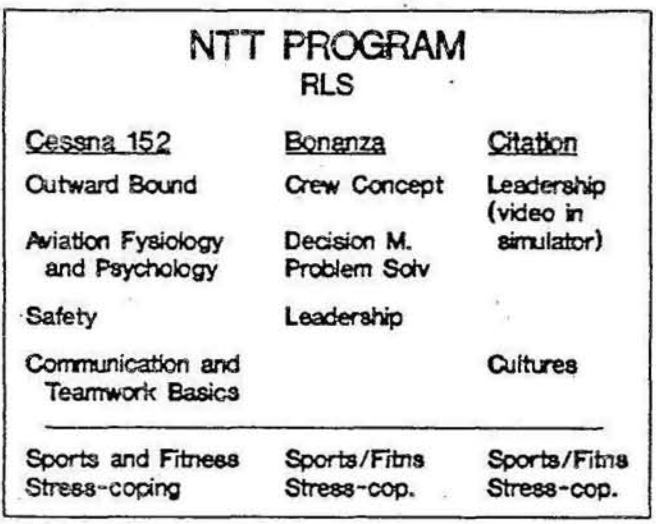
- being open to ideas and feelings of others and those from within one's self;
- experimenting with new ideas and feelings, and helping others to do so;
- stimulating these behaviours in such a way that one contributes to the norms of:
  * individuality (beside conformity),
  * concern (instead of competition), and
  * trust (instead of mistrust).

Groups increase their effectiveness to the extent that the leader and the members facilitate the above mentioned conditions, behaviours and norms. This is best done by (1) shared leadership, (2) reduction of the gap between leader and members, (3) attention of the group members to the group processes to reduce blocks, and (4) group members expressing their concern for the effectiveness of the group whenever they feel this is necessary.

The above mentioned conditions are the philosophy behind the RLS non-technical training programme.

NON-TECHNICAL TRAINING WITHIN RLS

A non-technical training programme will be most effective when it is integrated with pilot training. Themes which need attention should be spread out over the total time available and be dealt with at moments that the student pilot needs them most. Problems and conflicts in the human factors field, experienced by the young student pilot in the course of his training, must be taken into discussions and practices.



NTT PROGRAM
RLS

Cessna 152	Bonanza	Citation
Outward Bound	Crew Concept	Leadership (video in simulator)
Aviation Fysiology and Psychology	Decision M. Problem Solv	
Safety	Leadership	
Communication and Teamwork Basics		Cultures
Sports and Fitness	Sports/Fitns	Sports/Fitns
Stress-coping	Stress-cop.	Stress-cop.

The beginning of flight training (Cessna 152) is mostly individually oriented. The central themes of training are: learning to control the aircraft, learning the basic rules and procedures, and the building up of self-confidence and safety awareness.

Then, in the advanced training (Bonanza BE 33), the crew-coordination and crew-cooperation come into focus.

In the final training (Cessna Citation) the problems of flight organization, flight planning, anticipation and captaincy on a twin-engine jet aircraft must be mastered.

Outward Bound training (5 days)

A "take off" training in a totally unknown, non-flying environment. Themes: learning to know each other, self-confidence mutual trust, teamwork problems, leadership, communication.

Aviation physiology and psychology (briefing and number of lessons)

Themes: respiration, blood circulation, effects of altitude, human information processing, senses, disorientation, memory, stress, fitness, body rhythm, fatigue.

Safety (1 day, lesson and discussion)

Themes: stick to the rules, hazardous thoughts, human error, risk attitude questionnaire.

Communication and teamwork basics (2 days)

Themes: sender and receiver, active listening, blockings, multiple messages, team roles and team positions.

Crew concept (initial briefing by instructors and psychologist) (4 hours)

Themes: division of tasks and coordination, responsible captain and supporting F/O, explicit intentions, speaking up, cross-checking, crew-briefing and mutual agreement, check-lists, calls, acknowledgements, trans-cockpit authority gradient, timing, working styles, personality differences.

Problem solving and decision making

Themes: foreground/background problem, choice, conflict and stress, values, team decision-making processes, creativity in the cockpit environment.

Leadership

Themes: organizations, team leadership, motivate, how to say things effectively and respectfully.

Followed by taking video's during Citation training and discussion of these.

Cultures (2 days)

Theme: meeting people of other cultures.

CONSEQUENCES FOR MANAGEMENT

The task of the management of the RLS will be to stimulate programmes which (a) lead to integration, (b) contribute to psychological success of groups and individuals in the organization, and (c) contribute to the norms of individuality, concern and trust among groups in the school organization. For example the Flying Training Division pays attention to standardization and the regular evaluation of the flying training programmes by interviewing the student-pilots.

THE PSYCHOLOGIST

The psychologist may have multiple roles in the organization: trainer, supplier of Human Factors information to instructors and other staff, interventionist, counsellor of individual student pilots etc. He may benefit from the intervention methods of Argyris (which is not "selling" or "telling what is good for them" but a really interactional approach) in getting the commitment of the staff and the student pilot for a Human Factors programme.

CONCLUSION

The student pilot, being "in the loop" of a technical, social and economical system after two years of training, will benefit from knowledge and skills in the social and organizational field. The effects of non-technical training must be that a basis has been made for being open to others, independent judgement and thinking, the ability to express himself, a broader scope and outlook on life, role-awareness and skilful leadership.

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DESARROLLO DEL PROGRAMA DE FACTORES HUMANOS EN LA REPUBLICA ARGENTINA

R. Rubio

Demás está decir que reconocemos la insidencia de los Factores Humanos en la seguridad de vuelo y por ende nos preocupa como hacer para generar los cambios de conducta necesarios en los dirigentes, en los instructores y las tripulaciones para mejorar nuestros niveles de seguridad.-

Cuando escuchamos los distintos conceptos, que sobre estos temas, se sostienen en los países más avanzados en la materia, donde se teoriza sobre detalles que hacen al todo en este magnífico camino que es ir de lo particular a lo general, nos damos cuenta cabal que realmente estamos ante un cambio de actitudes.-

Creemos que en Argentina el problema no es muy diferente que en el resto de América Latina. De todas maneras, nos referimos exclusivamente a lo que nos concierne y, dentro de nuestro país a su hasta hoy Línea de Bandera : Aerolíneas Argentinas.-

Trataré de hacer aquí una breve reseña de nuestro acercamiento al tema que nos ocupa, para ello debemos remontarnos a fines de 1978, para esa época nuestra compañía sufrió una expansión que en breve tiempo prácticamente duplicó la cantidad de tripulantes técnicos y esto nos obligó a pensar y a preocuparnos por temas antes desconocidos y que podríamos resumir en lo siguiente:

1) Como analizar las capacidades para el comando en situación de crecimiento explosivo. Hasta ese momento solamente teníamos en cuenta los recambios vegetativos producidos por un mínimo de jubilaciones y de separaciones médicas.-

2) Como hacer para seleccionar, incorporar y formar profesionalemente a los nuevos tripulantes sin tener una infraestructura adecuada, en lo técnico, y si bien contábamos con un excelente nivel profesional en los instructores, no teníamos instrumentado el sistema y los procedimientos de trabajo ni actualizadas las técnicas de la instrucción.-

3) Y por último, como hacerlo pensando en el futuro.-

No se nos escapa que hemos vivido aislados del mundo durante mucho tiempo, pero el hecho de no contar con recursos humanos, elementos técnicos e infraestructura en cantidad suficiente, hizo que fuera necesario concurrir a Centros de Instrucción en el extranjero donde vimos reflejadas nuestras mismas inquietudes, y nuestros mismos problemas, también observamos que en muchos casos ya se estaban instrumentando soluciones. Vimos y aprendimos qué se hacía en el mundo. Mientras tanto, en nuestro país vivíamos un autoritarismo que no permitió organizaciones gramiales, y de hecho intervino los gremios aeronáuticos, más tarde participamos en acciones bélicas, saltamos luego a una democracia que instauró en Aerolíneas Argentinas una conducción que no sabía absolutamente nada del negocio aéreo pero sí mucho de política, y se dedicó a eso, hacer política hasta tal punto que en 1986 desembocamos en una muy dura huelga de casi 30 días que provocó despidos y reincorporaciones, y donde todos perdimos; a continuación, Argentina entra en una profunda crisis económica con hiperinflación de la cual no podíamos estar al margen, en esos tiempos tuvimos el primer intento de nuestro gobierno para vender nuestra compañía. Actualmente estamos inmersos en otro intento de licitación a nivel internacional para que sea privatizada en un 95% antes de fin de junio del presente año.-

No está en nosotros dar ningún tipo de opinión o juicio de valor sobre las medidas tomadas, menos aún sobre sus causas, sí sabemos que se ven algunas consecuencias. A los que de alguna manera saben de los temas referidos a la salud física y mental de las personas, no les escapará que la situación no era, ni es, la mejor para garantizar la seguridad aérea, no en vano en los últimos 4 años hemos tenido cuatro accidentes graves y varios incidentes, en los cuales afortunadamente no debemos lamentar pérdidas de vidas, pero sí, pérdidas totales de un Boeing-737 y un Fokker F-28 y daños materiales en otras aeronaves.-

Hasta el año 1987 todo lo que se hizo en lo referente a conocimiento sobre la incidencia de los factores humanos en la seguridad y en el desarrollo de nuevas técnicas de instrucción fue producto de grandes esfuerzos, hecho por personas aisladas y con grandes dificultades en la continuidad. Recién a fines de ese año, se crea la Comisión de Desarrollo Profesional, a la que concurrían las Gerencias del Area de Personal y la del Area Operativa conjuntamente con la Asociación de Pilotos de Líneas Aéreas, y desde allí, de alguna manera se comenzó a unir los esfuerzos individuales en un objetivo común. Esfuerzo que llevaron adelante las distintas Jefaturas de Línea, de pilotos como Daniel Mauriño que sembró y mucho en todo lo concerniente a C.R.M., de Jorge Prelooker en lo que a Medicina y Fatiga de vuelo se refiere, a lo que algunos médicos de nuestra Fuerza Aérea, de la Asociación de Pilotos, y de la Empresa Aerolíneas Argentinas insinuaron al amparo de un luchador como Silvio Finkelstein desde la OACI.-

Y se empezó a gestar un cambio.-

Fuimos convocados al amparo de un Proyecto Regional de OACI (el RLA/86/031) y pudimos conocer el programa C.R.M. en varias versiones en inglés y una en español, fuimos a Australian Airlines y a System One, nos comunicamos, leímos y estudiamos, totamos lo que existe en común y analizamos hasta donde son necesarios los objetivos propuestos o donde están nuestra diferencias.-

Fue así que durante el año 1988 comenzamos a realizar Seminarios de Introducción a los Factores Humanos. Llevamos a cabo ocho en total donde los participantes en su gran mayoría fueron voluntarios con el objetivo de acercamiento a la problemática general y difusión de la idea más que con el intento de que allí pudieran surgir soluciones.-

Mientras tanto se creó un Laboratorio cuya misión era estudiar e investigar, el cual progresó al amparo del entusiasmo de los profesionales más que de las posibilidades económicas, y que espulgó lo que estaba en el mundo de manera de ir creando nuestro propio curso. Este Laboratorio está compuesto por 3 Psiquiatras, uno de ellos Presidente de la Asociación Psicoanalítica Argentina - ex Presidente de la Asociación Psicoanalítica Latinoamericana, 1 Sociólogo del Area de Personal, 1 Especialista en Educación a distancia, 1 Psicopedagogo, Auxiliar de a Bordo y varios Comandantes, Copilotos y Técnicos de Vuelo.-

A esta altura no estaría de más decir que no nos sentimos distintos, solamente intentamos poner la inteligencia al servicio de nuestras necesidades. Y es por ello que estamos seguros que la aproximación del piloto a este programa, es diferente cuando se plantea una situación socioeconómica, de la gravedad que existe en nuestro país, concepto que sí se puede extender a otros países de Latino América.-

Y esto lo decimos porque no nos sentimos totalmente identificados con los programas existentes, así que nuestro Laboratorio fue elaborando un programa que, si bien básicamente apunta a los mismos objetivos que se plantean en los programas que se desarrollan a través de O.A.C.I., y de otros organismos o líneas aéreas, lo tratamos de adaptar a nuestras propias necesidades.-

En nuestros seminarios, hemos dado un especial énfasis a los Grupos Operativos para la determinación fehaciente de la problemática general y nos hemos encontrado con resultados tales como:

a) No hemos terminado ideológicamente con la huelga del año 1986, donde se subvirtieron valores relativos a la autoridad formal e informal.-

b) Todavía se cree, en algunos sectores, que implementar mecanismos de verificación y control de las tripulaciones basta para superar todos los problemas y no se llega a lo profundo e individual sobre todo en las investigaciones de incidentes y accidentes.-

c) Es extremadamente lento el cambio, sobre todo por falta de poder económico y al miedo de perder posiciones en la administración.-

Nos dimos cuenta que debía existir un mayor programa de divulgación y Concientización de las tripulaciones, pero ello va de la mano de la autoridad de turno. Así que, después de un duro primer semestre del año 1989, en el segundo se destrabaron las limitaciones impuestas y se pudo terminar con el Curso de Factores Humanos, que pusimos a consideración del Comandante Daniel Mauriño, y a través de su crítica y nuestras propias conclusiones hemos corregido algunos errores, y seguramente encontraremos más en el futuro, producto de lo que creemos debe ser una evolución constante con mente siempre abierta a la crítica y a las nuevas ideas. Hoy creemos estar listos para ofrecerlo a Latinoamérica, para avanzar en un programa común.-

Hemos comenzado la programación del presente año con un Seminario que se dictó los días 28, 29, 30 y 31 de Marzo teniendo previsto cursos mensuales durante el primer semestre, un mes de análisis en Julio y posteriormente, es nuestra intención, hacer dos cursos mensuales durante el segundo semestre.-

Tenemos fechas previstas para la revisión de los LOFT y su implementación en base a criterios uniformes de aplicación de los mismos. Tenemos claro que el instructor es la pieza clave para ello y su formación resulta indispensable.-

Hemos previsto, y se fijarán los alcances, de un plan de divulgación de todo lo referente a Factores Humanos, como así también el recolectar lo referente a accidentes e incidentes y su posterior análisis.-

Se está analizando el reciclado de los cursos de Factores Humanos y el como ir cuantificando los cambios de actitudes.-

Para ello deberíamos:

a) Mantener el Laboratorio y su grupo profesional y hacer que el resto de Latinoamérica intervenga en el mismo.-

b) Poder lograr aportes, sobre todo con informes de incidentes y accidentes.-

c) Incrementar los cursos a nivel latinoamericano pidiendo que OACI y AITAL (IATA) den a través de sus programas, ayuda efectiva para llevarlos adelante.-

d) Concientizar a las Autoridades.-

e) Organizar seminarios para recibir, nosotros, información. A ellos trataremos de invitarlos y deseamos que puedan asistir.-

Confiamos que pueda liberarse de trabas el proyecto de OACI RLA/86/031, dado que si ello ocurriera podríamos contar con una ayuda más efectiva para este programa, o que podamos acceder a algún otro implementado o a implementarse, lo que nos permitirá incrementar el intercambio (hoy sólo con México y Brasil dentro del proyecto precitado) y que sería de ayuda para toda Latinoamérica, unificando los proyectos individuales de cada país en un ente integrador que daría mejores resultados y una mejor consistencia al esfuerzo.-

Nuestro planteo futuro es tender a que concurran a nuestro Curso de Factores Humanos, todo aquel personal que directamente (caso de los Pilotos e Ingenieros de Vuelo) o indirectamente, estén involucrados con la operación del avión y efectuar, además, un reciclado de los mismos. Suponemos que podremos recibir 240 alumnos durante el presente año y tener una meta de 2000 en cinco años. Si a esto le unimos un plan de divulgación y descentralización de cursos podemos incrementar geométricamente las posibilidades de lograr que el total del personal argentino y los que se adhieran de Latinoamérica estarían en condiciones de afrontar un cambio de actitudes ante el avance de una industria en constante cambio.-

Para terminar quisiera que estén seguros de que hemos tomado conciencia de los alcances de este programa, por lo tanto intentaremos alcanzar objetivos que podemos sintetizar de la siguiente manera:

1) Propiciar un cambio en la formación de futuros pilotos desde su inicio en la aviación y su posterior seguimiento, en base a perfiles prefijados, teniendo en cuenta los objetivos de la aviación general y de la línea aérea.-

2) Aunar esfuerzos con los organismos nacionales y los de todas las naciones que componen Latinoamérica a fin de minimizar los costos y solucionar problemas futuros.-

Y por último,

3) Concientizar a la industria en el orden mundial a fin de que asuman que, los aviones que hoy y en el futuro estén tanto en el aire como en tierra, pertenecen a todos los MUNDOS ECONOMICOS.-

MUCHAS GRACIAS

Use of Magnetoencephalography (MEG) and Electroencephalography (EEG) in Processes of Selection and Training of Air Traffic Controllers

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Abstract

Low success rates in the selection and training of air traffic controllers (ATCs) are a concern for aviation safety in light of predicted shortages of these operators over the next decade. Any meaningful attempt to solve this problem will require that procedures and instruments used in these processes are highly related to skills required on the job. However currently used aptitude tests and training performance criteria do not have high predictive validity, this suggesting that on-the-job skills are not yet adequately defined. This paper describes an approach, using MEG/EEG and an information-processing time line model, which may have greater sensitivity to elements underlying skills and, hence, be useful in generating aptidue tests and training criteria with greater performance predictability. Additionally, the approach appears capable of developing remediation capability that could help to increase the yield of ATCs from an original set of applicants. It is suggested that research carried out now with these techniques would help pave the way for efficient selection and training processes as automation proceeds.

Introduction

It is a well known fact that the success rate in processes of selection and training of air traffic controllers (ATCs) is exceedingly low. The statistics for Canada (Cote, 1990) appearing in Table 1 are certainly far from encouraging. Of approximately 25,000 applications for training, about half show up for an initial aptitude test - a Canadianized version of the Multiplex Controller Aptitude Test (MCAT) - and, of these, about 6,000 obtain the pass mark of 70%. Another 500 are then screened out, this leaving 5,500 which are interviewed on the basis of both personal suitability and proficiency in simulated decision-making exercises. Only about 600 of those interviewed are successful, and further considerations reduce this number to 312 who enter training each year.

Among trainees, some who are successful in the classroom fail during exercises in a simulator, so that only about half go on to on-the-job training. Here, the success rate for those assigned to control towers is about 80%; however only about 50-60% of those assigned to radar control centres are successful (Cote, 1990). According to Cote, Canada has a shortage of 300

Table 1

Statistics for Canadian Air Traffic Controller Applicants and Trainees (Cote, 1990)

Selection Process	
Applicants per year	25,000
Show for aptitude test	12,500
Pass aptitude test	6,000
Interviewed	5,500
Pass interview	600
Accepted for training	312
Training Process	
Pass class/simulator	156
Pass on-the-job training	
- area control centres	50-60%
- control towers	80%

ATCs today and, based on the Transport Canada Air Traffice Services human planning model, no improvement is expected until at least 1996.

While it is true that automation may eventually reduce the numbers of ATCs required (Rodrigue, Proulx, MacDonald, & Blair, 1989), efficiency of selection and training processes will result only if relevant performance assessments have high validity. Yet current psychometric techniques for isolating and measuring the special skills required for ATC operation are not sufficiently sensitive for accurate prediction of either training or on-the-job performance. Manning, Rocco, and Bryant (1989), for example, have shown that the MCAT used for selection of training candidates correlates with radar training at only .17 and at only .03 with tower cab training. Hopkins (1988) calls for better quantification of training assessment criteria that are highly valid predictors of on-the-job effectiveness and urges that the full range of skills required under an automated system be identified. Referring to results of a task analysis, Phillips (1988) points out that implementation of the first system of the Advanced Automation System (AAS) will bring about changes in 136 ATC task elements. On balance, then, a first step toward assuring a high success rate among ATC applicants is research leading to identification of the skills ATCs actually use on the job and, ultimately, to fresh psychometric approaches to selection and training.

A second factor affecting the success rate of trainees is that there is currently no means of developing or upgrading identified skills in those who do not possess them innately, or who possess them only to an insufficient degree. Exploratory work to develop such potential, in line with Hopkins' (1988) recommendation that it is essential for the ATC system of tomorrow, could result in a method of greatly increasing the yield of ATCs.

This paper explains how a new technique, combining use of magnetoencephalography (MEG) and electroencephalography (EEG) with an information-processing model, might be used to address these issues in the research recommended above.

The Information-Processing Time Line

To understand the roles of EEG and MEG in the approach to be described, it is necessary first to explain the information processing model. This model, which is the theoretical basis of ergonomics, holds that human responses to external situations are determined by the flow of information through the brain (Sanders & McCormick, 1988). Moreover it is generally agreed that several stages of processing intervene between the impact of stimulus energy on a sense organ and the emission of an overt response. These stages include, but are not limited to the following:

- detection of the stimulus
- sensory persistence, during which an image of the stimulus remains for a very brief period in some sort of storage system
- storage of some neural transformation of the image in short term memory (STM)
- update of long term memory (LTM) where all experience is classified and stored
- recognition of the form of the stimulus
- interpretation of the stimulus
- decision regarding an appropriate response
- preparation of an overt response

Figure 1, summarizing these sensory, perceptual, and cognitive events, implies that the process is not linear but rather one involving a good deal of interaction between information-processing components and, further, that the processes are influenced by other factors such as motivation and the general state of arousal of the brain.

This model suggests that, in measuring performance on the job as well as in selection and training processes on the basis of external responses, a great deal of information about how the applicant or trainee is coping with the stimulus situation is being missed. It can be reasoned that, with knowledge about what is happening at the various stages of information processing, it would be possible, first, to determine how experts are performing in various ATC-related tasks and, hence, to obtain more precise information about the skills involved. It would then be possible (a) to determine the precise nature of an applicant's or trainee's difficulty, if any, in performing such tasks. (b) to design remedial exercises precisely geared to that difficulty, and (c) to monitor improvement. Subsequent sections of this paper attempt to show how EEG/MEG techniques can assist in obtaining this type of detail.

Use of EEG and the Information-Processing Time Line

The term "EEG" is used rather loosely here. To be precise, EEG refers to the measurement of the overall state of the brain, that is, of its continually changing responsiveness to input, including the interaction of that input with existing perceptual, cognitive, and memory states. Superimposed on this spontaneous activity are evoked potentials (EPs), these representing electrophysiological changes that take place as the result of exposure to some stimulus situation.

Computer averaged signals for EPs are obtained by applying electrodes to certain sites on the scalp and passing the wires through an amplifier to a computer. The pattern of these and other brain responses obtained in this way is so typical that the EPs can be labelled. For example, in Figure 2, the peaks labelled P100, P200, and P300 represent positive activity occurring at, respectively, 100, 200, and 300 msec after introduction of a stimulus. Because of this feature, EPs can be indexed to events on the information processing time line. Examination of the amplitudes and latencies of these wave forms for an ATC expert during performance of a set of control-related tasks would produce detail regarding the types of sensory, perceptual, and cognitive components of skills not available to the observer of only overt behaviour. Moreover, the nature of the variability among experts with respect to these skill components could be more accurately defined, and this would give an indication of the extent to which ATC expertise is not a unitary concept, as is assumed now (Hopkin 1988) in the practice of training to standard. This information could lead to development of aptitude tests and training criteria that would have high predictive validity. Electrophysiological output for an applicant or trainee could then be compared to normative data in order to assess how that individual is managing the processing of information, and to pinpoint where on the information processing time line his/her difficulty (if any) lies. It would then become possible to design cognitive retraining exercises that are tailored exactly to the difficulty in question (eg. detection of the stimulus, memory updating, form recognition, decision-making, response preparation, or whatever).

Additional Information with Magnetoencephalography (MEG)

A counterpart of the the EP is the evoked field (EF) which can be measured with MEG. The relevant apparatus, unfortunately cumbersome at this point in time, consists essentially of a gantry system supporting a large dewar containing superconducting sensors, a noise balancing system, and liquid helium which cools the superconducting materials to room temperature. Figure 3 shows the gantry system while Figure 4 presents a schematic drawing of the dewar for a 20- to 60-channel system which is now being developed by CTF Systems Inc., Vancouver, B. C., with the assistance of funding from the Defence and Civil Institute of Environmental Medicine and the Transportation Development Centre.

Unlike volume currents, magnetic fields are not smeared as they pass through the brain, skull, and scalp. Thus EFs, which result from the electrical fields that are producing the EPs, provide an undistorted signal and, therefore, generate even more accurate information than do EPs about what is happening in the brain along the information-processing time line. This property of magnetic fields also enables more accurate source localization than is possible with EEG signals. Knowledge of which parts of the brain are responsible for less-than-optimal performance facilitates prediction about future performance. Moreover it provides information that enables an evaluator, perhaps wishing to do follow-up tests outside the MEG laboratory, to use a very small number (perhaps one to three) of accurately placed electrodes. For these reasons, a combined MEG/EEG approach is recommended in order to obtain the maximum amount of information regarding operator performance.

Validity of the Approach

Weinberg (1987) used MEG/EEG techniques to study visual discrimination and categorization of targets moving across a screen with different probabilities, a task very similar to that performed by ATCs at radar centres. Currently, he and his associates at Simon Fraser University, Vancouver, B. C., are successfully using this technology to assess the extent of loss of perceptual and cognitive skills in brain-damaged individuals, as well as to design relevant cognitive retraining exercises (Weinberg, 1989). Figure 5 outlines the full program of MEG/EEG research that is underway at the U. S. Navy's Personnel Research and Development Centre in San Diego, California, where early findings (Lewis, 1983) are to the effect that biomagnetic data appear to be more sensitive to individual differences than either EP records or paper-and-pencil tests and, hence, may offer greater predictability of on-the-job performance. Lewis (1989) has also shown event-related potentials (ERPs) to be related to success in aptitude indices, sonar operator simulator performance, pilot and radar intercept officer performance, decision making and workload, and other operator behaviours.

Conclusion

The foregoing suggests that MEG/EEG approaches could be used profitably in research regarding both selection and training processes. It would be necessary to begin with a group of ATC experts in a study attempting to identify and define the nature of their skills, and to determine the extent of variability among these subjects for the identified skills. In addition to establishing the basic criteria for training processes, these normative data could also be used as a baseline for comparing the performances of both applicants and trainees. In both cases, the technique appears to offer the possibility not only only of making more accurate diagnoses of an individual's performance difficulties than is possible by making inferences from overt responses but also, and in turn, of designing cognitive retraining exercises that are precisely tailored to that individual's difficulties. It is suggested that, in sum, use of MEG/EEG techniques could lead not only to aptitude tests and training criteria with greater predictive validity but also remediation capacity and, thereby, to an increase in the yield of ATC applicants.

Acknowledgments

The use of MEG/EEG with the information-processing time line model is attributed to Professor H. Weinberg, Brain Behaviour Laboratory, Simon Fraser University, Vancouver, B. C., Canada. His invaluable assistance in writing this paper is sincerely appreciated. (Thanks are due also to R. Cote, Air Traffic Services, Transport Canada, for his help in providing statistics and other information.) The efforts of D. Iwanycky (TDC) and her staff in preparing visual material are also gratefully acknowledged.

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INFORMATION PROCESSING MODEL

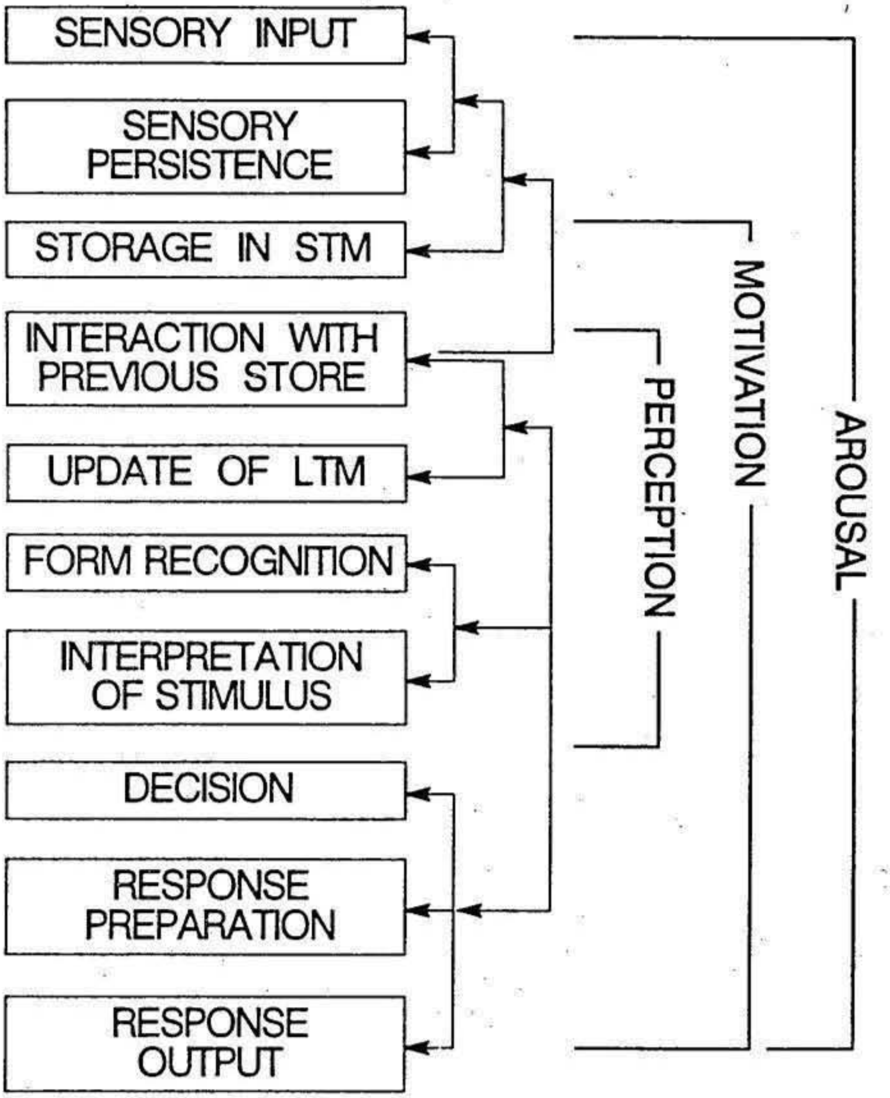


FIGURE 1

IDEALIZED WAVEFORMS OF HUMAN EVOKED POTENTIALS

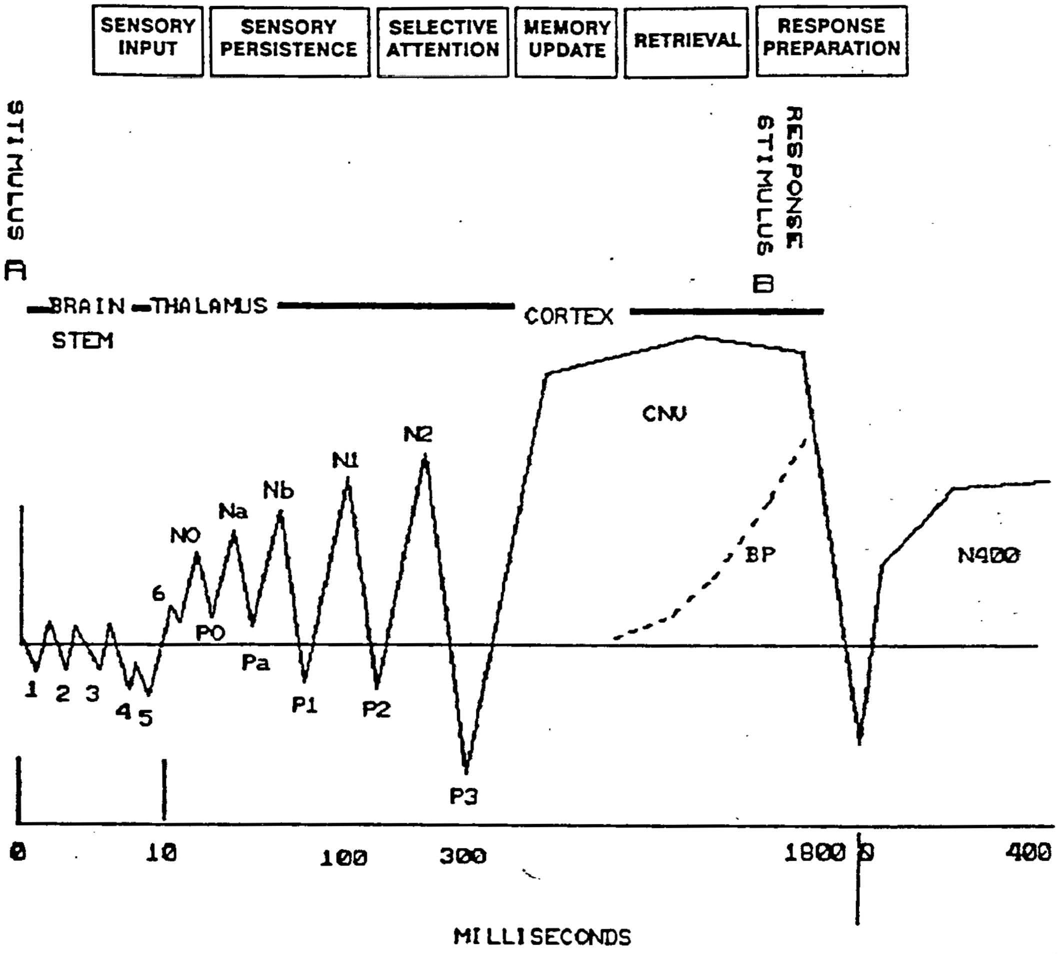
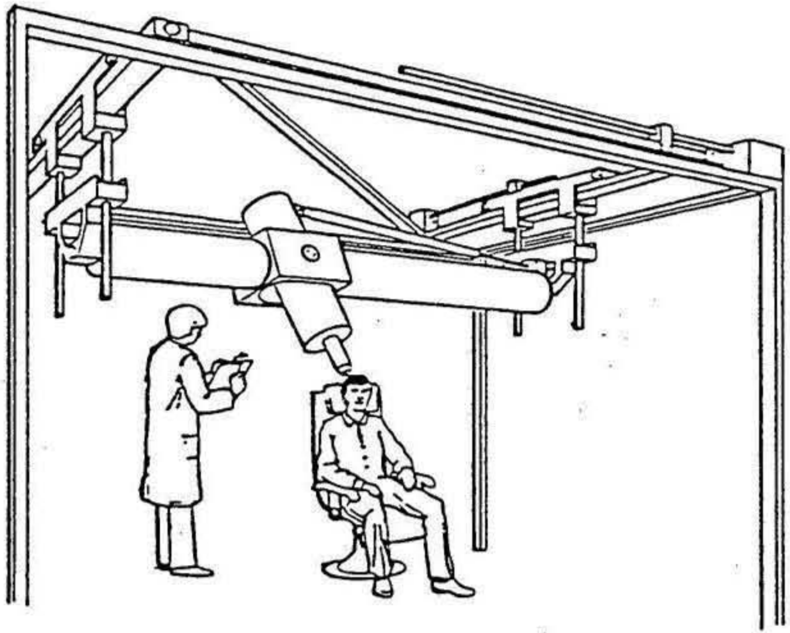
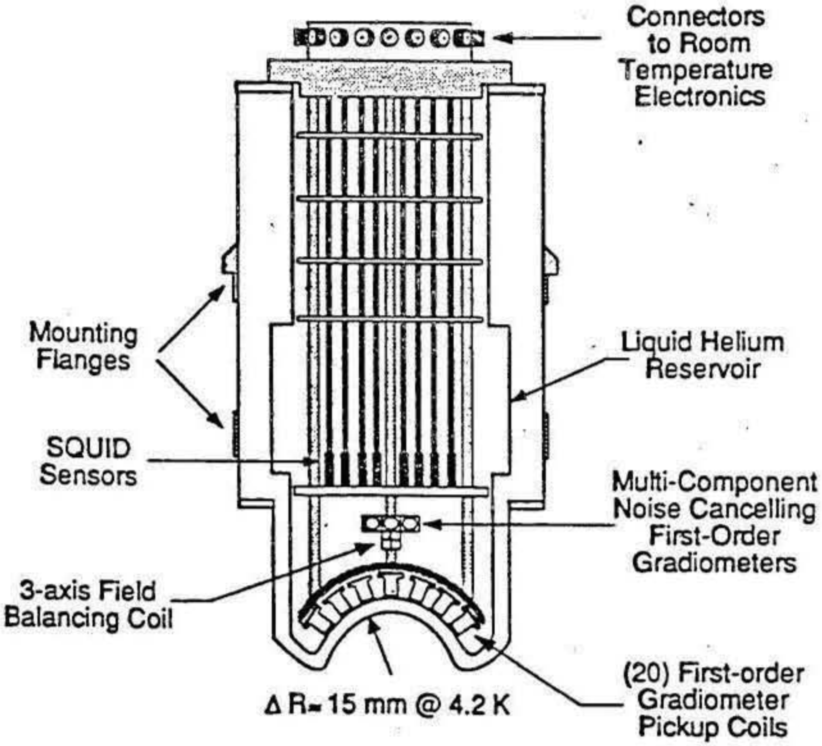


FIGURE 2



ARTIST'S RENDITION OF THE MECHANICAL GANTRY FOR MANIPULATION OF THE BIOMAGNETIC DEWAR AROUND THE SUBJECT'S HEAD

FIGURE 3

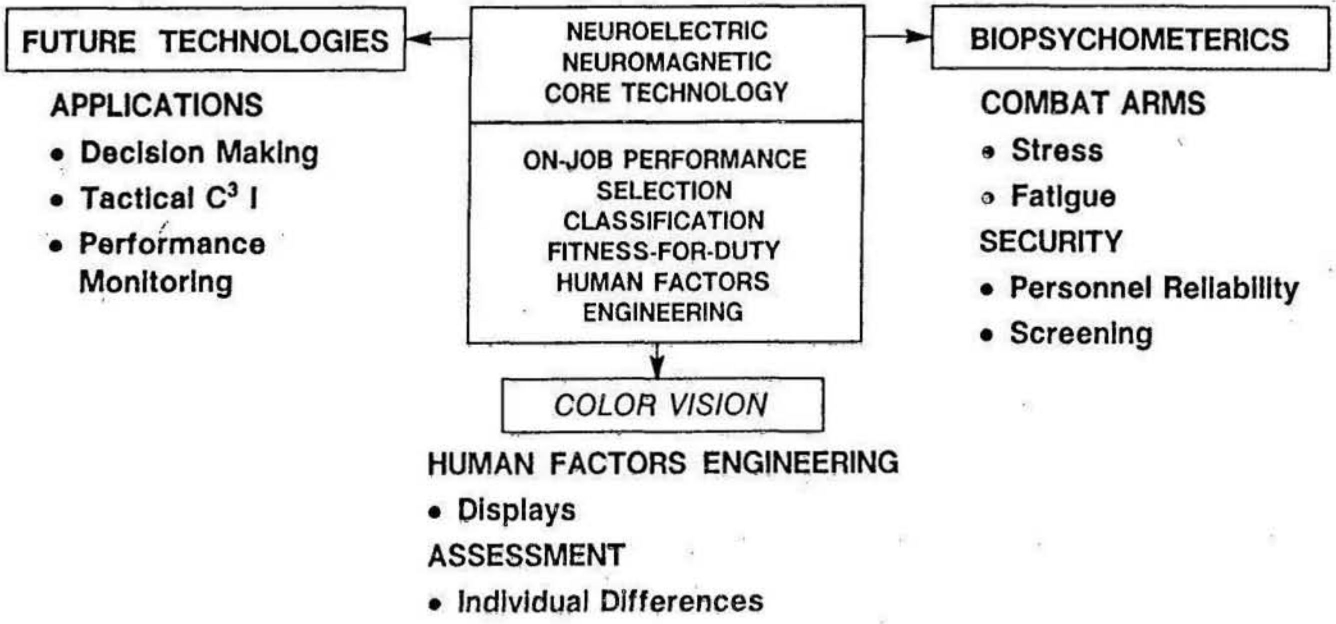


SCHEMATIC DIAGRAM OF HEMISPHERICAL TIP DEWAR WITH A POSSIBLE IMPLEMENTATION OF A 20-CHANNEL FIRST-ORDER GRADIOMETER ARRAY AND ENVIRONMENTAL NOISE CANCELLATION SENSORS

FIGURE 4

U.S. NAVY PROGRAM INCORPORATING BIOMAGNETIC RESEARCH

NPRDC
NEUROSCIENCE PROJECTS OFFICE



NEUROELECTRIC
NEUROMAGNETIC
CORE TECHNOLOGY

ON-JOB PERFORMANCE
SELECTION
CLASSIFICATION
FITNESS-FOR-DUTY
HUMAN FACTORS
ENGINEERING

FUTURE TECHNOLOGIES

APPLICATIONS
- Decision Making
- Tactical C³ I
- Performance Monitoring

BIOPSYCHOMETERICS

COMBAT ARMS
- Stress
- Fatigue

SECURITY
- Personnel Reliability
- Screening

COLOR VISION

HUMAN FACTORS ENGINEERING
- Displays

ASSESSMENT
- Individual Differences

FIGURE 5

Appendix

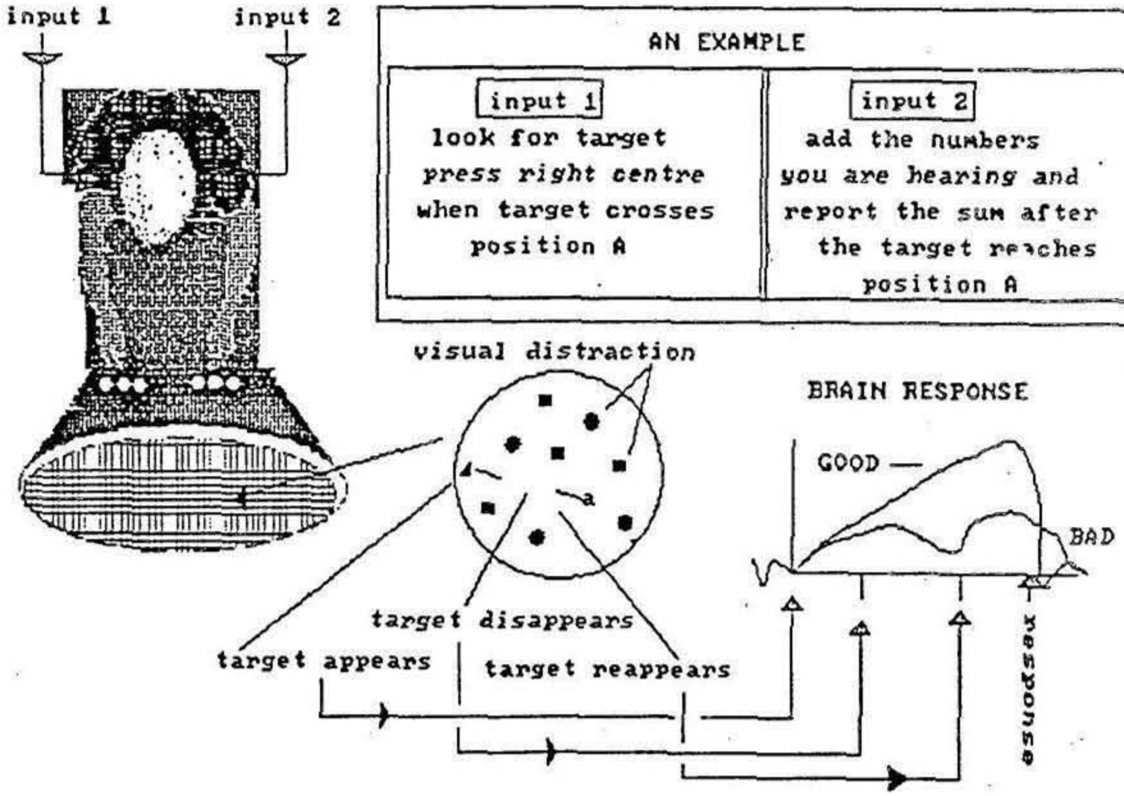
An Illustrative Example

Figure A1 illustrates how data might be collected and interpreted in an experimental paradigm that mimics one of the tasks carried out by ATCs in radar control centres. The subject on the left faces a circular screen across which a target stimulus (a triangle) appears, disappears, and reappears at different intervals. He/she is required to give a push-button response each time the target appears on the screen and, at the end of a sequence, to trace its trajectory. The task can be made more difficult (i.e. more complex) by adding distracting stimuli to the screen (squares, circles, etc.) which can be either static or moving; the more similar to the target stimulus, the more distracting are these additional stimuli. Difficulty can be further increased by including an additional (secondary) task: the illustration indicates that instructions for the primary task could be presented to the right ear (input 1), those for the secondary task to the left ear (input 2).

The brain response shown on the lower right in Figure A1 is the contingent negative variation (CNV), the large amplitude curve indicating that the subject is performing very well in discriminating the target in the presence of distraction, the low amplitude that he/she is not.

Figure A2 gives a blow-up of a hypothetical CNV response for a task of the sort described above. Again, a small amplitude for the CNV would be expected if the subject is having difficulty with form discrimination. The EP to the right of the CNV is the P300 wave form: a delay in the appearance of this EP and/or a small amplitude of the wave form would indicate subject difficulty with respect to memory update. Cognitive retraining, in the first case, would take the form of practice with pattern discrimination tasks, in the second case practice with memory update tasks.

It should be understood that the paradigm described above is designed to elicit information regarding only <u>one</u> element of the skills used by ATCs under <u>one</u> set of conditions (namely, discrimination of one moving stimulus from other moving stimuli). In order to arrive at an understanding of the complete range of these skills, data would need to be collected for a number of paradigms designed to represent an inclusive set of ATC task elements.



AN EXAMPLE

input 1
look for target
press right centre
when target crosses
position A

input 2
add the numbers
you are hearing and
report the sum after
the target reaches
position A

FIGURE A-1

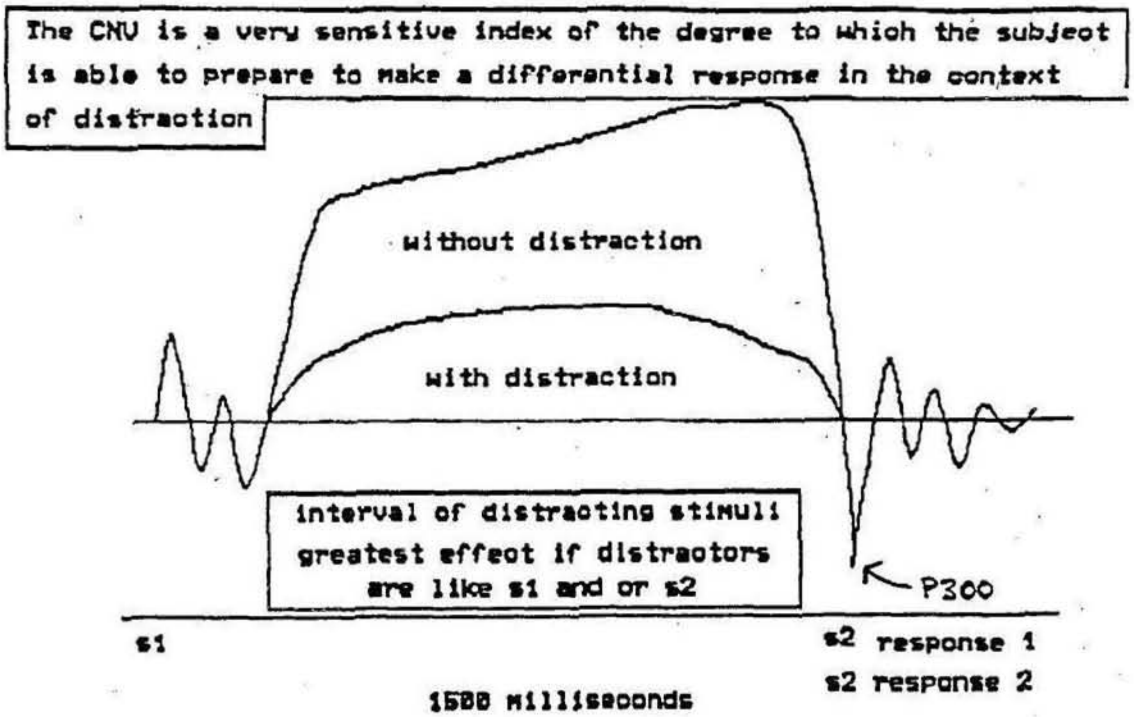

The CNU is a very sensitive index of the degree to which the subject is able to prepare to make a differential response in the context of distraction
without distraction
with distraction
interval of distracting stimuli
greatest effect if distractors are like s1 and or s2
P300
s1
s2 response 1
s2 response 2
1500 milliseconds

FIGURE A-2

AUTOMATION OF FLIGHT DATA PROCESSING AND PRESENTATION IN REPLACING FLIGHT PROGRESS STRIPS

I. Deuchert

In the beginning of the 1980's the "ad hoc group for the coordination of the STT programme on colour displays, stripless systems and speech processing in ATC" was established within EUROCONTROL.

The basic question in the beginning was whether colour should be applied at all in an ATC-environment. Meanwhile the development in industry suggests that before long monochrome displays will no longer be on the market, leading to the point that the above question is of no further relevance. The question to be answered now is how to code information by means of colour in order to gain capacity within the European ATC-System.

In order to expedite the work and to stage specific simulations, the so called ODID-Group was established in 1986 as a sub-group of the "ad-hoc group" mentioned above. ODID stands for "EUROCONTROL Member States ATC Operational Display and Input Development Group".

The objectives for the working group are specified by the following terms:

1. Define and establish by using an operational ATC proving model at the EUROCONTROL Experimental Center (EEC) in static and semi-dynamic evaluations and real time simulations, an operationally acceptable and efficient control environment using electronic displays to replace flight progress strips.
2. Develop from these results a further improved ATC environment to test and validate previous findings.
3. Prepare a valid European standard of data-coding rules and flight progress strip replacement principles.

Meanwhile two ODID simulations have been executed at the EEC at Britigny and the third is due at the end of the year.

For ODID I-simulation two adjacent control sectors within the airspace of the United Kingdom were simulated. The simulation was based on specifications which were already available in the United Kingdom (Project ECC 404). The simulation was carried out in June 1987 with the participation of five controllers made available by the National Air Traffic Services, London Air Traffic Control Center.

The basic operational concept was the following:

1. The simulation assumed a sector-team composed of one EC' and one PLC', a (not simulated) flight data assistant at a remote working position was assumed to have ensured manual flight plan handling as necessary.
2. Controllers at measured sectors had identical equipment, EDD messages and input functions at their working positions; this provides for equipment redundancy in the event of failures and for flexibility at a given sector. At the same time, each controller manages his own displays autonomously.
3. Although all displays are considered complementary to each other, the principal display for the PLC was the EDD and the SDD for the EC.
4. On the basis of automatically displayed messages replacing flight progress strips, PLC's planned the transition of aircraft throughout his sector and

communicated by TID input options affecting the evolution of traffic to the data processing system. The SDD essentially was used to verify the effect of previous planning action.

5. The EC' was warned of the traffic anticipated to enter his sector also by electronic messages replacing flight progress strips. He was however to base his actions on dynamic information displayed on the SDD. To assist him in doing so, the dynamic label management was based on the principle: "The bigger the label, the greater the outstanding task" (max. 3 lines against 1 1/2 lines signalling: no task outstanding).

6. Some emphasis had been placed on attention getters for a number of purposes. First glance recognition of outstanding tasks, peripheral vision highlighting and colour changes for warnings have been employed in a first pragmatic approach.

7. Another concern has been the design of TID input order sequences to follow, whenever possible, R/T phraseology and to prevent time consuming non-valid inputs.

8. Finally it was considered important that no change in the data display configuration occurs without a voluntary act by a controller in the form of an input.

The measured sectors (Pole Hill and Irish Sea) were simulated with a manning comprising a PC and EC per sector. Two possible seating arrangements were foreseen.

In Organisation 1 the arrangement was:

EC PC PC EC
(POLE HILL) (IRISH SEA)

and in Organisation 2:

PC EC EC PC
(POLE HILL) (IRISH SEA)

Initially two colour conventions were defined for evaluation. However, during the running of the simulation the participating United Kingdom controllers developed a third convention which, in their opinion, combined the most appropriate portions of the initial conventions proposed.

Colour Convention A was direction orientated.

Colour Convention B was outstanding task orientated.

Colour Convention C - brought forward by the participating controllers - maintained the direction orientation but added to it the notion of task outstanding.

As results it could be shown that both organisations were workable, but organisation 2 (both executive controllers seated next to each other) was preferred because it allowed more "elbow-coordination" which reduced telephone coordination to a large extent.

Concerning the Colour Conventions both given conventions deemed not satisfactory, which led to the invention of Colour Convention C. However, some major statement could be isolated:

- brightness coding should not be used,
- colour should be used sparingly.

Beyond these results it became apparent that for all three conventions the system was too input heavy because hardly any automatic coordination was implemented. The touch input displays were too slow in reaction, which led to the fact, that the participating controllers repeated the inputs and so overloaded the system completely.

The structure of the TID's was not adequate and led to search times which were intolerably long. However, the general finding of ODID I simulation showed that even under heavy traffic conditions and in spite of all deficiencies concerning the equipment the stripless system was workable and even showed some advantages concerning flexibility of the information display.

The next step was ODID II simulation. Here for the first time the adjoining airspace of two member states - Brussels-East and Frankfurt-West - was simulated.

The general objectives for ODID II simulation were:

- to assess the adequacy of the data displayed and input functions for the PLC and the EC under various loads and
- to investigate the suitability of system supported coordination functions used by the PLC's in different sectors.

For this simulation two organisations were compared:

- Organisation I was based on Colour Convention C and the message formats used in the ODID I simulation;
- Organisation II followed a completely different concept, which was taken from the GATC 80 (German Air Traffic Control Concept of the 1980's) specified by the BFS in the early 1970's.

The main idea within organisation II was that coordination is generally automated. Reactions of the receiving controller were not required unless he was unable to accept certain flights.

For ODID II simulation two teams each consisting of two Belgish and two German controllers were made available. However, only half of them could be taken for measured exercises because during the first two weeks the system was still under debugging.

Severe problems occurred during the simulation because

- several items could not be displayed as specified
- the input-media were too slow
- the blip drivers were overloaded
- the quality of the radar display was insufficient.

Nevertheless some valuable results could be gained.

The major outcome of ODID II was:

- the system simulated was workable in spite of "teething troubles" and extensive technical difficulties
- the method employed in organisation II (coordination by exception) was preferable to that employed in organisation I (systematic coordination)
- as a conclusion it was found that for further investigation pre-defined automatic coordination methods (such as standard levels) should be developed wherever possible.

During ODID II for the first time objective physiological measurements could be taken. *The EEG measurements showed the following results:*

- this simulation confirmed that it is possible to operate EEG equipment in the course of a real-time ATC simulation without significant disturbance to the simulation or significant loss of data. Electrical interference appeared to be minor (perhaps because of the relatively low frequencies involved)
- where alpha rhythms were present at rest, they appeared to be reduced under mental load

- the patterns of mental activity observable in EEG's appeared to be related to the nature of the ATC work being performed - PLC's tended to show no lateralisation of mental activity in the performance of their tasks, suggesting that it involves both recognition and reasoning.
- there was an indication of controllers under heavy pressure running into a state of mental overload which - for fractures of seconds - puts them into a "dreamlike state", unable for normal perception. However, this effect is likely to occur in a "conventional system" as well, provided the traffic load is high enough.

Another objective measure used was the SWAT.

The SWAT divides the work assessment into three aspects:
- time pressure
- mental load
- emotional strain

Each of the three aspects is assessed on a three level scale.

SWAT standard scores vary closely with the number of aircraft actually present in the sector. They suggest that, in both Organisations, the EC is more highly loaded than the PLC, but that Organisation II reduces the EC's loading.

It is planned to put ODID III simulation on stage by January 1990 dealing with vertical sectorisation of the adjoining airspace of Geneva and Aix en Provence Centers.

In ODID III more emphasis will be put on graphic displays and input devices.

In parallel to the activities of the ODID-group the BFS is doing own research work in the field of optimizing the controller/computer interface including the replacement of flight progress strips and automation of ATC-coordination.

The facility used is the "Experimental Working Position Simulator" (EWS) at the BFS-Experimental Center (Erprobungsstelle).

The first two BFS-simulations were dynamic presentations of flight plan data on coloured EDD's which did not allow any interaction between controller and system. Results gained from these two attempts in 1980 and 1981 showed that the replacement of the "old fashioned" flight progress strip is rather difficult. On one hand the strip is the oldest tool used in the ATC. It is easy to handle, and by manually putting the strip in its appropriate position in the bag, it marks itself in the memory of the controller. Manual updates again assist memorizing. Beyond these advantages taking the strip off the board again leaves bench marks in the memory.

During the past years radar and synthetic radar containing a vast amount of information and various other sources of data have been added to the working position of the controller. Replacing flight progress strips for the first time involves the withdrawal of a well accepted and handy tool. As controllers tend to be rather conservative as far as innovations in their working environment are concerned, the change from conventional flight progress strips to dynamic data displays had to be executed with great caution.

Considering these thoughts, the first question to be answered following the first two experiments in 1980 and 1981 was whether the participating controller considered the system presented - following specifications of GATC 80 - as principally acceptable.

Here a fairly clear answer emerged. All 32 participants stated that they could imagine that a dynamic data display combined with automatic coordination features and automatic updates derived from the correlation between flight plan data and radar data would be of advantage and open spare capacity. Following a long period of time, which was necessary to establish the Experimental Working Position Simulator (EWS), the first dynamic simulation allowing interaction between the controller and the system could be staged in February of 1989.

For this simulation the Frankfurt West sector was set up, using basically the same specification and the same traffic samples as were used for ODID II simulation. In order to reach high traffic loadings, 50 up to 100% additional traffic was added to the traffic sample derived from the busiest day of 1987.

To gain objective results time spent on frequency, telephone and input devices was recorded. Besides this, the same questionnaire as used for ODID II and the SWAT were used. The main difference compared to ODID II was a closer adherence to the original GATC 80 specification.

In this context - for example - an address number was put in front of each callsign, both on EDD and SDD. This change led to a drastic reduction of search tasks and input time on the TID and allowed a free choice to use a keyboard in addition. The main point derived from the answers to the questionnaire was that all participants judged the system as an advantage compared to the conventional flight progress strip as far as the planning controller is concerned.

However, the controllers stated that the amount of necessary inputs has to be reduced further and that a still higher degree of automation is required in order to gain capacity.

Generally spoken the concept - as it was presented - seemed acceptable. The principle to reduce the information displayed as far as possible and present specific information on request only, seems to be a step into the right direction.

However, other ways of displaying information - like graphic displays - should not be neglected. As a result of ODID I and II simulations and the last simulation executed at the Experimental Center of BFS some principles should be kept in mind:

- problems may occur with controllers wearing visual corrections,
- the colours used should be matched concerning intensity and brightness,
- colour coding should be used sparingly,
- brightness coding should not be used,
- more automatic functions should be implemented, in order to relief the controller from standard tasks,
- the information displayed permanently should be kept to a minimum,
- the amount of necessary inputs has to be reduced as far as possible,
- the transfer of displayed data into memory has to be ensured.
- pre-defined automatic coordination methods should be developed wherever possible,
- input menus should be linked more closely to the task to be performed and should be furnished with artificial intelligence,
- in order to get valid results three to four weeks of systematic training should be compulsory prior to measured exercises.

It seems that the point is reached at which all findings should be set together in order to issue a first recommendation towards common standards.

Méthodes de surveillance et vérification au personnel du contrôle de la circulation aérienne

R. Marsan et V. Soitu

La conviction ou plus exactement l'espérance que la technologie moderne-lancée à partir de la 6^e décennie de notre siècle résout tous les problèmes de l'homme paraît être plutôt un piège.

Jamais la technologie ne délivrera l'homme de l'obligation d'être discipliné, responsable de ses actes. Par contre, les caractéristiques du procès et des moyens de travail modernes réclament de la part du facteur homme une haute fiabilité. C'est un besoin s'imposant dans n'importe quel domaine d'activité, donc implicitement dans celui du transport aérien.

La principale nécessité en aviation est qu'on assure la sécurité des vols. Deux catégories professionnelles y sont directement impliquées:

-le personnel navigant et

-le personnel du contrôle de la circulation aérienne.

Il y a aussi des participants auxiliaires "invisibles" dans le domaine de la sécurité des vols, des spécialistes - médecins et psychologues qui effectuent la sélection du personnel navigant et de contrôle de la circulation aérienne et font une évaluation de la capacité de travail de ceux-ci, en fonction des sollicitations devenant de plus en plus complexes.

Dans cet ouvrage nous nous occuperons des méthodes psycho-médicales de surveillance et vérification (contrôle) du personnel de côntrole de la circulation aérienne au cadre de l'aviation civile.

En Roumanie ces méthodes se présentent sous deux formes:

A. l'expertise de le capacité de travail et

B. l'activité de recherche orientée vers l'exploration des possibilités d'apparition de l'erreur de la part du facteur humain.

A. Dans notre conception l'expertise de la capacité de travail est le procès qui détermine dans quelle mesure l'individu dispose des qualités requises par une certaine activité.

Elle est effectuée dans les situations suivantes:

- à la sélection
- au contrôle périodique
- dans des circonstances spéciales (lorsqu'on passe a une autre étape de l'évolution professionnelle, après certains événement de vol, lorsqu'on observe des phénomènes de nonadaptation, a.s.)

L'expertise de la capacité de travail est réalisée au Centre de Médecine Aéronautique, fondé en 1920, une des plus anciennes institutions de ce genre du monde entier.

A la base des examens médicaux et psychologiques effectués dans ce Centre dans le sens ci-dessus se trouve une vision-dynamique-integraliste, ayant à l'origine les acquisitions de certaines disciplines relativement nouvelles comme la théorie de l'information, la cybernétique, la théorie générale des systèmes.

L'adoption d'une telle vision de système s'est reflétée spécialement dans la méthodologie de l'examen psychologique. La reconsidération de la base théorique a été suivie par la modification de la structure de l'examen tant par l'introduction de certains tests plus adéquats que surtout par l'adoption d'un mode nouveau d'interprétation des données quantitatives fournies par les divers tests.

Outre les examens médicaux et psychologiques faisant partie du procès d'expertise de la capacité de travail, le personnel de contrôle de la circulation aérienne est soumis à un contrôle obligatoire avant le commencement du programme de travail.

Ce contrôle est fait dans le but d'établir si l'individu est apte du point de vue de la santé à réaliser en sûreté l'activité de contrôle de la circulation aérienne. Il consiste de :

-l'enrégistrement des valeurs de la tension artérielle
-l'enrégistrement de la fréquence du rythme cardiaque
-l'observation de l'aspect et du comportement généraux.

Celui-ci peut-être complété, en fonction de la situation, avec:

-l'analyse des troubles
-la mesure de la température cutanée
-examen clinique sommaire.

3. Pourtant les méthodes mentionnées ci-dessus ne peuvent pas surprendre et objectiver les phénomènes de fatigue ressentis mais non-déclarés ou non-ressentis par le personnel en cause (subjectivement).

Nous comprenons par fatigue la réduction du débit énergétique de l'organisme diminuant la capacité de travail de l'homme.

La fatigue a pour conséquence immédiate une attention de plus en plus réduite concernant le travail à accomplir et l'environement,

Une des plus typiques suites de la fatigue est constituée par des actes (actions) erroné(e)s.

C'est de là que dérive l'intérêt particulier pour l'ensemble des préoccupations visant la sécurité des vols, le problème de la fatigue.

Les recherches entreprises au cours de plusieurs années au laboratoire de psychologie du Centre Médical Aéronautique de

Bucarest ont eu pour résultat l'élaboration d'une méthode dénommée "Psychotonus" pour l'évaluation de l'état de fatigue.Si les méthodes indirectes sont basées sur l'analyse des oscillations - produits spécifiques de l'activité respective,la méthode "Psychotonus" utilise deux indicateurs - subjectif et objectif - la relation entre eux reflétant le niveau de la mobilisation énergétique du sujet.

Les indicateurs sont obtenus par l'application des sous-tests composant la méthode:

a) l'évaluation par le sujet de son propre fond de ressources énergétiques et

b) l'association libre des nombres (ASLN).

L'autoévaluation de la mobilisation énergétique suppose une description par le sujet de "l'état" dans lequel il se trouve,par 5 facteurs.Pour chacun de ces facteurs il doit indiquer une valeur entre "0" et "100". Afin de faciliter l'estimation requise, les 5 facteurs sont représentés sur un formulaire séparé et on y donne une courte description du complexe des sensations correspondant aux niveaux "100","50" et "0".

Le deuxième sous-test-ASLN- réclame de la part du sujet la réalisation d'une série de 404 nombres d'un chiffre,en employant tous les nombres de "0" à "9" dans un délai très court et au hasard, comme ordre.

La méthode decrite a été utilisée au cadre d'une investigation parmi les contrôleurs de circulation aérienne de l'Aéroport International Bucarest-Otopeni.

L'investigation entreprise a eu pour objet la détermination du mode où differents facteurs comme la sollicitation sensorielle et intellectuelle,la tension emotionnelle se répercutent sur le tonus psychique(le support énergétique de l'activité psychique) dans les conditions du contrôle de la circulation aérienne.

L'hypothèse d'où on est parti est celle que ces facteurs déterminent des oscillations en sens regressif du tonus psychique, quelques unes étant reflétées sur plan subjectif par l'apparition de la sensation de fatigue.

L'investigation a été subie par 11 contrôleurs de la circulation aérienne des services TWR,APP,ACC de l'Aéroport Bucarest-Otopeni.De tous ceux-ci une seule était femme.

L'âge des sujets a varié entre 35 et 45 ans.

On a choisi pour l'investigation la période de la saison d'été(caractérisée par un trafic intense) durant deux relèves: de jour et de nuit.

Le test a été réalisé pendant 4 moments du programme de 12 heures: au commencement de la relève,à la fin de la période d'activité en qualité de contrôleur I de circulation aérienne, à la fin de la première pause de travail et à la fin de la relève.

Les résultats obtenus de ces épreuves ont été interprétés à l'aide des méthodes statistiques.

On a fait 38 déterminations, pour chacune d'entre elles étant établis les indicateurs subjectif et objectif.

On a attribué ensuite aux deux types de relations établies par la confrontation des deux indicateurs les significations prévues par l'auteur du test.

Résultats et conclusions

Les résultats enrégistrés ont confirmé partiellement l'hypothèse de travail, c'est-à-dire on remarque des modifications du tonus psychique dans l'activité du personnel entraîné dans le système de conduite et contrôle de la circulation aérienne.

L'évolution des oscillations du débit énergétique n'a pas, comme on pourrait penser, un sens généralement régressif; elle est caracterisée par une grande variété à forte marque individuelle.

La modification des formes de la relation des deux indicateurs-subjectif et objectif- est l'expression de la manière personnelle dans laquelle chaque sujet a répondu aux sollicitations de l'activité.

Les différences entrégistrées sont déterminées par les facteurs psychophysiologiques qui confèrent l'unicité de la personne, parmi lesquels s'imposent ceux liés à la dynamique neuro-psychique, la structure de tempérament respectivement, à la mobilisation volitive, à la structure et l'intensité de la motivation à laquelle s'ajoute l'expérience professionnelle.

La comparaison de l'évolution de deux sujets appartenant au groupe qui a fait l'objet de l'investigation offre un exemple éloquent d'influence exercée par les facteurs "tempérament" et "type de mobilisation volitive".

Le sujet R.O. a des caractéristiques de tempérament à prépondérance sanguine et certains attributs du type flegmatique. Cela se traduit sous aspect énergétique-volitif par un fond énergétique riche et dosage adéquat de l'effort volontaire et des ressources énergétiques. Ces caractéristiques sont reflétées dans son évolution aussi, qui est constante pendant toute la durée des déterminations, se maintenant à des valeurs situées au-dessus du niveau moyen.

Le sujet G.C. est d'un type à prédominance colérique, caractérisé par un fond énergétique riche, mais aussi par une grande consommation énergétique insuffisement dosée.

Les gens de cette catégorie enregistrent quelquefois des vrais sauts sous l'aspect de la mobilisation des ressources énergétiques, d'une massive dépense d'énergie jusqu'à l'épuisement.

Un facteur influant aussi la consommation énergétique est, en plus des facteurs psycho-physiologiques, l'expérience personnelle.

On constate ainsi qu'à un niveau modéré de fatigue l'expérience professionnelle exerce un rôle de compensation, influant positivement l'aspect quantitatif et qualitatif de l'activité. Mais l'effet de compensation s'atténue avec le progrès de l'état de fatigue vers sa forme accentuée.

L'analyse des résultats de l'investigation a permis, outre les observations relatives aux aspects spécifiquement individuels de la dynamique de tonus psychique, l'observation de certains aspects communs à tous les membres du groupe.

Les composants du groupe ci-dessus manifestent une tendance générale de surestimation des ressources énergétiques au commencement de l'activité, même lorsque -objectivement- on enregistre l'apparition de la sensation d'effort et un début du phénomène de fatigue. A la fin de l'intervalle de travail on observe la réduction du niveau de motivation, le groupe oscillant entre un niveau assez haut de ressources énergétiques, mais mobilisées en partie, et un autre réduit, caractéristique au phénomène de fatigue effective.

Cette constatation s'explique par le fait que l'indicateur subjectif, calculé en vertu des réponses données par les sujets au sous-test d'appréciation des ressources énergétiques, constitue une résultante qui unit le fond de motivation et les aspirations du sujet, l'image sous laquelle il veut être identifié par les personnes de l'entourage respectivement.

L'analyse de la relation entre le niveau des performances moyennes du groupe et le moment du jour quand on les a obtenues permet l'observation d'autres aspects communs.

On a constaté à tous les membres du groupe subissant l'investigation la diminution invariable de l'indicateur subjectif-reflétant l'apparition(subjective) de la fatigue- d'un point supérieur à un autre inférieur à la moyenne vers la fin du programme d'activité.

L'évolution de l'indicateur objectif se présente sous formes différentes, selon le déroulement de l'activité de jour et de nuit.

De jour l'indicateur objectif entregistre une évolution descendente jusque dans l'après-midi, ensuite l'évolution de celui-ci devient ascendente vers la fin du programme d'activité. Cela s'explique d'une part par le declin des fonctions psychophysiologiques marquant "l'acrophase" dans l'après-midi, d'autre part par l'effet de l'apparition de ladite excitation de "finish".

Pendant la relève de nuit l'évolution de l'indicateur objectif se présente sous la même forme que de jour, sa situation au-dessus de la moyenne à la fin du programme pouvant s'exprimer par le phénomène de croissance-pour un court intervalle- de l'intensit du procès excitant à l'aube après une nuit de privation de sommeil.

Il faut faire un mention spéciale relative aux contrôleurs de la circulation aérienne travaillant dans le service T.M. de nuit. Les valeurs plus petites enregistrées entre les heures $00^{30}-3^{30}$ par les indicateurs subjectifs et objectifs constituent une illustration de l'abaissement du débit énergétique n'exprimant pas tant la fatigue, que la sous-sollicitation due au volume réduit d'activité de vol. dans ledit intervalle.

En pensant aux aspects ci-dessus, nous croyons que d'une réelle utilité serait une bonne amélioration du procès du travail par l'introduction de deux pauses supplémentaires à celles déjà prévues, plus courtes (15-20 minutes), bien entendu sans modifier le temps entier d'activité. Nous considerons que de cette manière la sensation subjective de fatigue serait attenuée et la répartition de la consommation énergétique serait plus équilibrée.

Pour conclure, on pourrait dire que l'application de l'épreuve "Psychotonus -"Psihotonus" en roumain -dans divers moments de l'activité réelle fournit des indications relatives à la forme et à la gravité de la fatigue. Elle permit aussi d'identifier les individus qui, par des raisons tenant de leur propre structure psychique ou d'une activité déroulée en-dehors du programme, agissent avec un support énergétique déficitaire, condition ~~ce~~ qui par sa nature agrandit la probabilité de la production d'erreurs dans l'accomplissement des charges professionnelles.

Les résultats obtenus au cours de cette investigation complétés avec ceux fournis par le développement de l'étude par extension à un plus grand nombre de sujets de la même catégorie professionnelle pourraient améliorer le mode de solution des problèmes comme: l'organisation du programme de travail (l'établissement de la succession des durées des séquences en activité et du rétablissement relatif à la capacité de travail), les différences entre les salaires, le sélection et l'orientation du personnel.

ANNEXE

1. L'examen psychologique de sélection est constitué:

- d'épreuves expérimentales de type classique,écrites ou effectuées à l'aide de certains appareils,
- questionnaires,
- méthodes permettant l'évaluation de type clinique: l'anamnèse, observations sur le comportement du sujet en diverses situations ou activités,l'analyse des données socio-biographiques et de l'évolution de la situation scolaire et professionnelle,s.a.

Notons quelques unes des épreuves expérimentales à passer par écrit: barrer certaines figures géométrique ,la première partie s'effectuant en conditions de tempo libre et la deuxième en tempo imposé,donc sous la pression du temps; une série d'épreuves impliquant des opérations d'abstract (l'établissement de la continuation logique de certaines séries de nombres,de figures, le tri des conclusions correctes de certaines syllogismes).

Ce sont des épreuves réalisées en collectif le premier jour d'examens,en séances d'environ 4 heures en tout.

Parmi les épreuves expérimentales individuelles notons la Preuve associative-verbale.On lit au sujet 60 mots usuels -après chacun il doit répondre le plus vite possible avec un autre mot. On prend note de la lenteur de la réponse,et ainsi du mot associé.

On répète ultérieurement les mots inducteurs auxquels le sujet doit répondre par la réproduction des mots associés.

Au cadre de l'examen on applique ensuite la méthode du questionnaire.Un premier questionnaire est formé de quelques questions visant le mode d'utilisation du temps libre,les disciplines préférées à l'école,la présentation sommaire des dernières lectures, l'évolution des aspirations professionnelles,la motivation pour la profession.Les réponses seront libres,sans limitations.

L'interprétation des réponses permet l'évaluation des connaissances et des préoccupations du sujet,du mode d'expression par écrit (de la capacité d'opérer avec des notions respectivement), de la sphère de ses intérêts,des raisons de son orientation vers l'aviation.

On peut aussi employer un autre questionnaire,élaboré par le psychologue dr.V.Ceaușu, à une structure plus complexe,formé de 101 questions relatives au comportement dans diverses circonstances de vie et d'activité quotidienne.Chaque question est accompagnée par 4 réponses possibles,le sujet devant choisir celle qu'il considère comme la plus proche de son mode de comportement dans la circonstance respective. Dans l'interprétation des réponses à notre questionnaire, nous sommes partis, à la différence de la plupart des questionneres connus où une ou plusieures questions visent un même aspect de l'activité psychique, du principe dérivé de la théorie générale des systèmes- que n'importe quel aspect lié au comportement a une détermination complexe étant révélateur pour plusieures caractéristiques psychiques.

Enfin, au cadre de l'examen on applique aussi des méthodes dont les résultats ne consistent pas dans des expressions quantitatives, mais en évaluations, appréciations du type clinique, dont l'utilité a été depuis longtemps prouvée. Citons dans cette catégorie:

- l'anamnèse
- les observations sur le comportement du sujet durant les diverses épreuves subies
- l'analyse des données socio-biographiques de l'évolution à l'école et de l'évolution professionnelle, etc.

Les résultats des divers types d'épreuves sont soumis à une analyse quantitative et qualitative, à l'aide de laquelle sont mis en relief les aspects positifs et négatifs de l'activité psychique, on apprécie aussi la capacité d'assimilation des connaissances, d'adaptation et compensation, et finalement on évalue l'aptitude pour l'activité de contrôle de la circulation aérienne.

2. L'examen psychologique à caractère de contrôle périodique de la capacité de travail est effectué annuellement.

La méthodologie de l'examen diffère d'un sujet à l'autre, en fonction des résultats de la confrontation des conclusions ressorties au dernier examen à celles découlant de l'activité déroulée par le sujet pendant la dernière période ou aux troubles qu'il présente.

On discute systématiquement avec le sujet, discussions où on aborde: son activité(nombre des contrôles de la circulation aérienne, interromptions de cette activité et les raisons, premisses éventuelles ou situations critiques éventuelles dans le contrôle des aeronefs où il a été impliqué, recompenses ou, s'il y a lieu, sanctions reçues, relations avec les membres du collectif professionnel, vie de famille sous divers aspects, mode d'emploi du temps libre, motivation pour l'activité, aspirations professionnelles, a.s.

A la suite du contrôle périodique on établit si le sujet peut dérouler aussi à l'avenir son activité professionnelle ou, si on constate une détérioration de la forme psychique-sa retraite de cette activité, temporairement ou définitivement.

3. L'examen des circonstances spéciales

Outre les situations ci-dessus, on recourt à l'examen psychologique toutes les fois qu'il est nécessaire de déterminer : l'aptitude pour la promotion dans une autre étape de l'évolution professionnelle, l' état psychique après des accidents ou des situations particulières survenues dans le déroulement de l'activité de contrôle de la circulation aérienne, les causes de certaines réductions du rendement, de certaines manifestations au lieu de travail, enfin la composition psychique pouvant constituer soit l'echo, soit l'un des facteurs déclenchant d'états maladifs. Dans des cas pareils l'examen est strictement individualisé, les méthodes utilisées étant très différentes d'un sujet à l'autre.

ENVIRONMENTAL FACTORS INFLUENCING FLIGHT CREW PERFORMANCE

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Introduction

Developments in commercial long-range aviation include an increase of the distances covered by a non-stop stretch, an increase of flight frequency, and a reduction of the number of crew members on the flight deck. The level of mental stress is expected to raise due to commercial pressure and increasing density of air traffic.
Automation has changed the pilot's task from that of an "airframe driver" to that of a flight systems manager (1). Increasing time is spent with vigilance and monitoring tasks. Vigilance and monitoring performance are particularly vulnerable to degradation by fatigue, loss of sleep, effects of drugs, hypoxia, and (probably) dehydration and ozone.

As non-stop stretches become longer, the time that is spent in the cockpit will further increase and operations of 12 hours or more will be no exception. The increasing operational time also signifies prolonged exposure to physical cockpit-conditions which might affect the physical and psychological condition of flight deck crew. These physical cockpit-conditions include the following factors: lower cabin pressure, low relative humidity, ozone, and noise (2).

The aim of this paper is to discuss the effects of loss of sleep, lower cabin pressure, low relative humidity, ozone, and noise on a pilot's performance.

1. Loss of sleep

Loss of sleep due to desynchronization of the circadian body rhythm is expected to occur more frequent, because of the increase of flight frequency and increase of non-stop distances. Cockpit crew engaged in European charter operations are frequently faced with very early departure times, due to ever increasing air traffic density (e.g. flights to holiday destinations often depart at 03.00 or 04.00 a.m.). For the crew member this means irregular shift work and a consequent disturbed sleep.
Disturbed sleep leads to fatigue and impairment of performance (3,4) and is a major potential risk for degradation of flight safety.

Recently several studies provided objective evidence for the occurrence of disturbances of the physiological sleeping pattern in cockpit crew after a transmeridian flight (5,6).

In 1988 the Netherlands Aerospace Medical Centre conducted an inquiry into the occurrence of sleep disturbances among cockpit crew of two Dutch airlines (7). Anonymized questionnaires, comprising 24 items concerning sleep and the use of sleeping aids/methods, were mailed to 1191 cockpit-crew members. The Groningen Sleep Quality Scale (8) was used to evaluate sleep quality. On all items the home situation was compared to the layover situation.

The response was 60%, and a positive correlation between operating on transmeridian flights and complaints about the quality of sleep was demonstrated. Sleep quality during layovers was significantly worse than at home (p<.0001). 47% Of the transmeridian flying crew members with sleep disturbances judged their disturbed sleep to affect their performance in the cockpit. Sleeping aids used during layovers included alcohol and hypnotics.

A disturbed sleep and the use of sleeping aids, such as alcohol and hypnotics, might affect flight safety. Therefore further studies on the residual ("the day after the evening/night before") effects of disturbed sleep, alcohol, and hypnotics should be encouraged. These studies should be performed under simulated cockpit conditions (e.g. cabin altitude 8000 ft, relative humidity <10%), and should be designed to assess pilot's performance, including performance on vigilance and monitoring tasks.

2. Cabin pressure

Most high-flying commercial aircraft are pressurized to maintain the pressure in the cabin at or below a cabin altitude equivalent to an altitude of about 8000 ft. This ceiling of the cabin altitude was apparently accepted after considering the penalty of the extra weight and expense which would have to be paid in order to reduce the ceiling much further.

In practice, during a long-range flight, the "cabin-altitude" is maintained between 6000 and 8000 feet (ft), which corresponds with an atmospheric pressure between 81.2 and 75.2 kPa (pressure at sea level: 101.3 kPa; Table I).

The lower ambient pressure leads to expansion of the gases entrapped in the cavities of the body. For a healthy individual operating at 8000 ft this may result in only minor symptoms (mild abdominal discomfort, flatulence, belching).

Table I: Atmospheric pressure, partial oxygen pressure at various altitudes, and arterial oxygen pressure and oxygen saturation of haemoglobin ($HbSaO_2$) of resting subjects acutely exposed to altitude (nd = no data available; data based on ref. 9 and 10).

Altitude	Pressure ft	P.Part. O_2 kPa	PO_2-art. kPa	$HbSaO_2$ kPA (mmHg)	%
	0	101.3	21.2	12.7 (95)	98
	6000	81.2	17.0	nd	93
	8000	75.2	15.7	7.5 (56)	90
	15000	57.2	11.9	4.9 (37)	77
	18000	50.6	10.6	4.3 (32)	72
	20000	46.5	9.7	3.9 (29)	66
	22000	42.8	8.9	nd	58

At 8000 ft the partial pressure of oxygen (P.Part. O_2) is 15.7 kPa (sea level: 21.2 kPa; table I), and the pressure of oxygen in arterial blood comes to 7.5 kPa (56 mmHg) in a healthy individual. The oxygen saturation of haemoglobin ($HbSaO_2$) at this altitude will be 90-93 % (sea level: 97-99 %) indicating a mild degree of hypobaric hypoxia. It should be emphasized that $HbSaO_2$ values in healthy subjects under hypobaric hypoxic conditions show marked inter-individual differences and values below 90 % are not uncommon at 8000 ft.

Symptoms of hypoxia that occur at altitudes of 15000 ft or higher are well described and include impairment of higher mental processes and neuromuscular control, loss of critical judgment and willpower, changes in emotional state, lightheadedness, paraesthesia, muscular spasm, headache, (physiological) hyperventilation, central cyanosis, and unconsciousness.

The aforementioned symptoms occur at altitudes above 15.000 ft (pressures below 57.2 kPa). These altitudes clearly exceed the usual cabin altitude of a normal functioning commercial airliner (problems related to a rapid decompression will not be discussed in this context). Therefore further discussions will be limited to the symptomatology of mild hypoxia occurring at altitudes up to 8000 ft (75.2 kPa), which signifies the range of cabin altitudes that apply to long-range commercial aviation.

Recently the Aviation Safety Institute stated that "low cabin oxygen levels may be more of a threat to safety than previously believed" (11). This statement was based on results of measurements which showed $HbSaO_2$ values to come below 90 % in passengers and crew members at cabin altitudes of 7000 ft.

The effects of hypobaric hypoxia occurring at a cabin altitude of 8000 ft include subjective complaints, physiological effects, neuro-endocrine effects, neuro-sensory effects, and psychological effects. The following effects apply for healthy subjects examined during simulated altitude experiments in a low pressure chamber.

2.1. Subjective complaints

Mild headache, lightheadedness and fatigue are mentioned frequently by subjects exposed to mild hypoxia. The complaints become more frequent as duration of exposure increases.

2.2. Physiological effects

Respiratory as well as cardiovascular reactions to increasing hypoxia can be observed already at 6600 ft (12), and include the following:

- increase of respiratory minute volume
- increase of heart rate (proportionally to altitude)
- increase of systolic blood pressure
- increase of cardiac output

These changes represent a normal physiological adaptation to the hypoxic stimulus. Furthermore, a decline of the T-wave on the EKG is observed. The interpretation of this electrocardiographic phenomenon remains unclear. Lagica and Koller (12) consider the changes in voltage and duration of the electro-cardiographic features to be caused by hypoxic metabolic disturbances of the myocardium.

2.3. Neuro-endocrine effects

Several authors mention changes in plasma cortisol, adrenaline, and noradrenaline concentrations under hypobaric hypoxic conditions. However results on these parameters are conflicting and the interpretation remains unclear. The observations are not typical for hypoxia, because various physical stressors cause changes in hormone and neuropeptide levels and the results only indicate that hypoxia is a stressor.

Research on the role of endorphines in hypoxia might provide a neuro-endocrine basis for certain psychological symptoms (e.g. euphoria).

2.4. Neuro-sensory effects

Neuro-sensory effects of mild hypoxia (observed at altitudes of 5000-8000 ft) include the following:

- impairment of postural stability (13)
- impairment of brightness discrimination (14)
- impairment of night vision (15)
- impairment of colour detection (16)
- decrement in the cortical processing of the auditory stimulus (17,18)

2.5. Psychological effects

The minimum altitude at which perceptual-motor decrements due to hypoxia can be detected is a controversial issue having implications for flight safety.

In fact, Ernsting (19,20) recommended that cabin altitudes should be maintained at or below 8000 ft in the interests of safety. This suggestion was based primarily on a study by Denison et al. (21), who reported increased response times at 8000 ft using a spatial transformation task (the Manikin test).

Based on his study Denison stated that "mild hypoxia affected performance while the task was being learned, but not after practice", which means that mild hypoxia affects novel tasks. In the same study Denison found that even at 5000 ft a significant increase in response time could be demonstrated while the task was being learned. Supporting evidence for the results of Denison is provided by an experiment of Crow and Kelman (22).

Ledwith (23) reported significant impairment of total reaction time at altitudes as low as 5000 ft using a variety of novel tasks with simple and complex spatial and code relationships between stimulus and response. Miroliubov (24) reported a degradation in tracking quality in subjects breathing a gas mixture containing 15.8 % oxygen, which is equivalent to an altitude of 7500 ft. He also reported significant individual differences in performance.

In contrast with the results of Denison, Crow and Kelman, Ledwith, and Miroliubov, other workers have been unable to obtain consistent performance decrements below 12.000 ft, using a selective attention test (complex card sorting,25), a serial choice response time task (26), and a logical reasoning task (27).

Concerning the relationship between the duration of exposure to mild hypoxia and impaired performance, no firm data exist. Vaernes et al.(28) studied visuo-motor speed and coordination over time (6.5 hours) at an altitude of 10.000 ft using the Trail Making Test. They found a significant effect of hypoxia, however they did not find a relationship between impaired performance and duration of exposure.

At present, no study has been attempted in which performance has been assessed over time during an 8 to 10 hour stay at 8000 ft, which condition represents the working conditions of flight deck crew on long-range flights.

It can be concluded that, at an altitude of 8000 ft, tests of selective attention failed to confirm the decrement in task performance found by workers using orientation tests. Furthermore, it can be concluded that novel tasks show impairment of performance at this altitude and that learned tasks generally fail to do so.

For future research sensitive tests should be selected that match better with the special tasks flight deck personnel has to perform. Performance on vigilance tasks should also be assessed, as vigilance becomes increasingly important in long-range pilot operations. Moreover performance should be measured over time during an 8 to 10 hour exposure to the hypoxic conditions prevailing at an altitude of 8000 feet.

3. Relative humidity

Relative humidity (RH) is the ratio of the amount of water vapour in the air at a given temperature to the capacity of the air at that temperature. The term is used to mean the percentage of moisture present, relative to the amount the air can hold (at a given temperature and pressure).

In most aircraft, fresh air is brought in from outside through the engines, cooled, and delivered directly to the cabin with no humidification. Available water from this source remains at approximately 0.15 g/kg, and at 20-22 °C the relative humidity of the fresh air is less than 1 percent. Moisture from the passengers and crew will cause relative humidity to increase, depending on the outside-air ventilation rate and the load factor, and it will decrease as rate of outside ventilation increases.

As represented in table II, RH in the cabin of a commercial airliner is very low. The values represented in this table are well below the lower limit standard set by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE, 32).

For heated rooms, a RH of 40-45 % is considered to be comfortable and when heating is not required, 40-60 % is generally considered agreeable.

Table II: Lowest Relative Humidity measured in aircraft cabins.

Study	Aircraft	lowest RH %
Hawkins (29)	DC 10	3.0
	DC 10	12.0
Lufthansa (30)	B 747	8.5
Applegate (31)	B 747	6.0
	DC 10	5.0
	DC 8	6.0
	B 727	6.0
	B 737	17.0

3.1 Symptoms of low relative humidity

Documented direct effects of low relative humidity on crew members are few. Complaints caused by a low RH include dry eyes and redness, dry throat, and dry nose. Corneal ulcerations have been reported in wearers of contact lenses after long flights. A study by the Netherlands Aerospace Medical Centre, in which subjects stayed for 8 hours at 8000 ft simulated altitude, and RH =<20 % in a low pressure chamber, demonstrated the development of punctate keratitis in wearers of contact lenses (33).

Evidence on the common belief that low relative humidity increases the risk of respiratory infection is conflicting (2).

In aviation medical literature thus far little attention has been paid to the question whether or not the low relative humidity in the cockpit can cause systemic body dehydration in flight deck personnel. One of the few authors which address this matter is Hawkins (29), who emphasizes that it is necessary to learn how much to drink and then take it whether thirsty or not. He further emphasizes that the sensation of thirst is not a good indicator of the amount of fluid needed as replacement to avoid dehydration.

In a pilot study at the Netherlands Aerospace Medical Centre, in which 6 healthy subjects were exposed during 8 hours to a simulated altitude of 8000 ft and a RH <10%, a rise in plasma- and urine osmolality was found, while subjects were allowed to drink a maximum of 2 liters of fluid.

Dehydration was indicated by an increase of the mean (n=6) plasma osmolality from 289 mosml/kg to 295 mosml/kg, mean urine osmolality from 410 mosml/kg to 807 mosml/kg, and urine specific gravity from 1012 to 1022. In the control condition (8 h. at sea level and RH: 30-40%) a slight fall in these parameters was observed during the session.

It has been demonstrated (34) that a 2% dehydration level results in an increase in heart rate and body temperature, and a significant decrement in psychological performance, as was measured by means of a word recognition test, serial addition test, and trail-marking test. In this study the 1% dehydration level also produced impairment of performance (although not statistically significant). A 1% dehydration level signifies a loss of body weight (via dehydration) of 0.8 kg in a subject with an initial body weight of 80 kg.

Data on the effects of dehydration on psychological performance are extremely scarce. The study of Gopinathan et al. (34) provides enough evidence to justify further research on the psychological effects of dehydration.

4. Ozone

Measurements of inflight ozone concentrations have produced variable results. This might be caused by the fact that the amount of ozone in the cabin varies with the type of aircraft, flight level, season, weather condition, latitude, and the stretch on which the measurements were performed.

Results of measurements are represented in table III.

Table III: Inflight ozone concentrations (ppm).

Study		Aircraft	Ozone conc.
Benett	(35)	B 707	0.05-0.12
Daubs	(36)	B 747-100	0.30-0.50*
van Heusden	(37)	D 10-30	0.20-0.40
GASP	(38)	B 747SP	0.05-0.65
		B 747-100	0.04-0.40
Unpublished	(39)	unknown	0.30**
Preston	(29)	unknown	0.57***

* cumulative exposition densities (ppm/hour)
** average conc. with peaks of 1.035 ppm
*** peaks measured on the polar route (ppmv)

The FAA established a standard for cabin ozone concentration (40). The regulations of January 1, 1985, stated the following: "The airplane cabin ozone concentration during flight must be shown not to exceed 0.25 ppm (parts per million), sea level equivalent, at any time above flight level 320 (32.000 ft at standard atmosphere); or 0.10 ppmv (ppm volume) during any 3-hour interval above flight level 270 (27.000 ft at standard atmosphere)".
In fact, in 1978-1979 FAA monitored ozone on flights (mostly at 30.000-40.000 ft) and found that 11 % were in violation of FAA's ozone concentration limits (41).

The generally accepted Threshold Limit Value of ozone in industry is 0.1 ppm (max. average concentration to which working individuals may be exposed for an eight hours working day without harmful effects on health).

Symptoms of ozone intoxication include cough, upper airway irritation, chest discomfort, retrosternal pain, pain in taking a deep breath, dyspnea wheezing, headache, fatigue, nasal congestion, and eye irritation.

Controlled human studies, using ozone concentrations of 0.14 up to 0.50 ppm, have reported respiratory symptoms and significant decrements in pulmonary function (42). The decrements in pulmonary function are well documented and are most pronounced in subjects performing exercise, while females seem to be more sensitive for ozone than males (43). Observations on the persistence of the acute effects of ozone exposure are conflicting.

Unfortunately double-blindness is precluded in these studies, because the characteristic odour of ozone can be detected by some subjects at concentrations as low as 0.001 ppm, and most people can detect ozone at 0.02 ppm (44).

Serious impairment of mental functions has been demonstrated at ozone concentrations of 5.0 ppm. These concentrations play no role in aviation. At lower concentrations no impairment of mental functions has been described, although only a few workers have assessed this problem. Higgins et al. (43) studied the memory quotient, using the Wechsler Memory Scale at 0.30 ppm ozone concentration, and found no significant differences between the ozone group and the non-ozone group.

The effects of ozone exposure on flying performance have not been studied as yet. The developments in long-range aviation necessitate the assessment of effects of prolonged exposure to low ozone concentrations (0.10-0.25 ppm) on pilot performance, using vigilance and monitoring tasks.

5. Noise

For most practical purposes, noise may be taken to mean continuous broad-band sound with a sound pressure level (SPL) over 80 dB.

Acceptable noise levels

In the long term, continuous noise may damage the mechanism of hearing, at first reversibly but later permanently. It is difficult to establish an "acceptable" or "safe" noise level whether by retrospective or prospective means, because such a survey depends on a population which has been exposed to a reasonably constant source of noise for a long time. It is generally agreed that exposures to noises of less than 80 dBA (A scale-weighted SPL) produce no increase in deafness in a population. In industry a SPL of 85 dBA is generally considered to be the upper limit of acceptable ambient noise, and all personnel should wear ear defenders whenever working in an environment where the ambient noise is in excess of 85 dBA. Final conclusions, about what is to be considered as a safe noise level, can only emerge from the study of regular audiograms of flight crew <u>and</u> controls over a long period.

Aircraft noise

The results of measurements of noise levels in the cockpit depend on the type of aircraft, position in the cockpit where the measurement was taken, airspeed, air conditioning, and phase of flight. In a study performed by the Netherlands Aerospace Medical Centre (NAMC, 45) noise was measured in the mid-position between captain and first officer, without radio-telephony (RT) sound, in aircraft at cruising altitude. The following weighted sound pressure levels (dBA) were found:

- DC 10 : 75 dBA
- A 310 : 76 dBA
- B 747 : 78 dBA

These noise levels are below the generally accepted limit of 85 dB. However this limit value represents the total noise, whereas in the results of the NAMC, RT-noise was excluded. Moreover, it should be taken into account that, in long-range non-stop flights, flight crew members will be exposed to these noise levels for 10 hours and more.

Psychological effects of noise

It is generally agreed that noise above 90 dB increases the degree of physiological arousal and hence irritability, fatigue, and the risk of accidents. In addition, by masking auditory signals, including speech, high noise levels make many tasks more difficult by increasing the degree of concentration required. Also the processing of information in active memory is affected (46), which increases workload even further. Flight crew operating noisy aircraft state that the noise causes fatigue, makes them irritated, and effectively increases their workload. Studies on the effects of continuous noise on vigilance and cognitive task performance have yielded inconclusive results. Results of studies from Cohen and Weinstein (47) strongly suggest that at least part of the noise effect (direct and after-effect) is due to the individual's interpretation of the physical environment and the threat it poses.

As long-range flight crewmembers spend 10 hours or more in an environment with sound pressure levels of 75-80 dBA, this sound pressure might contribute to fatigue.

Conclusion

Flight deck crew engaged in long-range operations and European charter operations are frequently faced with problems caused by a loss of sleep. A disturbed sleep (and the use of sleeping aids such as alcohol and hypnotics) might lead to fatigue and degradation of performance.

The effects of sleeploss and/or drugs might be further detrimentally influenced by the addition of effects of cockpit-environmental factors, such as lower ambient pressure, low relative humidity, ozone, and noise. A single factor inducing only minimal impairment of performance can contribute considerably to the overall result.

To anticipate these problems, research on the effects of a combination of these factors on performance is needed. Such research should include controlled simulation studies, employing over time assessment of psychological performance, using tasks that are representative for the flight systems managing task of a modern pilot. The following conditions should be included in such a study:

- exposure time : >8 hours (long-range operations).
- cabin altitude : 8000 ft
- relative humidity: <10 % (temp.: 20-25 °C)
- ozone concentr. : 0.10-0.25 ppm
- noise : 75-80 dBA (continuous)

Emphasis should be placed on the observation that the effects on performance show large inter-individual (and intra-individual) differences. The results of most studies are usually given as "mean scores" of the experimental group. When considering effects on performance, one should bear in mind that the subject with the worst performance score is the one who might cause an accident.

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HUMAN RESOURCES DEVELOPMENT AND ACCIDENT PREVENTION IN FOCUS THE HUMAN NATURE.

By Carlos Manoel Machado Pernambuco 2 lt

According to the last five years accident analyses, education seems to be *the main field of interest as far as* safety matters are concerned. Education should be divided in two specific areas to focus on the last expression of human nature, the relations which the individual deals with.

One area is defined by the relation between the individual and environment. It may be treated through management development. The second one relates to the individual dealing with himself, which may be accomplished by *"self management"*. This last one is directly related to human nature, being determinant in the *effectiviness of the first one.*

In fact most of the manegement development methods search for behavior change, what doesn't mean that subjacents attitudes have changed. A manager can learn *how to behave* democratically, but his attitudes may still remain autocratic. There may happen an *incongruity between the behavior and the* attitudes. And how will employees react? What's better to them? The incongruous democratic maneger or a sincere autocratic one?

Otherwise, it's been *said that* the aeroplane has been developed, *but man remains the same. In fact*, because man didn't change, we are still undertaking man's potential. It's quite clear that "human machine" has a great potential, which can be developed.

As far as concerned attitudes problems, motivaton, decision making, psychomotor skill, which have contributed to aeronautic accidents are samples of the human potential misus.

How to prevent accidents, resulting from education *process, which forms* attitudes, *behavior,* acts *an reactions* skills, have to be reviewed. For so, instead of only study the individual past, the present - "here and now" - should also be observed, *just focalizing on* the *first relation* established between the individual and himself.

In this relationship we can find four elements: the "self", *corresponding to what someone really=is; the "ego" or* personality, what someone is=being; the "self-esteem", how someone think=to=be; and the *"ideal-self", what* someone would=like=to=be. These four elements will define basic conflicts, and the difficulty of establish the congruity. The nature of almost all individual's problems and mistakes could be found in this area.

The "ego" arises from the indididual consciousness derived from the difference perceived between him and the environment. The sansations originated from the individual differs from those originated from the world, saying something about "I" and "the others". The sensations are memorised and added to the "ego", till start to be classified as pleasant or unpleasant. The classification of pleasant and unpleasant grows up arriving into concepts and attitudes, which, also added to the "ego", will drive perceptions and reactions. So the perceptions, and even the sensations become determined by the "ego". The individual starts to react according to his perceptions, and perceive according to the "ego", who controls those processes so as to fortify them and himself. The objects start to be agreable or not, now according to the "ego" perceptions and needs, no more to the object proper characteristics. The "ego" starts to look for his congruity, so he will perceive the world as he whants to.

Some authors show that the individual doesn't search for satisfactions or pleasure, neither to avoid pain, he also looks for congruity between his "self-esteem" and his experiences, between his ego and the world. When someone acts autocratically or democratically, he is trying to be congruous with hinself, or with what he thinks about himself.

As time goes, the sensations, perceptions and cognitions are treated to establish the congruity and make it strong. If the environment doesn't agree with his own congruity, it will adjusted to the ego's needs and perceptions.

As mecanic processes of reactions are added to intelectual process, the ego assumes this identification and becomes conscious about it - "that's me". The ego is complete, he doesn't perceive the world as it really is, he projects his own images, feelings, emotions and thoughts, looking for his congruity.

All psychological process as decision making, perception, attention, motivation and others are contaminated by the ego. When a manager choose to be autocratic or not, the choice isn't made because he's really so, but because he thinks that he has to act so. When a pilot makes one mistake as inattention, that's because his attention is driven or his perception is deformed by the ego; or indirectly affected by another ego, either by the manager's.

If the individual has self knowledgment in adequate level, allowing him to really know his thoughts and emotions, and to discriminate when he's projecting and letting them interfer in his perceptions or decisions, he will be able to get more clear perceptions and make better decisions. But it can only happen, according to his self-kowledgement.

The own body is a good beginning to someone to know hinself. Relax technics associated with body visualization can provide individual's first contact with hinself, and the opportunity to know how he really perceives himself. The analysis of each part of his body will show details that were unknown, parts having difficulty to be visualized will show difficulties to establish relations with himself and the environment.

Experience may be improved by exercising body observation in a mirror, those exercises will bring the necessary material to compare and complete the visualization. It's waited that with the pratice of the relax and comparison, the visualization will get closer to the reality.

In the course of the exercises some members / regions of the body won't be easily visualized, because they are associated with experiences and emotions. Thoughts and emotions are more fluid than body seems to be. The second step will be the knowledge of toughts and emotions.

Thoughts continuous flux ought to be observed, without any intention of increase or suppress, only observed, till it become really familiar. So will be done with emotions, they will be observed, till become as well known as it's possible. This part is more difficult, because the emotions have exciting qualities, they use to come together with thoughts and memories through individual's mind as it is attending to an involving movie.They have to be observed till they don't envolve or distract anymore.

While observing thoughts and emotions, some concepts and intelectual expeculations will appear. When thoughts and emotions become clear it's time to review some concepts. Almost everything is labelled, the individual have to try glance over the concepts scenario, since each concept was built by the ego to supply his view.

Since there's no more labels, things will start to appear as perceptions, and from every perception the individual will learn a specific reaction, which represents his own images being projected. The next step consists in recognize personals images that are projected to the object. This knowledgment will result in the possibility of the individual to stablish a more natural relations with himself and the world.

Without projection, perceptions will be reduced to sensations that really represent objects. Getting the hole sensations and work with them, whithout any accessories, the individual will become aware of real things.

Aware of reality, individual will be able to fell real stimuli, getting free from their projections. These feelings will provide real perceptions, that will have more adequate answers. Without estereotypes, decision making process will flow. Indeed, most of the psychological process will flow with self-knowledgement, being the human factor focalized in it's main field. Education process will allow the individual to improve himself according to human nature preventing accidents.

CARACTEROLOGIA Y SEGURIDAD DE VUELO:

EL MITO DEL "RIGHT STUFF" EN LA AVIACION CIVIL

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1) INTRODUCCION:
    1) Antecedentes bibliograficos
    2) La "aeronavegabilidad" de la diada piloto-avión
    3) La falacia conceptual del "accidente" por "error de pilotaje".

2) CAUSAS DE LAS "CONDUCTAS OPERATIVAS SUBSTANDARD":
    1) Sindromes de Desadaptación Secundaria al Vuelo
    2) Incapacitación psicofísica relativa, parcial y velada
    3) Caracteropatías Aeronauticas
    4) Limitaciones Psicofisiológicas
    5) "Arribaritis" ("Get-there-itis")
    6) CRM - Instrucción
    7) Stress
    8) Acting Out
    9) La cultura de la empresa

3) DETECCION Y DIAGNOSTICO PRECOZ:
    "ALARMAS AMBAR"
    "ALARMAS ROJAS"

4) PREVENCION:
    1) Sistema preventivo no policíaco-persecutorio.
    2) Selección no instantanea sino procesual.
    3) Re-selección de pilotos-instructores
    4) Feed-back instructor-medico aeronautico
    5) Concienciación-actualización-adiestramiento
    6) Evaluaciones periódicas (Operat, proced, met, FFHH, etc.)
    7) Propender a la EXCELENCIA tambien en el pilotaje

1.1. ANTECEDENTES BIBLIOGRAFICOS:

El porcentaje de accidentes aereos por "error de pilotaje" varía desde un 65% para Humphrey(17) hasta un 85% para Geratewohl(11). Las cifras no son menores en la aviación militar segun Vigier(31). Se suele clasificar el "Error de Pilotaje" en: "Error de Juicio" si se trata de un calculo equivocado de la distancia o la elección de una pista o terreno inadecuado para aterrizar; "Tecnica de vuelo deficiente" si se trata de mal uso de los mandos de vuelo o de los frenos o del grupo motopropulsor; "Imprudencia" si se trata de la continuación de un vuelo VFR en condiciones IMC, de vuelo temerario, vuelo intentado sin suficiente pericia o experiencia, no ajustarse al procedimiento de entrada por instrumentos; "Descuido" si se trata de no observar otras aeronaves u obstaculos, no desplegar el tren de aterrizaje, agotar el combustible en pleno vuelo; y "Negligencia" si se trata de preparación inadecuada del vuelo, aterrizaje con viento fuera de norma, etc.

Falckenberg(8) propuso otra clasificación:

1. Error de input o falsa impresión producida por los sensorreceptores perifericos.
2. Erránea interpretación de la información instrumental.
3. Falla en la obtención de información (meteorológica etc.).
4. Reacción errónea.
5. Ausencia de reacción.
6. Reacción retardada.

Shuckburgh(27) estudió los accidentes en el Reino Unido entre 1962 y 1971 y clasificó los resultados de la siguiente manera:

1. Operación incorrecta en condiciones instrumentales	30%
2. Planeamiento inadecuado del vuelo	20%
3. Error de juicio	17%
4. Miscelanea	13%
5. Falta de supervisión del CPT	8%
6. Mal uso de los mandos	7%
7. Errores de otros tripulantes (no pilotos)	5%

Para Digo y Lavernhe(5) la causa del 80% de los errores de pilotaje es de origen psíquico, y lo discriminan en los siguientes puntos:

-Manifestaciones emocionales paroxísticas
-Perturbaciones del humor, emergencia de problemas personales, psicoafectivos, económicos, etc.
-Descompensación de estados neuróticos latentes, en particular neurosis fóbica y de angustia.
-Trastornos transitorios de la atención, la memoria y el juicio. Decisiones equivocadas, exceso de trabajo, etc.
-Trastornos de personalidad, personalidad psicopatica, rígida, hipertrofia yoica, exceso de autoconfianza, etc.
-Emergencia de procesos inconscientes, autopuniciones e,in extremis, conductas suicidas.

Como se puede apreciar, históricamente al menos, el piloto ha sido el "villano de la película" ya que por su culpa -de hecho el descuido, la negligencia o la imprudencia implican un cargo moral- comete "errores" que eventualmente producen da#os a la propiedad ajena o la muerte de víctimas inocentes.

Esta concepción estanca no sólo es injusta sino que ademas no sirve para implementar recursos correctivos. En lo que sigue se expondra un enfoque sistemico del problema y las soluciones posibles.

1.2. AERONAVEGABILIDAD DE LA DIADA PILOTO-AVION:

Desde hace algun tiempo, la tecnología aparentemente ha alcanzado un nivel de confiabilidad casi absoluto, y se considera que el Factor Humano es el elemento limitante de la seguridad, pues es el que tiende a "fallar" reiterada, inexplicable e impredeciblemente.

Esta concepción teórica parte del supuesto falso que sostiene que el hombre tiene una capacidad ilimitada de adaptarse a cualquier entorno por mas atípico que fuese y de responder apropiadamente a cualquier estímulo o grupo de estímulos por mas confusos o inexactos que se presenten.

Cuando los especialistas y tecnócratas tomaron conciencia parcial de esa falacia, comenzaron a inventar ingenios para auxiliar al hombre en sus limitaciones fisiológicas. Si no podía ver de noche o a traves de las nubes le pusieron un radar meteorológico luego, un radar a colores para distinguir la peligrosidad de las formaciones nubosas y finalmente un radar doppler para detectar hasta los cambios de dirección del viento en la trayectoria de su avión. Pero algunos pilotos persisten en su costumbre de no demorar el despegue o interrumpir la aproximación cuando son advertidos de la presencia de cortantes de viento en el area.

Como su agudeza visual, naturalmente limitada a un angulo de 0.3 grados, le impedía advertir en el espacio a una aeronave en trayectoria presuntamente colisionante con la suya, la tecnología inventó un Transponder Colission Avoidance System (T-CAS) que en su versión mas completa hasta le indica al piloto hacia donde debe efectuar la maniobra evasiva para evitar el peligroso encuentro cercano. Pero mientras este sistema no este reglamentado continuaran algunos pilotos reportando posiciones incorrectas a los efectos de obtener el primer turno para incorporarse al procedimiento de aproximación, provocando quasi-colisiones de alto riesgo.

Peque#as desviaciones en el regimen de descenso, olvidarse de bajar el tren o aproximarse al terreno sin estar configurado suelen ser situaciones que la tripulación puede no advertir, entonces se inventó el Ground Proximity Warning System, que ya lleva 15 a#os en servicio. Cabe mencionar, no obstante, que a pesar de su precisión han habido accidentes como el del B-747 en Mejorada del Campo (Madrid) en 1983, en el que el GPWS vociferaba "pull up, pull up" 14 segundos antes del impacto.

Ademas, como saben, encerrado en el cockpit o en cabinas abiertas el piloto no puede advertir con precisión la velocidad del aire, elemento crítico en la aproximación y el aterrizaje, de modo que se inventó para todo avión de transporte una dramática alarma de perdida que se denomina "stick shaker", pero deben saber tambien que existen pilotos que aterran a sus noveles copilotos demostrandoles cuan habiles son, al efectuar un circling (esto es a 600 metros de altura) al borde de la perdida con el "stick shaker" activado.

Los otolitos y los canales semicirculares no le permiten al ser humano detectar cual es la vertical gravitacional ni el horizonte si pierde la otra fuente fundamental de datos: la visión. Para ello existe el horizonte artificial desde hace decenas de a#os. Sin embargo la desorientación espacial sigue siendo causa de accidentes fatales hasta en un 14% segun infromes de la USNavy.

Como la radiación electromagnetica capaz de estimular la retina humana (es decir en la gama del espectro óptico) no puede atravesar las nubes o la niebla y la aproximación con VOR o NDB y radiobalizas es limitante en el sentido de que los mínimos son bastante altos (aprox. 500 pies), se creó el utilísimo ILS, ahora con Categoría III, y esta en uso experimental el MLS que permite un aterrizaje con 0-0 de techo y visibilidad. No obstante los accidentes en la aproximación y el aterrizaje con o sin ILS (caso en que la probabilidad de chocar contra el terreno es nula porque a la altura de decisión si no se ve la pista hay que irse) se repiten, por que los mínimos no se respetan.

Todo lo cual permite sospechar que la tecnología, aun logrando un aterrizaje a ciegas, no podra prevenir las conductas operativas inseguras o substandard y no podra evitar la toma de decisiones operativas inadecuadas. El factor limitante continuara siendo el humano, mientras no se tome conciencia de que el viejo paradigma de los compartimentos estancos no permite una aproximación teórica correcta a la "infinita complejidad" del Factor Humano en la aviación.

1.3. LA FALACIA CONCEPTUAL DEL "ACCIDENTE" POR "ERROR DE PILOTAJE":

El pensamiento analógico suele ser de utilidad para la intelección de temas abstractos.

En este caso hemos de servirnos de ese recurso heurístico. Imaginemos a un avión elemental cuya sustentación es directamente proporcional a su rendimiento alar y a la velocidad e inversamente proporcional a su peso.

Este avión imaginario, no comete error alguno si alguien pretende hacerlo volar por debajo de la velocidad de perdida de sustentación, o con un angulo de ataque que implique la entrada en perdida por segundo regimen, o con hielo acumulado en los planos de tal manera que el perfil alar se deforme, o con exceso de peso, o en aire muy poco denso y en una pista a 3000 metros de altura, etc, etc. En esas condiciones el avión si intenta volar, se caera, y ello no por "*error del avión*", sino porque se habran SOBREPASADO SUS LIMITES OPERATIVOS, o se lo *habra exigido mas alla de lo que aconseja el fabricante.*

Para evitar ese tipo de "accidentes" (luego veremos que no son tales), *el fabricante o dise#ador* escribe detalladamente cuales son las condiciones en las cuales el avión puede volar y cuales son aquellas condiciones en las cuales el avión no vuela.

Se entiende por accidente un episodio fortuito, un suceso eventual e inesperado que altera el orden regular de las cosas. Si nos atenemos a la letra de la definición ese avión teórico, no puede cometer errores ni accidentarse a menos que algo o alguien lo coloque en una situación anómala, que viole las limitaciones que el dise#ador estableció claramente en el Manual del Usuario. Hasta una plantada de motor se puede resolver si se siguen estrictamente los consejos operativos y las reglamentaciones aeronauticas. Por supuesto que la propia *plantada del motor tampoco lo es, pues si el mismo estaba bien* mantenido, si el combustible estaba bien filtrado, si el piloto coloco *aire caliente al carburador*, etc, etc., el accidente no existe, desde el punto de vista de la maquina.

El Manual del Usuario tambien recomienda evitar las tormentas y las "cortantes de viento" en final, y en caso de verse atrapado en un "microburst" hacer escape de inmediato, de modo que calificar una catastrofe aerea como accidente porque el avión fue aplastado contra el terreno por un "downburst" es otro error conceptual. No es un hecho fortuito ni un suceso eventual, sino absolutamente previsible y evitable.

El otro miembro de la diada, el piloto, tampoco comete errores o sufre accidentes. Al igual que el avión -o mejor dicho analógicamente- el piloto tambien tiene sus "limitaciones operativas" pero en este caso, no estan previamente escritas en un Manual del Usuario porque el dise#ador o fabricante lo lanzó al mercado a "medio terminar" y, mientras el propio ser humano completa su proceso de hominización, es decir trata de descubrirse a si mismo y averiguar cómo funciona, y desarrollar todas sus potencialidades, otros seres humanos tratan *de escribir, sobre la marcha*, el *inexistente, pero* imprescindible "Manual del Usuario".

Ya *sabemos mucho* y hay decenas de miles de paginas escritas de ese "provisorio manual del usuario". Ya sabemos que hay un colesterol malo y un colesterol bueno que bien balanceados reducen el riesgo a la enfermedad coronaria y al infarto agudo de miocardio en pleno vuelo.

Sabemos que el ser humano-piloto no debe alcoholizarse en las 12 horas previas a un vuelo, pero que sería mejor que no lo hiciese 48 Hs antes ya que en la endolinfa de los canales semicirculares de su oido interno, los órganos del equilibrio, quedan rastros de sustancias químicas derivadas de la combinación del alcohol con algunos lípidos llamados "esteres etílicos", que eventualmente podrían *entorpecer* su percepción y orientación espacial.

En *ese manual provisorio del usuario tambien dice* que el piloto no debe volar si tiene congestionadas las vias aereas superiores por el *peligro de la barootitis* y una eventual incapacitación psicofisiológica por el dolor consecuente que lo dejase fuera de servicio, y lo condujese NO a un accidente (porque sería un hecho no fortuito ni eventual sino absolutamente previsible y prevenible), sino a una catastrofe por mal uso del "equipo".

Para vuelos nocturnos, sugiere que se oxigene adecuadamente respirando oxígeno puro durante media hora antes del despegue y que evite fumar o respirar el humo de otro *cigarrillo, ya que la nicotina* produce un efecto adverso sobre la visión nocturna.

En *cambio, hace poco* que se escribió el capítulo de los tiempos maximos de servicio y mínimos de descanso, donde dice que para reciclar los ciclos circadianos si en el vuelo anterior voló hacia el Este debe descanzar un dia por cada 56 minutos de desfasaje horario y un dia por cada 83 minutos si el vuelo fue hacia el Oeste. Aunque la recuperación de la velocidad de los tiempos de reacción tardan un 70% mas.

Y se estan escribiendo los capitulos referidos a las condiciones que deterioran la performance psicofisiológica del piloto y las recomendaciones para prevenirlas y evitarlas.

Si una tripulación despega un B-737 bajo los efectos de la cocaína, como parece ser el caso de un reciente episodio en el aeropuerto de La Guardia (NY), o si otra despega otro B-737 desde el JFK con hielo en los planos y en los sensores de EPR de sus turbinas y se caen en el Potomac, no se trata de un error del avión el hecho de no haber informado adecuadamente la potencia requerida ni haberse podido sustentar, y en el primer caso no fue un mero error de pilotaje que el copiloto haya apretado el botón equivocado y apagado las turbinas, se trató de incapacitación psicofisiológica de ambos pilotos, cuyas causas se analizaran mas abajo. Otro ejemplo:

El 26 de setiembre de 1988 un B-737 se fue largo en el aterrizaje en Ushuaia porque un microburst lo "desacomodó" en final entrando con una fuerte componente de viento de cola y exceso de velocidad. Como otra veintena de accidentes similares en ese tipo de avión al no apoyar con firmeza el tren principal no se envió la se#al desde el sistema selector aire/tierra para el despliegue de los "ground-spoilers" ni para el armado de los reversores ni para obtener un frenado efectivo de las ruedas sino hasta que ya era tarde y el avión se fue al agua.

Las recomendaciones que propuso la Asociacion de Pilotos de Linea fueron:

1) Instalar sistemas detectores de wind shear.
2) Mejorar la infraestructura del aeropuerto.
3) Mejorar la INSTRUCCION sobre el uso del Speed Brake.
4) Implementar la INSTRUCCION sobre wind shear y microburst.
5) Reforzar la INSTRUCCION de "aproximación frustrada".
6) Impartir INSTRUCCION sobre CRM y Factores Humanos.
7) Programar TRIPULACIONES ARMONICAS para ese vuelo.
8) Restringir esa operación al CPT para evitar demoras en la toma de decisiones.
9) Investigar posibles errores de dise#o en los sensores aire/tierra de los B-737 de la empresa.

De donde se puede deducir claramente que:

EL AVION NO SE EQUIVOCA, SINO QUE PUEDE ESTAR MAL DISE#ADO O EL PILOTO PERMITE QUE SE EXCEDAN SUS LIMITES OPERATIVOS O LO COLOCA EN SITUACIONES ANOMALAS DE LAS CUALES NO PUEDE SALIR.

EL PILOTO NO SE EQUIVOCA, SINO QUE EL SISTEMA AERONAUTICO PERMITE QUE EXCEDA SUS LIMITES PSICOFISIOLOGICOS U OPERATIVOS, SI ANTES NO FUE INSTRUIDO, ENTRENADO Y PROGRAMADO PROFESIONAL Y CIENTIFICAMENTE.

Esta reconceptualización del clasico "error de pilotaje" tiende a desmitificar el "factor limitante". En efecto, mientras sigamos creyendo que nada se puede hacer para evitar la falibilidad del piloto estamos perdidos antes de comenzar.

Si usamos de nuevo el pensamiento analógico, caeremos en la cuenta de que si el avión tiene sistemas "fail-safe" y duplica o triplica aquellos que pueden fallar para GARANTIZAR la seguridad de la maquina, con el ser humano-piloto hay que hacer lo propio, duplicarlo en la medida de lo posible (tripulaciones de dos pilotos), pero antes que ello, implementar esa filosofía operativa a prueba de fallas, mediante los recursos pertinentes que se discutiran a continuación.

2. CAUSAS DE LAS "CONDUCTAS OPERATIVAS SUBSTANDARD":

En los antecedentes bibliograficos (1.1.) se pudo apreciar hasta lo anticuado que resulta el lenguaje empleado para describir conceptos tan perimidos y equívocos como el llamado "error de pilotaje". En este apartado, se han de describir someramente las causas que condicionan o determinan que el piloto exceda sus "limites operativos o psicofisiológicos" e incurra asi en conductas operativas inseguras o substandard.

2.1. SINDROMES DE DESADAPTACION SECUNDARIA AL VUELO:

Autores franceses como Missenard y Gelly (23), Digo (4), y Hadny y Galle-Tessoneau(15) desde 1969 vienen hablando de la necesidad de que el piloto genere en su psiquis un SINDROME DE ADAPTACION AL VUELO. En 1871 el peruano Llosa Rojas (22) propone denominar "Flight Decompensation Syndrome" a lo que los anteriores denominaban "Sindrome de Desadaptación al Vuelo".

Hace cinco a#os hemos descripto 10 modalidades clinico-psiquiatricas de este sindrome, a partir de las alteraciones cuali o cuantitativas de los componentes de la ecuación que, sostenemos, debe cumplirse en la interioridad del piloto para mantener su "adaptación" al vuelo profesional.

Estos elementos son: la Motivación Aeronautica en sus tres niveles de conciencia, los Mecanismos de Defensa del Yo (negación, represión, supresión, racionalización, humor, identificación con el instructor, formación reactiva, desplazamiento, etc), necesarios para contrarrestar el denominador de la formula: la Angustia Aeronautica, que incluye el stress, ansiedades y fobias no resueltas.

En este lugar no hemos sino de mencionar apenas estos 10 sindromes pues estan publicados "in-extenso" tanto en Ingles como en Castellano (20, 21):

$$1)\ \text{TEMOR A VOLAR} = \frac{M \times D}{A:}$$

$$2)\ \text{FOBIA AL VUELO} = \frac{M \times \text{"D"!}}{A:}$$

$$3)\ \text{FATIGA CRONICA DE VUELO} = \frac{M! \times D}{A}$$

$$4)\ \text{CLIMATERIO AERONAUTICO} = \frac{M!! \times D}{A}$$

$$5)\ \text{AERONAUROSIS TRAUMATICA} = \frac{M \times D}{A:::}$$

$$6)\ \text{CARACTEROPATIAS AERONAUTICAS} = \frac{\text{"M"} \times \text{"D"}}{A} \quad \text{(vide infra)}$$

$$7)\ \text{CONDUCTA OPERATIVA SUB-STANDARD} = \frac{\text{"M"} \times \text{"D"!}}{A:}$$

$$8)\ \text{AERONAVEGANTE COMPULSIVO} = \frac{M: \times \text{"D"}}{A:}$$

$$9)\ \text{SINDROMES HIPERDEFENSIVOS} = \frac{M \times D::}{A:}$$

$$10)\ \text{ADICCIONES} = \frac{M \times \text{"D"!!}}{A:}$$

Cualquiera de estos desajustes psicofisiológicos pueden conducir al mal funcionamiento del "aparato psiquico" del piloto y provocar conductas inseguras, errores de valoración o toma de decisiones equivocadas.

La evaluación del Sindrome de Adaptación al Vuelo profesional de los pilotos debe ser chequeado en primer lugar por el propio piloto, pero ademas, habida cuenta de que el autoanalisis puede ser enga#oso, sus colegas y eventualmente los medicos aeronauticos deben estar al tanto de los signos y síntomas incipientes de los sindromes de desadaptación secundaria al vuelo (cf. libro homónimo).

2.2. INCAPACITACION PSICOFISIOLOGICA PARCIAL Y VELADA:

Los analistas suponen que en accidente del jumbo de Avianca en Barajas (1983) se debió a la incapacitación psicofísica del capitan. Se podría afirmar que en el Rio de la Plata (1981) y en Posadas (1988) ocurrió lo propio. En Tenerife el C. de KLM estaba incapacitado.

Tanto el Comandante Oscar Elizalde (6), experto en Factores Humanos, como nosotros (18) hemos detallado la importancia de este concepto. Como se#ala Elizalde, el Comandante es el unico sistema que en el avión no se halla duplicado de alli es que sea necesario incluir en la instrucción de los pilotos claras directivas acerca del modo en que el propio CPT como el F/O pueden advertir una velada incapacitación del piloto al mando, particularmente cuando es el CPT, y tomar las acciones correspondientes.

Los síntomas a pesquizar serían: desorientación, distracción, miedo, conducta no habitual, temeridad, agresividad, errores de valoración, preocupación por cosas menos en fases críticas del vuelo, falla en el establecimiento de prioridades o asignación de tareas, dificultades con el control distributivo, volar detras del avión, etc.

2.3. CARACTEROPATIAS AERONAUTICAS:

Hace unos a#os Berlin (3) desde una óptica conductista describió cinco actitudes psicopaticas re#idas con la seguridad de vuelo: el piloto "macho", el "antiautoridad", el "invulnerable", el "destinado" y los "impulsivos".

Nosotros, desde una óptica psicodinamica describimos tres: la actitud "icariana", la "belerofóntica" y la "faetóntica" (19).

Cuando nos referimos a caracteropatías no estamos aludiendo sino a actitudes comportamentales que el propio individuo considera egosintónicas razón por la cual no es conciente de su peligrosidad.

Son las instituciones medico-aeronauticas en conjunto con los instructores de vuelo, quienes deben detectar estas tendencias caracteriales ab-initio y descalificar al aspirante a piloto en sus primeros pasos. Una vez incorporados y en carrera, estas personaliades suelen ser temibles por la cantidad de inconductas en las que incurren, tales como "pinchar cumulo-nimbus" o entrar bajo mínimos en forma sistematica.

La propia ideología del "Right Stuff" no ha hecho sino incentivar esas caracteropatías, a tal punto que a lo que tradicionalmente se denominó Right Stuff, hoy en dia comienza a llamarsele "Wrong Stuff".

Los "Top gun" son aceptables y hasta deseables en la aviación de guerra, pero en la línea si siguen volando, es por falla del sistema de prevención de accidentes o de instrucción de la empresa.

2.4. LIMITACIONES PSICOFISIOLOGICAS:

Los órganos sensorreceptores poseen "umbrales" por debajo de los cuales no estan en condiciones de recibir estímulo alguno. Eso es valido tanto para los "otolitos" y los canales semicirculares, como para la visión crepuscular y la agudeza visual. La clasica descripción de las ilusiones sensoriales en vuelo, que se pueden hallar en cualquier libro de medicina aeronautica son una clara evidencia de ello. Este es un tema no siempre tenido en cuenta en la instrucción de pilotos.

El estado de "alerta" del cerebro humano no sólo tiene su umbral sino que este es variable con el transcurso del tiempo y con la desincronización de los ritmos circadianos en el llamado sindrome "jet lag". Las reglamentaciones sobre tiempos máximos de servicio y minimos de descanzo estan poniendose al tanto de los nuevos hallazgos experimentales, pero aun queda mucho por hacer en este campo.

La Fatiga de Vuelo, en sus diversas modalidades, produce un deterioro adicional e inexorable de las habilidades psicofisiológicas fenómeno del cual el piloto debe estar adecuadamente advertido. Aparte de la fatiga operacional propiamente dicha, debe tenerse presente al analizar este tema, la "diatesis o susceptibilidad a la fatiga" que presentan algunos pilotos. Esta propensión esta intimamente ligada a la calidad de la motivación profesional del aviador, y debe ser pesquizada con atención por parte de los jefes e instructores para adoptar las medidas correctivas precoces que correspondan.

La memoria activa, la memoria de corto plazo y la memoria de largo alcance poseen cada una, específicas limitaciones y condiciones en las cuales su funcionamiento es inapropiado. Los pilotos deben recibir instrucción recurrente sobre este y los demas temas que limitan su performance.

El efecto sobre la performance de la nicotina, la cafeína, las comidas a bordo, los medicamentos supuestamente inocuos (analgesicos, (antiespasmódicos, etc.) suele ser un tema descuidado por los pilotos, muchos de los cuales vuelan automedicados o medicados por medicos no aeronauticos, con farmacos que no siempre son seguros.

2.5. "ARRIBARITIS":

Los ultimos 5 accidentes importantes que hemos tenido en Argentina en los ultimos 24 meses ocurridos en el aterrizaje contaron a este siniestro componente en su cadena causal. En efecto, un DC-9 Super 80 choca contra los arboles 2 Km antes de la cabecera cubierta por niebla, la intención del CPT era descender hasta los 100 pies en una aproximación con VOR-DME cuya MDA es 460 pies... murieron todos. En el mismo aeropuerto, meses despues, un LearJet 25 acuatiza y por milagro salen del avión todos vivos, el acuatizaje se produjo porque el piloto estaba empe#ado en aterrizar en el aeropuerto de su ciudad natal, aun en plena lluvia torrencial con visibilidad reducida a 50 metros. Tres B-737 se despistan en accidentes similares: exceso de velocidad en cabecera por lo que excedieron las posibilidades operativas de la maquina para frenarla en los limites de la pista (dos de ellos quedaron inutilizados).

La "arribaritis" es una enfermedad operativa que tiene diversas causas, que van desde sentimentales hasta económicas, pero en casi todas existe el orgullo de un CPT para quien efectuar un "go-arround" es una afrenta narcisística o una maniobra sub-standard.

El componente psicológico debe tratarse desde la psicología institucional, y el instruccional desde el Departamento Capacitación Profesional de los pilotos.

2.6. COCKPIT-RESOURCE-MANGEMENT:

La FAA por sugerencia del NTSB y la proppia OACI en la enmienda del 8 de setiembre de 1987 al anexo 6, recomiendan enfaticamente a las empresas dictar cursos de FFHH y CRM a todos sus pilotos. En otro "paper" en este seminario presentamos nuestros hallazgos sobre el tema

2.7. STRESS:

Este es otro capítulo del "Manual del Usuario" que si bien comenzó a escribirse hace 40 a#os por parte de Selye, todavía se siguen descubriendo los modos en que esta entidad psicofísica actua sobre la performance de las tripulaciones.

Recientemente Green(12) clasificó al stress al que esta sometido el piloto en: 1) Contextual u operativo ("environmental")
2) Reaccional agudo ("acute reactive")
3) Stress existencial ("vital stress")

Simmel et al.(28) sostienen que es el tercero el mas importante dado lo inmanejable de algunas situaciones, la cronicidad con que se establece, y lo difícil de cuantificar y prevenir, aparte de que no todos los pilotos reaccionan con la misma respuesta al mismo elemento estresante ("stressor"). Para cuantificarlo se han hecho varios intentos tanto retrospectivos como prospectivos mediante los clasicos questionarios sobre "Life Change Units", corriente iniciada por Holmes y Rahe(16) en 1967, al que siguieron trabajos Alkov(1), y Haaksohn(14) entre otros.

Pero recientemente ha comenzado a tomar jerarquía el segundo stress mencionado arriba, que suele tambien denominarse "time stress" (Anne Edland citada por Fahlgren)(7). Dice la autora: "Cuando se toma una decisión bajo "time stress" hay un cambio cognoscitivo producto de dos fenómenos: la cadena de pensamientos se interrumpe cuando expira el tiempo o se saltan pasos procesales y se altera el procesamiento de la información. ESTO SIGNIFICA QUE UN INDIVIDUO CAMBIA SU FORMA DE PENSAR Y PROCESAR LA INFORMACION CUANDO SE ENCUENTRA EN "TIME STRESS".

Resumiendo los diversos hallazgos descriptos en la literatura con relación a los efectos del stress sobre la performance podemos decir que:

1) Se pierde la visión periferica
2) Se reduce la capacidad de asimilar infromación auditiva
3) Se traba el procesamiento de la información
4) Se altera el juicio: se sobreestima o subestima la realidad
5) Se deteriora la aptitud para la toma de decisiones
6) Se obstaculiza el proceso de aprendizaje

Como dice Fahlgren, el 60% de las catastrofes aereas se producen en la aproximación y el aterrizaje, segmento del vuelo que insume sólo 4-5% del total del tiempo que el avión esta en el aire. El principal problema a resolver aquí es lo que se denomina "time stressed rushed approach", es decir aproximaciones con prisa y con time stress.

En esas condiciones, como vimos, el juicio del piloto no sólo estara alterado por la presión psicológica del "get-there-itis", sino que su capacidad para tomar decisiones se vera modificada porque por los tiempos acortados, debera procesar la información habitual en un menor espacio de tiempo (la "esfera activa" en la cual se mueve se transformara en un elipsoide), es decir mas información por unidad de tiempo, menos tiempo para efectuar las "check-lists" y los "callouts" y sumado a todo ello la modificación de los procesos cognoscitivos inadvertidamente, como se#alara Edland.

En los casos en que se presente una situación así en la aproximación final, la tripulación -sin falsos orgullos- debe adoptar la decisión alternativa anticipada en el "approach preparation": GO-ARROUND !!!...

2.8. ACTING OUT:

El termino Acting Out (AO) se refiere a una variedad de conductas caracterizadas por una incapacidad para abstenerse de la acción.

Otto Fenichel(9) fue quien presentó la mejor descripción sistematica del AO: "Una actuación que INCONSCIENTEMENTE libera tensiones internas y aporta una descarga parcial a impulsos rechazados (sin importar si estos impulsos expresan demandas instintivas directas o son reacciones a demandas instintivas originales, como por ejemplo un sentimiento de culpa)", la situación actual, de alguna manera conectada asociativamente con el contenido reprimido, se usa como ocasión para la descarga de la energía reprimida utilizando como mecanismo defensivo el "DESPLAZAMIENTO", elemento nocivo en la psiquis de todo piloto, cómo hemos observado en otras publicaciones (19,20).

AO en otras palabras, es una forma especial de recordar, en la que el antiguo recuerdo es re-actualizado de una manera mas o menos organizada y a veces de una manera apenas disfrazada. No es un recuerdo claramente consciente, ni hay conciencia que esa actividad especial este motivada por la memoria. Al sujeto, la conducta le parece plausible y apropiada, mientras que al observador y los propios colegas aparece como singularmente desproporcionada e inapropiada.

Parecerla que en el AO deberla haber especiales problemas en aceptar y entender la realidad actual ya sea porque 1) hay problemas especlficos en la situación real inmediata, 2) hay una persistente memoria de experiencias precoces perturbadoras, 3) hay una inadecuada percepción de la realidad.

Debemos diferenciar el AO aislado u ocasional, de aquella condición en la cual el AO es frecuente, habitual, o caracterlstico de tendencias evidentes a lo largo de la vida del sujeto. Es obvio que la impulsividad se basa en la ineptitud para tolerar la frustración, una particular alteración de la percepción de la realidad y de la autocrltica, conductas de caracterlsticas dramaticas que en su extremo parecen muy cercanas a la psicosis o las psicopatlas.

En la etiologla, al trauma precoz, la tendencia aloplastica y la fijación oral propuesta por Fenichel, Greenacre(13) agrega una tendencia a la dramatización o el exibicionismo y una importante aunque inconciente creencia en la magia de la acción. La necesidad de la dramatización puede ser uno de los factores mas influyentes para modificar una tendencia a los actos neuróticos en una tendencia al AO, ya que podrla fijar en la memoria, patrones de conducta organizados.

Ana Freud(10) enfatiza el hecho de que los AO ocurren en sujetos con defectos en el desarrollo yoico y superyoico que dificultan el control de los impulsos. Impl1citamente, tales defectos estan relacionados con la incapacidad de postergar la gratificación y de tolerar las presiones instintivas sin recurrir a la acción como forma de aliviar la tensión.

Un piloto con esta tendencia al "AO", ACTUARA sus conflictos o reaccionara inapropiadamente en situaciones de stress adoptando decisiones operativas inapropiadas. No se trata, una vez mas de "errores" sino de slntomas de una personalidad inapropiada para el pilotaje, no detectada en su momento por el pseudosistema de prevención.

2.9. LA CULTURA DE LA EMPRESA:

Podemos definir cultura como la "programación mental colectiva"(24). En la cultura del cockpit y en la cultura del grupo de pilotos de una empresa, suelen privilegiarse actitudes concordantes con la ideologla del "Right Stuff", competitivas, temerarias, etc. Se suele dar por sobreentendido que es mejor piloto el que "siempre sale" o "siempre entra" y suele catalogarse como sub-standard efectuar un QRF o demorar un vuelo por meteorologla.

Los jóvenes pilotos, a medida que se ven incorporando a la empresa no tienen otra alternativa que asimilarse à esa modalidad.

La "cultura" de la empresa va condicionando paulatinamente la conducta y el juicio operativos y la capacidad de tomar decisiones.

El mito del piloto invulnerable, que se mete en cuanta tormenta encuentre en su ruta y sale indemne, que despega o aterriza cualesquiera sean las condiciones meteorológicas, etc., en tanto modelo identificatorio legendario, debe ser definitivamente desplazado por el propuesto por los comandantes Sosa Riera y Elizalde Alcorta: el comandante "Director de Sistemas"(6, 29).

En Viasa, compa#la que sigue estrictamente los patrones instruccionales de KLM desde hace 28 a#os y no tuvo un solo accidente en toda su historia, se alienta permanentemente a los capitanes a efectuar una circulación o irse al "alterno" si las condiciones asi lo aconsejan. En este momento KLM contrata los pilotos de Viasa para que vuelen sus DC-10, pues sus propios pilotos estan pasando a equipos modernos.

3. DETECCION Y DIAGNOSTICO PRECOZ:

En aquel hipotetico "Manual del Usuario" que debe escribirse sobre las limitaciones operativas y psicofisiológicas del piloto deben discriminarse lo que podríamos denominar las "ALARMAS AMBAR" y las "ALARMAS ROJAS".

Instructores de vuelo, jefes de línea, colegas pilotos y medicos aeronauticos debemos estar mancomunados en la conciencia y la determinación de co-laborar en la erradicación de los factores de riesgo del sistema aeronautico y en la prevención de desajustes psicofisiológicos del piloto, que eventualmente lo conduzcan a incurrir en alguna "conducta insegura".

La siguiente lista se compuso a partir de otras publicadas por nosotros(18) y otros autores como Elizalde(6), Platenius(25), Voge(32), Reinhardt(26) y Alkov(2), en la médida que sus items nos resultaron aplicables a nuestro "aqui y ahora":

"ALARMAS AMBAR":

3.1. Antecedentes de fracasos escolares y profesionales.
3.2. Antecedentes de accidentes o incidentes en los que estuvo implicado el piloto como factor causal o contribuyente.
3.3. Accidente o muerte de algun compa#ero, amigo o pariente.
3.4. Enfermedad de familiares directos.
3.5. Problemas contextuales (económico-finanieros, habitacionales, etc.).
3.6. Personalidad introvertida y poco comunicativa.
3.7. Personalidad sin sentido del humor.
3.8. Personalidad con exceso de confianza y sin autocrítica. (Sd. del piloto infalible o del que se las sabe todas).
3.9. Personalidad impulsiva o con tendencia al "acting-out".
3.10. Personalidad con tendencia a bloquearse en condiciones de stress operácional agudo (emergencias).
3.11. Personalidad excesivamente obsesiva y controladora.
3.12. Rigida formación religiosa de corte moralista, conversión religiosa de tipo mistico-fundamentalista.
3.13. Tabaquismo, cafeinomania, automedicación.
3.14. Alcoholismo "social".
3.15. Falta de profesionalismo o motivación por el perfeccionamiento (Sd. del "chabacano").
3.16. Tendencia al vuelo temerario violando reglamentaciones. Tendencia a violar las reglas de transito.
3.17. Tendencia a mostrar sus habilidades en vuelo y considerarse el "master" (Sd. de Marconcini).
3.18. Tendencia a descubrir o inventar nuevos procedimientos. (Sd. del "desculamonos").
3.19. Dificultad con la crew-coordination (detectada por el numero de F/O que no desean volar con el).
3.20. Dificultades en la adaptación a un nuevo avión.
3.21. Dificultades en simulador de vuelo.
3.22. Imposibilidad de anticiparse al avión ("el avión le gana").
3.23. Manifestaciones del Sindrome de Desadaptacion al Vuelo (temor, excusas espurias para no volar, etc).
3.24. Desadaptación manifiesta a las pautas culturales del grupo de pilotos (desafiliación al gremio, no participación de actividades sociales del grupo, etc.).
3.25. Enfermedades organicas ocultadas a la autoridad medico-aeronautica que amenacen su aptitud o actuen inconscientemente atentando contra su NORMAL sentimiento de "invulnerabilidad".
3.26. Comprometido laboralmente en cuestiones o negocios extra-aeronauticos (Sd. de Testorelli)
3.27. Piloto presionado o presionable (Sd. del pasajero VIP).
3.28. F/O "castrado".
3.29. Fatiga de vuelo (aguda, acumulativa y crónica).
3.30. Falta de atención a su estado físico (Fitness), obesidad, sedentarismo, desaseo personal, etc.

"ALARMAS ROJAS":

3.31. Mas de tres ALARMAS AMBAR.
3.32. Cambio de caracter, particularmente hacia la depresión o la euforia excesiva, con tendencia a manifestarse invulnerable.
3.33. Alcoholismo y otras adicciones (US.Air de La Guardia '89).
3.34. Compromiso sentimental conflictivo (pareja paralela sin resolver el divorcio previo, etc.).
3.35. Contexto laboral caótico: inestabilidad laboral, conducción arbitraria, etc.
3.36. Tripulación caracterial u operacionalmente incompatible.

4. PREVENCION:

Como insistimos en otra publicación (18), en la medida que consideremos al piloto (o mejor a la tripulación) el "liveware" del sistema aeronautico, y apliquemos para su intelección y administración la misma filosofla sistemica usada para el resto del "airline business", caeremos en la cuenta que NO HAY ERRORES DE PILOTAJE. Hay conductas inseguras que pueden prevenirse implementando un objetivo operativo:

NADA INESPERADO DEBE OCURRIRLE A UÑA TRIPULACION

Para lo cual es necesario instruirla en el manejo de sus propias variables y limitaciones operacionales y psicofisiológicas, mediante la implementación de:

4.1. Un sistema de prevención sistemico que reemplace al actual pseudo-sistema de compartimentos estancos y de caracterlsticas policlaco-persecutorias.

4.2. Criterio de selección de pilotos ab-initio no "instantaneo" sino "procesual". La aptitud psicofisiológica inicial deberla otorgarse "ad-referendum" del desempe#o del alumno-piloto en el proceso de aprendizaje, y eventualmente, deberla ser reexaminado si se detectan fallas en la adquisición de las habilidades y conductas propias del vuelo seguro. Menos "fomento"y mas rigurosidad "ab-initio"

4.3. Reseleccionar a los Pilotos-Instructores de todas las categorias. Uniformar los criterios instruccionales. Instruir a los instructores en FFHH. Deberla formarse una asociación de instructores con requisitos para incorporarse y mantenerse, con un código de etica y una nueva subcultura de valores y tradiciones(30).

4.4. Establecer un sistema de feed-back informativo entre instructores y medicos examinadores o gabinetes psicofisiológicos, a los efectos de mantener bajo observación a los pilotos que tengan en sus "tableros" encendida alguna "alarma ambar".

4.5. Crear un dispositivo de diagnóstico y "puesta a punto" de los pilotos profesionales que esten "al borde de la perdida".

4.5. Efectuar todos los esfuerzos posibles en la concienciación, actualización teórica y entrenamiento en simulador de los pilotos de todas las categorlas.

4.6. Realizar evaluaciones periódicas tanto de los instructores como de los pilotos, que los obligue a mantenerse actualizados y entrenados.

4.7. Propender a la EXCELENCIA tambien en el pilotaje.

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The Effect of Passenger Motivation and Cabin Configuration on Aircraft Emergency Evacuations

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INTRODUCTION

The public demand for air transportation has increased steadily over the last two decades and the civil aviation industry has adapted and grown to meet this demand. During the same period the industry has steadily reduced the accident rate (ref 1) and the public now perceive air travel to be a relatively safe and reliable form of transportation.

Unfortunately, the dramatic reduction in the overall accident rate has not been accompanied by an equivalent reduction in the fatality rate of those onboard an aircraft which is involved in an accident. Thus, one of the objectives of new or modified safety regulations, requirement or procedures must be to increase the probability of survival in aircraft accidents.

Recently in the UK, a number of steps have been taken by the Civil Aviation Authority to achieve this objective. These have included regulations relating to the introduction of fire blocking materials for aircraft seats, floor proximity lighting, smoke detectors in the toilet compartments, crew rest areas and cargo holds, together with additional access at the overwing exits. The objective to improve passenger survival rates has also led to a demand for human factors evaluations of new and existing safety provisions. It is hoped that if we had a better understanding of behaviour, in conditions which for many people are highly stressful and disorientating, we could determine which additional steps should be taken to improve the probability of a successful evacuation of all passengers from the aircraft.

Whilst no two accidents can ever be the same, it is possible to learn from the similarities and differences between the causes of the accidents, their location and the environmental conditions present, the types of passengers onboard and their responses to the emergency. For instance, there were many similarities between the accident which occurred at Manchester in 1985 and the one which occurred at Calgary in 1984, in that they were both caused by an engine fire at take off. However, they differed in one important respect, namely that at Manchester there were 55 fatalities whereas in Calgary everyone survived. We know that in some aircraft accidents everyone files out of the plane in a rapid although orderly manner. For example, in the evacuation of a British Airways 747 at Los Angeles in 1987 as a result of a bomb scare. In other accidents however, the orderly process is not adhered to and confusion in the cabin can lead to blockages in the aisles and at exits, with a consequent loss of life.

From the reports of a number of accidents it is possible to build up a picture of the exits typically used by passengers who survive an emergency where there is smoke and fire, as can happen following crash landing.

From this we know:

(a) that some passengers exit by their nearest door, as would be expected.

(b) that other passengers do not exit by their nearest available door but travel for considerable distances along the cabin, e.g.extreme cases of back to front. Why and in which circumstances do they choose to do this?

(c) that other passengers apparently near exits, do not survive. Do they panic and freeze, give up, get crushed by other people from behind or around, do they have their seat backs pushed onto them?

(d) we also know that blockage can occur in the aisles and at exits in some accidents, when this does not occur in evacuation demonstrations for certifications.

There are in fact a great many questions which as yet we are not able to answer about the behaviour of people in emergencies, including the important question of why in some accidents the passengers evacuate in an orderly manner, and in other accidents the behaviour is disorderly.

It is suggested that one of the primary reasons for the differences in behaviour, between the orderly and disorderly situations must rest with the individual motivation of the passengers. In some accidents as in the aircraft certification evacuations, all of the passengers assume that the objective is get everyone out of the aircraft as quickly as possible, and they therefore all work collaboratively. In other emergencies, however, the motivation of individual passengers may be very different, especially in the presence of smoke and fire. In a situation where an immediate threat to life is perceived, rather than all passengers being motivated to help each other, the main objective which will govern their behaviour will be survival for themselves, and in some instances, members of their family. In this situation when the primary survival instinct takes over, people do not work collaboratively. The evacuation can become very disorganised, with some individuals competing to get through the exits. The behaviour observed in the accident which occurred at Manchester, and other accidents in the UK, including the fire at the Bradford City football stadium and the Zeebrugge ferry disaster, supports this theory. In fact in the Zeebrugge disaster some adults pulled children off life rafts in order to survive.

The cabin safety research programme at Cranfield has been sponsored by the UK Civil Aviation Authority (CAA) and was inititated in 1986.

The CAA commissioned Cranfield to conduct an experimental programme, to investigate the influence of certain cabin configurational factors on the behaviour of passengers in situations where the evacuation process had become disorderly. The objective of the research was to assess the effect on passenger behaviour and flow rates during simulated emergency evacuations of:

(a) The influence of increasing the width of the passageway through the floor to ceiling bulkhead leading to floor level Type I exits, on the time taken for passengers to evacuate the aircraft.

(b) The extent to which an increased distance between the seat rows adjacent to the overwing exit, or the removal of the outboard seat beside the overwing exit, would improve the rate at which passengers could pass through the exit in an emergency.

In any research programme in which the objective is, to investigate accident or emergency escape behaviour (from either fires in aircraft, motor vehicles, fires in buildings, etc.) there is a primary dilemma: how to introduce sufficient realism into the experimental programme, whilst at the same time not putting people at serious physical and perhaps mental risk? It is the trade-off between safety and realism which is always the challenge for researchers faced with the task of investigating the human response to safety provisions for use in emergency situations, such as fire on aircraft.

For both ethical and practical reasons it is not possible to put members of the public in a situation of fear and threat for the purpose of research. However, a technique used in laboratory work in behavioural science is to offer an incentive payment to volunteers. This is done in an attempt to influence the motivation and performance of individuals either individually or in groups.

Two independent series of evacuation trials were conducted which included tests of all of the configurations under consideration. In the first test series, a system of bonus payments was introduced in order to increase the individual motivation of the volunteers to get out of the aircraft as quickly as possible. In the second test series all of the volunteers were simply told to evacuate the aircraft as quickly as possible and no bonus payments were made. The bonus payments were introduced in order to simulate experimentally the competition which is known to occur between people trapped in a confined space fighting for their lives. The second test series (in which no incentive payments were made) was conducted in order that comparisons could be made between the evacuation rates for the configurations being evaluated in the first test series and the evacuations conducted by the airframe manufacturers at the time of aircraft certification.

It was anticipated that with the data from the experimental programme of evacuations, it would be possible to determine whether there was an optimum aisle width through the bulkhead leading to the Type I exit, or an optimum seating configuration adjacent to the Type III exit.

METHOD

A Trident Three aircraft permanently sited on the airfield at Cranfield Institute of Technology was used for the evacuations. Volunteers from the public were recruited in groups of approximately sixty to take part in evacuations from the Trident. The aircraft provided an element of realism which was considered necessary. Additionally, the aircraft had a similar cabin layout, to many of the narrow bodied aircraft in operation at the time of the investigation.

a) Evacuations through the bulkhead

The following configurations were assessed:

(i) The international minimum, a width between the galley units of 20 inches (51cm)

(ii) A bulkhead which is typically seen on aircraft, a width between the galley units of 24 inches (61cm)

(iii) A width between the galley units of 27 inches (68cm)

(iv) A width between the galley units of 30 inches (76cm)

(v) A width between the galley units of 36 inches (91cm)

(vi) Port galley totally removed

The configurations are illustrated in Appendix A..

The flow of volunteers through the bulkhead was of prime importance in the evaluation of the optimum width between the galley units. It was therefore important that the number of volunteers attempting to reach the bulkhead was not influenced by a blockage at an exit downstream of the bulkhead. Consequently, both of the port Type I exits forward of the vestibule were utilised in all of the evacuations through the bulkhead. (See Appendix B).

In order to direct the volunteers in a way which would ensure that the only restriction to the rate of evacuation was that of the bulkhead, a member of cabin staff was positioned in the vestibule area forward of the bulkhead in order to direct passengers to the exits. (See Appendix B).

In order to avoid any interaction between the seating configuration at the overwing exit and the evaluation of the impact of the width between the bulkheads, the seating layout through the aircraft remained constant during all of the evacuations through the bulkheads.

The behaviour of passengers using evacuation chutes and their associated flow rate was not within the scope of this investigation. The use of ramps, rather than chutes, eliminated this variable from the design. It also removed the risk of volunteers being injured whilst using the chutes.

Evacuations Through the Type III Overwing Exit

The following configurations were assessed:

(i) The minimum configuration complying with CAA standards prior to Airworthiness Notice No. 79, which is also the FAA minimum standard, with a seat pitch of 29 inches (73cm) and a vertical projection between the seat rows of 3 inches (7.6cm). The outboard seats in the rows bounding the exit were modified to allow minimal recline and break-forward movement.

In conditions (ii) to (vii), the movement of the backs of the seats in the rows bounding the routes to both the port and starboard, Type III exits were restricted. The limited recline and break-forward of seats, ensured that the configuration were in accordance with the specifications of Airworthiness Notice No. 79. The configurations are illustrated in Appendix C.

(ii) A configuration in which the access to the exit between the seat rows was 3 inches (7.6cm) with a corresponding seat pitch of 29" (73cm).

(iii) The CAA standard in Airworthiness Notice No. 79 paragraph 4.1.2 (ref 2) in which 'Seats may only be located beyond the centre line of the Type III exit provided there is a space immediately adjacent to the exit which projects inboard from the exit a distance no less than the width of a passenger seat and the seats are so arranged as to provide two access routes between seat rows from the cabin aisle to the exit'. In the research programme the seat row adjacent to the exit had the outboard seat removed and the seat rows fore and aft of the Type III exit were at a seat pitch of approximately 32 inches (81.2cm), with the vertical projection between the seat rows being 6 inches (15.2cm).

(iv) The CAA standard, specified in Airworthiness Notice No.79, paragraph 4.1.1 (Ref 2), in which 'All forward or aft facing seats are arranged such that there is a single access route between seat rows from the aisle to a Type III exit, the access shall be of sufficient width and located fore and aft so that no part of any seat which is beneath the exit extends beyond the exit centre line and the access width between seat rows vertically projected shall not be less than half the exit hatch width including any trim, or 10 inches, whichever is the greater'. In the research programme the seats fore and aft of the Type III exit were at a seat pitch of approximatly 39 inches (99cm), with the vertical projection between the seat rows being 13 inches (33cm).

(v) A configuration in which the access between the seat rows vertically projected was approximately 18 inches (46.1cm), with a corresponding seat pitch of 44 inches (111cm).

(vi) A configuration in which the seat pitch between the seat row fore and aft of the exit was 51 inches (129.5cm). The resultant vertical projection between the seat rows was 25 inches (63.5cm).

(vii) A configuration in which all of the seats located in line with the exit were removed, leaving a pitch of approximately 60 inches (152cm) between the seats fore and aft of the exit. The resultant vertical projection between the seat rows was 34 inches (86.3cm)

The configurations are illustrated in Appendix C.

In all of the evaluations of the seating configurations adjacent to the Type III exit, the egress took place through the port overwing exit. (See Appendix B). Although it had initially been suggested that there might be differences between the ease of egress through the port and starboard exits, data which had been collected by the FAA indicated that laterality of exits did not affect the rate of evacuation (Ref 3). The FAA report indicated that an interaction was obtained between the method of opening the Type III exit and the seat configuration on egress rate. To remove this interaction, the method of opening the exit was held constant throughout the trials. This was achieved by a member of the research team being employed to open the exit and hand it to a trained observer on the wing.

PROCEDURE

As has already been indicated, the experimental programme comprised two separate series of evacuations involving volunteer members of the public. The first series included making bonus payments to the first half of the volunteers to evacuate the aircraft (competitive evacuations). In the second series no bonus payments were made and the procedure for the volunteers was the same as in an aircraft certification test (non-competitive evacuations). The procedure for each of the test series will be described separately.

Competitive Evacuations

Volunteers were recruited in groups to take part in an experimental session which comprised four evacuations from the Trident aircraft. In two of the evacuations all of the volunteers passed through the bulkhead and evacuated through the Type I exits and in two of the evacuations all of the volunteers evacuated through the port Type III overwing exit. The configurations were all tested on a minimum of eight occasions, with the exception of the configuration (b)(ii) above. This was considered to be of secondary importance and was tested on four occasions.

The test programme involved 28 separate test days of four evacuations. In order to account for the effects of fatigue and practice the order in which the configurations under review were tested, was systematically varied using a counterbalanced design based on a latin square. Although the volunteers were told that they would be required to take part in some evacuations from the aircraft, they were not given any information about the configurations under review, or the order in which the evacuations would be performed.

The volunteers were members of the public. They were recruited by local advertising and were told that they would be paid a £10 attendance fee after they had completed four evacuations. The volunteers were instructed that their task was to evacuate the aircraft as quickly as possible once the exits had been opened by the Cranfield staff. In addition a £5 bonus would be paid to the first half of the volunteers to pass through the exits which were used on each evacuation.

The bonus payments were made immediately after each evacuation. The seating plans which were developed for the volunteers on the four successive evacuations from the aircraft, gave each volunteer an equal chance of receiving the monetary incentive. Volunteers were not allowed to take part in a test session more than once in any six month period (this requirements is also specified for volunteers taking part in evacuation for aircraft certification).

The safety of volunteers was an important consideration. To this end, only volunteers who claimed to be reasonably fit and were between the ages of 20-50 were recruited. On arrival all volunteers were given a medical examination. They were also asked to complete a questionnaire indicating that (i) they had fully understood the purpose of the trials, (ii) the medical information which they had supplied was correct and (iii) that they were satisfied with the insurance cover. A doctor and the airfield fire service were present at all times. A system of alarms was employed to stop any evacuation should a real emergency occur or should there be concern for the safety of any volunteer.

In order to introduce as much realism as possible, not only did the evacuation take place from a real aircraft, but on their arrival at the airfield the volunteers were met by members of the research team trained and dressed as cabin staff. After boarding the aircraft, they were given a standard pre-flight briefing by the cabin staff, they then heard a sound recording of an aircraft starting up and taxiing to a runway. This sequence of recording lasted for approximately five minutes before giving way to the simulated sounds of an aborted take-off. This sequence was subsequently followed by a period of silence, in which time the pilots were supposedly shutting down engines and liaising with the cabin staff. The shut down period was predetermined for each evacuation, being either 7 or 25 seconds. The variation ensured that the subjects could not anticipate the precise time at which the call to evacuate would be given. On the command 'Undo your seatbelts and get out', the appropriate exits were opened by research personnel and the volunteers evacuated the aircraft.

After each evacuation all of the volunteers were required to complete a questionnaire indicating the route which they had taken from their seat to the exit, whether any person or object had hindered their progress and their assessment on a scale of 1 to 10 of the difficulty of their evacuation. Additional questions were included on the questionnaire completed after the fourth evacuation asking volunteers for information about whether they had adopted or changed their strategy for egress during the course of the evacuations. Demographic information relating to each volunteer's age, sex, height and weight was also collected.

Non-competitive Evacuations

Volunteers were recruited in groups of approximately sixty to take part in one experimental session which comprised two evacuations from the Trident aircraft. In one of the evacuations all of the volunteers passed through the bulkhead and evacuated from the aircraft through either of the two Type I exits. In the other evacuation, all of the volunteers evacuated through the port Type III overwing exit.

The six bulkhead configurations at the entrance to the galley unit and the overwing seating configuration (ii)-(vii) which were tested in the competitive evacuations, were each tested on two occasions. The test programme involved 12 separate test days of two evacuations. In order to account for the possible effect of practice, the order in which configurations under review were tested was systematically varied using a counterbalanced design. As in the competitive evacuations, the volunteers were told that they would be required to take part in some evacuations from the aircraft, but they were not given any information about the configuration under review, or the order in which the evacuations would be performed. On arriving at Cranfield they were told that they would be paid a £10 attendance fee after the had completed the two evacuations. The volunteers were instructed that their task was to evacuate the aircraft as quickly as possible once the exit(s) had been opened by the Cranfield staff.

After the competitive and non-competitive evacuations, before the volunteers left the site they were given a debriefing in which they were reminded of the safety of air travel and advised that they should get back in touch with Cranfield if they experienced any physical or mental problems as a result of the evacuations. At the end of the the test programme the volunteers were invited to return to Cranfield to attend a lecture about the work in which they had participated. This feedback to volunteers proved to be very popular and was a useful source of volunteers for other investigations.

A report including a description, methods and results may be obtained from the UK Civil Aviation Authority.(ref 3).

RESULTS

Competitive Evacuations

In the test series of competitive trials the final data base included information from 110 evacuations, of which 56 were through the bulkhead and 54 were through the overwing exit. Deteriorating weather conditions, poor quality video recording and damage to seating during preceding evacuations caused four evacuations to be omitted from the programme. Five evacuations were abandoned because blockages of people in the overwing exit caused the safety officer to consider it to be dangerous to contine. Two evacuations through the bulkhead were terminated when a volunteer fell and would have been trampled upon if the evacuation had continued. Thus data was not obtained from eleven of the planned evacuations. Over the trial series 1558 volunteers took part with an average of 55 participants on each test day. The mean age of the participants was 28.8 years and 71% were male.

The seating in the cabin was designed so that all volunteers would have an equal chance of receiving the bonus payments on two out of the four trials in which they took part. In practice, individual differences in behaviour meant that this did not occur. Table 1 indicates the frequency with which volunteers received the bonus payments.

Table 1 Age and sex of volunteers achieving bonus payments

No of bonuses	% of volunteers	% of males	Mean age (yrs)
0	12.2	56.7	29.0
1	17.2	67.2	29.8
2	37.3	73.5	29.0
3	24.6	76.6	28.4
4	8.7	82.1	27.3

Evacuations through the Bulkhead

Passenger flow rates through the exits were obtained from the video recordings. The evacuation times for each of the volunteers to pass through one of the exits were taken from the call to evacuate the aircraft rather than from the elapsed time from the first individual to reach the exit. Statistical analysis indicated that there was no significant difference between the results from the two methods. The evacuation times have been compared for the first thirty to pass through the exits used. These times were used as the criteria for determining the evacuation flow rate for each of the configurations tested. Since the bonus payments were only available to the first half of the volunteers to reach the exits, (approximately thirty), it was assumed that many of the volunteers reaching the exits in the latter half of the group had realised that they would not receive a payment and had therefore stopped competing. For this reason their data was not included in the analysis.

Table 2 Mean evacuation time for the thirtieth individual (time in seconds)

	Evacuation	
Bulkhead Aperture	Mean	SD
i) 20"	26.3	2.9
ii) 24"	24.5	5.8
iii) 27"	23.2	7.1
iv) 30"	18.4	1.9
v) 36"	17.2	3.1
vi) PGR	14.7	1.4

SD = Standard deviation associated with the mean

PGR = Port galley removed

As the means suggest, statistical treatment of the data indicated that as the aperture in the bulkhead was increased, the evacuation rate increased, leading to a reduction in the time for the first thirty individuals to evacuate the aircraft (F511 = 10.5 p<0.001*). There was no significant difference between the times for the first or second evacuations through the bulkheads which the individual groups of volunteers completed (F1,11 = 0.001NS). The individual comparisons of means indicated that there was a significant difference between the mean times when the aperture in the bulkhead was 27" or less, and the mean times when this aperture was 30" or greater.

Evacuations through the Overwing Type III Exits

As in the analysis of the evacuation times through the bulkhead, the evacuation times for the first thirty volunteers to pass through the exit have been compared for the range of configurations tested.

Table 3 Mean evacuation time for the thirtieth individual (Time in Seconds)

Vertical Projection	Mean	SD
i) 3"	83.9	9.7
ii) 3"	71.4	15.0
iii) 6"(OBR)	53.2	10.0
iv) 13"	55.9	10.3
v) 18"	53.7	8.2
vi) 25"	54.9	11.5
vii) 34"	62.3	8.1

SD = The standard deviation associated with the mean

OBR = Outboard seat removed

Note: In conditions (ii) to (vii) - all the seats in the rows adacent to access to the exit had limited recline and break-forward but, in condition (i) the movement of only outboard seat backs was restricted.

Blockages led to the abandonment of certain of the evacuations through configurations (i) and (iii). As a result the data for the second evacuation conducted on each test day are based on a sample of one for condition (i) and a sample of 2 for condition (iii).

As the means suggest, the statistical treatment of the data indicated that the seating configuration had a significant effect on the mean evacuation times ($F_{6,1} = 7.0 p<0.001$). Comparisons for the first and second evacuation times were not significantly different ($F_{6,1} = 0.9$NS).

Individual comparison of means indicated that the time for the first thirty volunteers to egress through the configuration involving a 3" vertical projection (ie pre Airworthiness Notice No.79), was significantly longer than the evacuation times for all of the other configurations.

The data from the configuration with the 6" vertical projection (condition (iii)) has not been included in this figure. In this condition the removal of the outboard seat meant that rather than being a single aisle with a 6" vertical projection adjacent to the exit which would be comparable with the other configurations tested there were two aisles with 6" vertical projections leading to the exits.

The Non-competitive Evacuations

In the test series of evacuations not involving bonus payments, the final data base included information from 24 evacuations. Twelve evacuations were through the bulkhead (2 evacuations were conducted for each of the 6 configurations tested) and 12 evacuations were conducted through the Type III overwing exit (2 evacuations for each of the configurations tested). Over the series of trials 704 volunteers took part. The volunteers were aged between 20 and 50 and 63% were male. All of the planned evacuations were successfully completed as it did not become necessary to halt any of the evacuations as a result of blockages, damage to the equipment or concern for the safety of volunteers.

As in the competitive evacuations, passenger flow rates through the exits were obtained from the video recordings with the evacuation time for each volunteer being taken from the call to evacuate the aircraft rather than from the elapsed time from the first individual to reach the exit.

Evacuations through the Bulkhead

Comparisons between the mean evacuation times for the six configurations tested were conducted for the first thirty individuals through the exits. This was in order that the analysis would be comparable with that carried out for the competitive evacuations.

Table 4 Mean evacuation times for the thirtieth individual (Time in seconds)

Bulkhead Aperture	Mean	SD
20"	25.1	2.0
24"	21.8	1.4
27"	23.7	2.7
30"	23.4	0.0
36"	21.4	3.4
PGR	17.6	0.5

PGR = Port galley removed

At first sight, the means suggest that increasing the width of the aperture through the bulkhead leads to a small reduction in the evacuation times. However, statistically there was no significant difference between the mean evacuation times for the first thirty to evacuate the aircraft (F5,11 = 3.2NS) through the six configurations, however this result may have been due to the fact that only two evacuations were conducted through each configuration.

Evacuations through the Overwing Type III Exits

Table 5 Mean evacuation times for the thirtieth individual (Time in seconds)

Vertical Projection	Mean	SD
3"	53.2	1.8
6" (OBR)	39.6	2.5
13"	39.9	3.3
18"	37.2	0.2
25"	40.8	2.7
34"	35.3	0.6

OBR = Outboard seat removed

SD = Standard deviation associated with the mean

The means suggest statistical treatment of the data indicated a significant difference between the main evacuation rates for the various configurations. (F5,11 = 16.84p<0.01).

Individual comparisons of means indicated that the seating configuration involving a 3" vertical projection gave rise to significantly increased evacuation times when compared to any of the other configurations.

Comparison between the Competitive and non-Competitive Evacuations

Table 6 Competitive and non-competitive mean evacuation times for the thirtieth person to exit over the six bulkhead conditions.

Competitive Trials			Non-Competitive Trials	
Bulkhead Aperture	Mean	SD	Mean	SD
20"	26.3	2.9	25.1	2.0
24"	24.5	5.8	21.8	1.4
27"	23.2	7.1	23.7	2.7
30"	18.4	1.9	23.4	0.0
36"	17.2	3.1	21.4	3.4
PGR	14.7	1.4	17.6	0.5

PGR = Port galley removed

SD = The standard deviation associated with the mean

The mean times show that for the 20" and 24" bulkhead apertures the times for thirty people to exit were a little faster in the non-competitive trials. For the remaining widths, the times were faster in the competitive trials. Statistical analysis indicated that there was an overall difference between the means for the six configurations (F5,1 = 11.87 p<0.01). The total of 12 non-competitive evacuations as opposed to 56 competitive evacuations meant that no significant difference was found between the means for the competitive and non-competitive evacuations.(F5,1 = 0.2NS).

Table 7 Competitive and non-competitive mean evacuation times of the thirtieth person to exit over the six overwing conditions.

Competitive Trials			Non-Competitive Trials	
Vertical Projection	Mean	SD	Mean	SD
3"	71.4	15.0	53.2	1.8
6"(OBR)	53.2	10.0	39.6	2.5
13"	55.9	10.3	39.9	3.3
18"	53.7	8.2	37.2	0.2
25"	54.9	11.5	40.8	2.7
34"	62.3	8.1	35.3	0.6

OBR = Outboard seat removed

SD = The standard deviation associated with the mean

As can be seen from the means, the times to evacuate thirty passengers were slower in the competitive trials for all of the configurations tested (F5,1 = 37.99p<0.001).

There was also an overall significant difference between the means for the six configurations (F5,1 = 9.28p<0.001).

CONCLUSIONS

1. The experimental programme successfully met the objective to produce a series of simulated emergency evacuations in order to explore the influence of (a) increasing the width of the aperture in the bulkhead at the entrance to the galley vestibule leading to the Type I exits and (b) increasing the distance between seat rows next to the Type III overwing exit.

2. The results from the programme of evacuations involving competition between passengers suggested that increasing the width of the aperture through the bulkhead will lead to an increase in the speed at which passengers can evacuate the aircraft in an emergency. The fact that the evacuation times for the 20", 24" and 27" apertures were

significantly slower than those for the 30" and 36" configuration, suggest that consideration could be given to a minimum width of 30" for a passageway through a bulkhead.

3. The results from the evacuations through the Type III overwing exit, indicated that changes to the distances between the seat rows either side of the exit will influence the speed of the evacuation.

4. The configuration flown by UK and other operators prior to the publication of Airworthiness Notice No. 79 was shown to reduce the evacuation rate and to cause serious blockages.

5. The configuration in which a seat row is completely removed was found to produce slower evacuation flow rates than those with a vertical projection between the seat rows ranging from 13" to 25".

6. The two alternative minimum requirements specified for the seating configuration beside the overwing exit in Airworthiness Notice No. 79, were shown to have significantly increased the rate at which passengers can evacuate an aircraft in a simulated emergency.

7. The CAA minimum (in AN79) in which the outboard seat was removed, gave rise to a rapid evacuation flow rate. However not only did this configuration have a tendency to give rise to blockages, but the opening and disposing of the exit was found to be more difficult in this configuration.

8. Further investigation are recommended to investigate the influence of (i) the seating configuration on the ease of operating the exit and (ii) the positioning of the hatch in the cabin on the evacuation rate.

9. The results from a comparison of the video data from the competitive and non-competitive evacuations indicated that the non-competitive evacuations provided an effective simulation of passenger behaviour in precautionary evacuations, and in aircraft evacuations when the physical conditions in the cabin have not deteriorated.

10. The introduction of incentive payments to volunteers, successfully induced a simulation of the behaviour reported to occur among passengers, when conditions in the cabin are perceived to be life threatening.

11. The use of incentive payments to produce a competitive evacuation has been shown to have the potential to provide both the behavioural and statistical data required for the assessment of design options or safety procedures for use in emergency evacuations which maximise the degree of realism. Nevertheless the technique should be used sparingly since it can be potentially hazardous for volunteers.

FUTURE RESEARCH

A further stage of the Cranfield programme has recently commenced. This involved replicating the evacuations conducted in the previous investigations using the same cabin configurations. The main factor which differed in these evacuations was that prior to the call to evacuate the aircraft the cabin was filled with non-toxic smoke. These evacuations were conducted in order to determine whether the configurations which give rise to rapid evacuation rates in clear air would also be the preferred configurations when there was smoke in the cabin and volunteers are unable to see their way clearly to the exits. For reasons of safety the number of volunteers in the cabin at any one time was restricted to thirty.

A system of auditory attractions to indicate the exits to be used in the evacuations is currently being developed by the Medical Research Council, Applied Psychology Unit, Cambridge in conjunction with the Institute of Sound and Vibration Research at Southampton University. It is hoped that an initial evaluation of the potential benefits of this system can be incorporated into a later stage of the programme.

It is hoped that in 1990 a series of tests in which the factors influencing the rate at which members of the public can open a Type III overwing exit will be conducted. In addition to the programme of research into passenger evacuation behaviour, a programme of research into the factors which influence passenger knowledge of the aircraft safety information has been initiated.

The paper has included an overview of the main programmes of research which have been instigated by the CAA at Cranfield. The Applied Psychology Unit have also been involved with other aspects of human factors in cabin safety. This has included both the selection, health and fitness of cabin staff and evaluations of the human response to systems for use in aircraft fires.

There are many other important areas for research in the field of cabin safety since there remain many unanswered questions. These include factors such as the influence of the behaviour of the cabin staff or the influence of the seating location of certain types of passenger on evacuation rates. However, there is now no doubt that the initative which has been taken by the UK CAA by instigating Cranfield in the field of cabin safety, will be closely followed by the aviation industry in all parts of the world.

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30 YEARS OF JET LOSSES - CONCLUSIONS REGARDING HUMAN FACTORS RESEARCH

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I FOREWORD

Looking back at 30 years of regular air transport in big jets above 20 tons which started in 1959 with DC-8 and B-707, we have been accumulating statistical data of sufficient numbers which enable us to gain knowledge to improve flight operation. 392 western built jet aircraft have been lost in normal operation (disregarding war, sabotage, test and training) from 1959 to 1988 either by complete destruction or damage beyond economical repair. They are representing a ghost fleet which belongs to the insurers, but left a tragic trace that affected men, companies and states, claiming the lives of 15198 passengers and 1471 crew.

It is our duty to use these empiric experiences of the past to build up a prophylactic scheme of avoidance strategies to be used by manufacturers, operators, aircrews and supervisory authorities. It is a sad experience that so very often we fail to foresee a potential hazard in the industry and that we then are forced to react after the mishap occurred and people and companies paid a terribly high price for this knowledge. On the other hand, economical pressure seems to be forcing companies and states to reduce spending money in prophylactical tactics and to invest only in the absolute minimum they are required to by regulatory bodies. This is a short-sighted policy but nevertheless you have to expect reactions like that in the struggle for survival under deregulated or liberalized conditions or otherwise increased economical shortages..

The overall situation is characterized by a booming air transport industry propulsed by the endeavour to conquer routes and slots and gatepositions, to show the flag on prosperous markets, to win market shares. The enormous increase in traffic due to decreasing regulation led to a high demand of aircraft which are not immediately available and therefore older types have to serve longer; fierce competition resulted in financial pressure and an increased demand of aircrews which cannot be trained fast enough to man the expanding fleets. Due to double digit growth rates companies recruit hastily whatever is available on the market; the air traffic control system, which has not been prepared equipment - and staffwise to cope with this situation has often reached its limits or even sometimes collapsed.

We are therefore facing a situation in which we are sharing the overcrowded and insufficiently supervised and controlled airspace with more and more companies with increasingly old aircraft, manned by sometimes inexperienced, hastily recruited and minimally trained crews, causing more stress, fatigue and motivation problems for all in the system. The dramatically changing working environment ahead of us and provided with the knowledge gained by the experiences of the past, what can we do to keep the overstressed system working safely or even improve the present standard?

II SAFETY AND HUMAN FACTOR

When saying this, it flashes through my mind that this word "safety" is often misunderstood and abused. Ultimate safety is unachievable and means death, the absolute absence of risk. I understand safety to be the acceptable amount of controllable risk. Whenever the engines are started and taxying is commenced, a certain risk is involved and accepted.

Civil aviation safety must be the major objective of ICAO. Following the 1986-Resolution A 26-9 the Air Navigation Commission stated the necessity to make "States more aware and responsive to the importance of human factors in civil aviation operations". In this context "Human Factors" was defined as the systematic application of the principles of human sciences and engineering to optimise the relationship between people and their activities, in their working and living environments.

But before we are able to optimise, we have to investigate and understand what happened prior to and during an accident - and there we are looking back to a large scale deficiency in the past. There is nearly not a single accident report available in which the human factors multi disciplinary field of physiology, medicine, psychology, sociology, anthropometry and engineering was properly covered when the causal factor was defined to be the cockpit crew. Human behaviour and performance, resource management, decision making and other cognitive processes seldom underwent in-depth investigation. Design of controls and displays, flight deck and cabin layout, communication and software aspects of maps, charts, documentation and notification as well as the refinement of staff selection and training were rarely touched.

The statistics of the past 30 years of western-built jet losses of big commercial jets over 20.000 kg offer us definite clues where the weak spots are and what to do about it. And: we could have done it earlier and most probably could have avoided a number of accidents which ranged from disaster to catastrophy.

III STATISTICAL BACKGROUND

World-wide we lost an average of 13 big jets over 20.000 kg per year over the last 30 years. Since the productivity shown in million hours flown increased steadily and at a high margin during the last 5 years,
the hours flown per total loss increased too.
While the average over the last 30 years was 785.000 hours per total loss, this average for the last 5 years alone rose to an unexpected 1,528 million hours, but will drop considerably for the 5 year-period including 1989 due to a very bad record in the last year.

With more and more aircraft produced and in service, a rising tendency of losses in absolute figures has to be expected, however the trend of flight hours produced is rising more steeply than the trend of total losses, thereby indicating that flying big jets statistically became safer.

Also regarding sectors flown per total loss we observe a positive trend towards better safety. While we lost nearly 2 aircraft per 1 million sectors (or departures) over the 30 year period, we narrowed this figure down to 1 aircraft only during the last 5 years. However it can be seen, that this trend has been reversed, leading to 20 lost jets 1988, the third worst figure in 30 years, and again 20 in 1989.

But positive results are also experienced by the individual line pilot. Long periods without incidents lead to over-confidence, complacency, low risk awareness and sloppiness.

Even without statistical data it can be assumed, that we are loosing the majority of our airplanes on our near the ground, simply because there's where the obstacles are. Over the 30 years the most endangered flight phase world-wide was Approach with 32,1 % of all lost jets, followed by Landing with 24,7 % and Take-off with 23,7 %. During the last decade from 1979 to '88 this trend changed and made Landing with 32,9 % the dominant phase, followed by Approach with 24,8 %.

The risk during Approach obviously can be better controlled now: The procedures were refined, more runways equipped with highly calibrated precision approach aids that allowed more automatic landings; call out procedures for altitudes hightened the awareness of the crews ,windshear and microburst were better understood and trained for, charts got more precise, and GPWS was implemented. But landing losses increased by nearly the same percentage and in absolute figures as the approach losses were reduced. 1987 was a typical year: The majority of all cases of Total Losses and Substantial Damages happened in the landing phase.

Apparently, the high risk in approach was noticed and led to solutions, which reduced that risk, while in landing (defined as crossing runway threshold until reaching taxi speed) this risk was underestimated. It is not difficult to let the autopilot fly down a category I- or II-ILS or let him land, even in worst weather. This might have changed our attitude and we misjudge and underestimate the dangers and difficulties of keeping the aircraft afterwards on that runway under adverse conditions like contaminated surfaces or crosswind, when deceleration actions were delayed, brakes were applied too late or reverse was reduced to early. We have seen pilots delay their braking actions just to land the nose gear smoothly on a runway covered by ice and only 2000 Meters long.

Nearly all landing accidents in our files could have been avoided, either by better mental preparation and more appropriate actions, or by a diversion. False pride, self-esteem, over-confidence, macho-behaviour or just carelessness led to the wrong decision to land in any case, whereby pilots put themselves and the aircraft in a position which is uncontrollable or where the conditions require actions beyond the pilots capabilities or the performance limits of the aircraft.

If this happens, an accident with severe consequences must be expected. Two basic mistakes lead to a cumulative handicap: The wrong decision to force the landing despite most unfavourable conditions, just to keep the schedule, to avoid additional costs or working hours, because fuel is running out due to wrongly calculated contingencies, or sometimes by company pressure or a waiting girl, and the result is the requirement to utilize extremest skills in trying to make the landing. The same applies to take-offs: Most of them are regarded as routine. A take-off briefing with exact description of what the pilot flying intends to do in the specific case should an abort be necessary or the take-off continued with one engine out is often missing. According to a paper published by Mr. Bruggink in the FSF - Flight Safety Digest, take-off accidents in the USA were the greatest loss producer during the past 5 years following a gradual increase in take-off accidents over the last 10 years, claiming 69 % of all occupant deaths during that period. He states, that too many of these mishaps were triggered by uncritical acceptance of operational, procedural and technical compromises, exactly what I said before regarding landings.

But how do we supervise and enforce adequate crew behaviour, as causal factors seem to include also lack in pilot motivation, excessive confidence and complacency?

IV THE ROLE OF MAN

Worldwide operators organized in the International Air Transport Association (IATA) have formed working committees and agreed on certain standards and definitions. Following these the IATA Safety Advisory Committee agreed to use the term "human factor" only in case of a cockpit crew failure, to concentrate on this major area of concern, since it is the opinion of the majority of safety experts that a breakthrough towards better safety can best be achieved by improving the performance of cockpit crews.

In a very generalized way it can be said that the causal factors for total losses over 30 years were

Man:	76 %,	cockpit crew (human factor)
Machine:	11 %,	technical reasons (including human factor in design, manufacturing and maintenance)
Medium:	13 %,	environmental conditions (airports, air traffic control, weather, terrain, navaids, information, support, cabin crew).

Looked upon on a yearly basis these percentages differ, but the more severe an accident is, the more predominant is the human factor, i.e. the failure of the cockpit crew. This can be clearly detected by comparing total losses, heavy damages and significant events and classifying all groups by the above mentioned categories.

It is evident that an effective breakthrough towards improved safety in air transport could best be achieved by concentrating the investigation on why the cockpit crew failed to identify deficiencies and to counteract by various means.

Reading the accident reports of major air disasters, you will repeatedly find phrases like: pilots failed to follow procedures, pilots misjudged the situation, crew had communication problems, was distracted, made handling mistakes. Trying to find out, why this so happened, you are left without further information, having to assume and speculate on different hypotheses.

Traditionally most investigators were and are aeronautical engineers, who were mostly needed in former days, when engineering played an even greater part than operations because the machinery failed, leaving the aviator with no options. Today we have aircraft with a reliability unthought of in previous days, and in all sorts of transportation. The probability that the mechanical systems will fail is extremely lower than a pilot error, and even if some systems break down, aren't the cockpit crews the last line of defence and basically employed to fight just these handicaps?

And yet, the last bolt with the slightest scratch is undergoing elaborate and most sophisticated scientific investigation, and rightfully so, but the crew record ends with a statement about a valid licence and a rest time according to contract. What do we know about the personal profile of all members of that crew who failed? What was the background, what the family situation, the financial status, the standing in the company, the health, the mental state, the support and training received, the possible fatigue, the professional involvement and engagement? Was the individual a dare-devil or over-cautious, was he enjoying bad weather to fight his personal battle with the elements, was he over-confident and macho or did he just try to reach the retirement age timidly avoiding all possible risks? When did a psychologist as part of the investigation-team tried to find these answers in personal conversation with crews involved, with relatives, friends, fellows, company staff?

Our needs to know all this - not meant to violate a persons privacy, but to improve our knowledge about possible avoiding strategies - ranks by far higher than the understandable desire to cover up personal deficiencies. It could very well be inappropriate to unveil. all this information in a publicly available report, considering certain cultural codices or even legal/liability consequences, but a mentioning of certain background investigation in a very generalized way would already help us to point out in which direction to proceed further.

It is the opinion of the majority of safety experts that a better safety record can best be achieved by concentration on the human elements in selection, training and supervision of cockpit crews. Newly liberalized practices in employment of pilots of no aptitude for commercial operations, of pilots with very low experience in general or on type or pilots with inappropriate experience, require managements to exhibit even greater responsibility to ensure crews are adequately trained to both, attain and maintain appropriate basic airmanship skills like they were demonstrated by the entire crew of the DC-10 in Sioux City lately. Aside of our existing theoretical knowledge we have to widen our horizon in defining the profiles for selection, the goals of adequate training and the key points of line supervision, based on systematic research with the help of appropriate accident investigation in the human field.

V HUMAN FAILURE CATEGORIES:

Statistically based we know empirically, of which categories Human Failure consists:

H1, Active Failures (Aware): 25 %

Non adherence to written rules and procedures, negligence of policies and training standards, gross lack of vigilance or adequate flight management, short cuts, private procedures: Lack of Discipline

H2, Passive Failures (Unaware): 20 %

Crew misunderstanding and communication problems, coordination breakdown, distraction, forgetfulness, fatigue, low arousal level (boredom), lack of assistance.

H3, Proficiency/Judgment Failures: 50 %

Sloppy preparation of decision making process, situation misjudgement, wrong alternative, inappropriate handling of aircraft and its systems, lack of experience, training, competence.

H4, Crew incapacitation: 5 %

Flight crew member unable to perform her/his duties due to physical/psychological inability. Subtle or obvious incapacitation which requires takeover.

What was most alarming in our findings was the unbelievable high amount of collective failures. Cockpit crews have decreased in number from 7 men on the flight deck of a long range Super Constellation to five, four, three and now two pilots on the flight deck of a long range plane, but the basic idea was to organize the work to be done and to provide redundancy for the human element. Too often we learned that this human redundancy-system simply did not function. The reasons were complex, often somebody, not necessarily the most experienced crew member, offered an explanation which prima vista seemed logical or possible, and all others went for it single-minded without even considering an alternative; or a dominant personality overruled all other considerations and everybody accepted this attitude without further objections until death.

The multitude of collective mistakes can be reduced to a certain scheme: A false sense of safety produced by many uneventful flights; the fascination of the goal, mostly to land even at high risk;and the follow-my-leader-syndrome, a tendency to place blind thrust in the person in front, the "herd-leader".

VI REQUIRED AUTHORITY INITIATIVES

This H1 - H4 pattern offers the authority and the operator several paths on which solutions should be tried:

H1: means conscious deviation from rules and standard operating procedures without sound justification, due to macho-behaviour, frustration, strive for self esteem and over-confidence. We have to try to keep these people out of the system in the first place, by a carefully set up selection process, whether the pilot enters a company ab initio or with licences. Despite the fact that the lack of an in depth human factors investigation in the past makes it more difficult to characterize a suitable pilots profile, we basically know, whom we do not want: little dictators or primadonnas, overly hostile or aggressive, insecure and overreacting, incapable to take criticism, unable to admit own errors. On the other hand we do not want people who are easily intimidated by dominant superiors, but good, stable, modest, frustration - resistant men who know their place, but would not tolerate an unsafe action in the cockpit, willing and able to interrupt the chain of events.

H1-mistake, a violation of discipline, has to be severely punished. Lack of discipline is intolerable in this profession and an investigation of underlying causes can be regarded as superficial, since a conscious neglect of rules which have been paid for with blood and tears reveals an unsuitable attitude and corrective actions are probably doomed to fail.

H2: Communication is our most urgent problem: intra-cockpit, with our colleagues in other fields, and ATC. Communication must be trained, especially in cultures where order and obedience are part of normal life. Coordination breakdown is less likely where precise crew coordination procedures exist which provide equal workload, clear distribution of tasks, strictly followed standardized phraseology inside the cockpit and with other agencies, systematic work distribution in static or dynamic situations, clear understanding of a well prescribed and defined cockpit resource management. All this can be taught and trained to proficiency. In the eyes even of professional pilots an easy cockpit atmosphere is a sign of a good crew. Of course everybody works better in a friendly and open atmosphere, but only a very thin line is separating a relaxed from a lax cockpit, in which lack of problem awareness, fatigue and distraction can lead to critical failures. Professionalism was defined as knowing the difference between the two.

A business-like exchange of information without prejudgement-of-intent would help to communicate in a professional atmosphere. Strange enough, this vital tool to improve a safe operation is not trained thoroughly if trained at all, and a good preparation of the future copilot concerning the psychology involved in his position as second in command is widely missing.

Man is faulty, and that is accepted. The error rate can be reduced by information, training, working concepts and check lists, but will never be eliminated. So another man is placed in the cockpit as a redundancy system. This 2-pilot concept will be valid for at least the next 30 years. But this redundancy system too often does not function due to the follow-my-leader-syndrome or psycho-social barriers. We have to select, educate and train especially copilots to step out of a scenario and question what is being done in the cockpit despite generation gap, company hierarchy, group loyalty or whatever the reason may be, and we have to educate captains to encourage just that attitude in their own interest. The announcement of the PNF, that a limit is going to be violated should be accepted with gratitude and a "thank you" instead of an angry reaction about the own mistake. We have to break "group loyalty " and encourage "rule loyalty".

Jurisdiction and licensing authorities have to define accordingly, which knowledge and training has to be offered by flying schools, operators and training departments. This knowledge has to be constructed in a way which enables the crew member to detect at which stage he is likely to glide into the passive-failure zone (Fatigue, Distraction) depending on his individual physiological, psychological and mental state. This knowledge has to observe the enormous individual differences in observation, concentration-, multi stress-, communication-, boredom- and distraction-problems.

Authorities have to instruct manufacturers and operators to create and optimize favourable arousal-levels in the cockpit-work, by careful evaluation of the amount of necessary automation and the corresponding organization of the type of specific cockpit-tasks and workload. These criteria usually differ between aircraft-types. Authorities have to issue regulations, to examine the ability of a future pilot to adequately communicate under different stress-levels prior to hiring or training of those pilots.

H3: Proficiency and Judgement Failures of flight crews are the absolutely predominant human factors. A good professional pilot accepts the fact that he is just an ordinary man and will make mistakes. Knowing this he will be modest, open minded, able to accept criticism and polite to his redundancy-system, the fellow crew member. But being human also means that under daily routine, frustrated by lack of success or appreciation, demotivated by a slow or unrewarding career, suffering from profession-related family problems, the strive for optimal performance may fade away to a degree, where duties are performed with nonchalance and without intellectual effort.

This will normally result in lack of mental preparedness, by an oversight or neglect of available or obtainable information, a following misjudgement of the situation, usually an underestimation of possible problems and consequently a wrong operational decision. There are certain ways to fight these deficiencies:

A standard pre-take-off and pre-landing briefing by the pilot flying the sector, addressed to the whole cockpit-crew, describing the normal procedures to be followed and actions envisaged in case of any system failure. A take-off briefing should include whether the pilot is stop-or go-minded considering the circumstances, it should prescribe the flight path to be followed in case of an engine failure after V_1, were there are normally 3 options like circle and land, follow SID or engine failure route; dumping required or not and so on. Landing briefings should include final altitude, minimum, runway conditions like length and slope, go-around procedures and other relevant data.

Filing reports after go-around should not be made mandatory by the management in order not to increase the decision-threshold for that action. Most landing-accidents could have been avoided by an even late go-around.

Line Oriented Flight Training (LOFT) should systematically call for carefully considered non-routine operational decisions, testing the whole crew in their participation of that process. A program like that reveals more deficiencies, is more rewarding for the crew and by far less boring as the ever-the-same base-check routine in the simulators.

Hand-on-missions like that should be planned as obligatory refreshers and should always be flown by a standard crew compliment like captain, copilot and if applicable flight engineer, to check their interactions realistically. These missions should be recorded for crew debriefing by video-takes which then should be erased. Confrontation with objective proof is normally accepted, while verbal criticism is rejected as subjective.

Authorities are requested to enforce by regulations, that the following abilities should be checked for in the selection process and later on improved by training means:

1. Willingness to evaluate and judge competing alternatives for operational decisions.
2. Decision-abilitiy under pressure and uncertain criteria (probability).
3. Structure of decision-making: Optimizing the process over a variety of variables.
4. Ability to organize the complete process of information gathering, in selection and judgement of information needed to reach a sound decision.
5. Ability to judge a situation.
6. Ability for problem-solving.

All this is generally neither called nor checked nor trained for despite the fact that deficiencies in these fields have caused the majority of all accidents.

Since roughly two thirds of the world commercial jet fleet consists of short/medium haul aircraft and even the flight time of a conventional B 747 averages not quite 4 hours, the average flight time for one sector is 1,4 Hours, 1 Hour 24 Minutes. Deviding this into the flight phases, we end up with 1 % of flight time for take-off and landing and nearly 50 % of all total losses in that fraction of our flight time. Including the 10 % of time for approach, we see that 80 % of our theoretical risks arises in only 12 % of flight time. This emphasises the necessity to carefully prepare the decisions associated with take-off and landing in order not to be caught by surprise in fractions of a second. With these data we should be able to convince a professional pilot that thorough preparation for these short phases and highest degree of discipline and vigilance in only a very short period of his flight duty time would largely control 80 % of his risk exposure.

It shows the necessity of management to review constantly the take-off and landing procedures and to check whether they are still appropriate. Sterile cockpit concepts for at least these phases and their preparation time are advisable, where all distractions or disturbances should be avoided by adequate procedures.

The size of the airplane and the relevant route structure played a role in the past 30 years, shown by the comparison of short- and long-haul fleets, their productivity and their losses.

The world jet fleet consists today of two third short- and medium range types and one third long range aircraft.

Grouping the different types into Short Range (up to 1 hour), Medium Range (up to two hours) and Long Range (> 2 HRS), Narrow Body and Wide Body, and counting their sectors flown and losses suffered, we see that the worst record is held by the long range narrow body-fleet, followed by long range wide bodies. Typical long range aircraft (without considering EROPS-Types like A 306 or B 767) performed 2,4 times worse than short/medium ones. The reasons are complex, among them unfavourable arousal level, unfamiliar routes or weather phenomena, jet-lag, fatigue, 60 % night flights, lack of sleep, language problems, fuel-problems, climate stresses, food problems, long absence from home and so on, but also handling difficulties of large heavy multi engine jets expecially when aborting high speed take-offs or performing critical landings, aggravated by lack of manual practice caused by the route-structure.

In a study in which we compared negative/positive deviation of sectors flown against operational total losses of a all aircraft types, we found only 3 long range aircraft among the 13 most successful types, with 3 short range aircraft leading the list.
On the lower side, where the comparison of sectors flown against losses tends to the high-loss-side, we find 8 long range aircraft among 11 types.

Especially the crews of modern long range types like the B 747-400 are threatened by a severe loss of basic flying skills due to extremely long routes, a high degree of automation and consequently seldom executed manual practices.

Regarding Service Entry Period IV aircraft (CRT- or glasscockpit) and their new developments in automation we are confronted with the basic problem, that though the automatic system is a better monitor than the human, usually it works the other way around: man has to monitor, sometimes over long periods of time.

Todays automation and glass (CRT-) cockpit layouts have several advantages:

- Though surprising failures are possible, the systems can be regarded as basically reliable.

- The crew is relieved of much of the routine work, fatigue is possibly reduced and capacity is available to manage, plan strategically and think of alternatives.

- The same applies to flying in terminal areas in the present ATC-environment with pre-programmed and engaged autoflight.

- Autoland increases the success rate in landing under marginal conditions.

Disadvantages are:

- Automation in the most advanced aircraft like A 320 has reached a degree that threatens to push the pilot to the periphery of the interaction cycle or even let him drop out of the loop. The A 320 has to be regarded as the preliminary limit of automation.
- Further reduction of workload in low workload phases leads to more boredom, a very low arousal level, possible break down of discipline like reading magazines, and subsequent monitoring failures.
- Programming of Flight Management- and Autoflight-Systems leads to Head-Down-Position of pilots also in descent and approach phases were head up and look-out is urgently required. Autoflight anomalies in approach increase the workload drastically.
- Pilots tend to fumble around to "repare" the program if anomalies occur instead of disengaging the automatic system and flying basically.
- Manual skills are reduced if pilots do not deliberately hand-fly regularly, either voluntarily or forced by company procedures.
- Especially in cruise flight, situation awareness is reduced or lost, the question "where are we really" is difficult to answer, preferably on INS-steered conventional types.

<u>Authorities are requested to supervise, that company policies and training philosophies should be defined accordingly, considering theses disadvantages and trying to avoid them.</u>

<u>Authorities are requested to develop regulations to be followed by operators, which ensure the continuity of basic manual flying skills, like simulator-sessions with limited panel information or emergency instrumentation only and/or rules to regularly hand-fly take-offs and landings on widely automated glass cockpit aircraft or on route structures with rare possibilities to exercise.</u>

H4: Crew incapacitation will occur occasionally. Medical advice should help the crews to stay healthy and fit. <u>Detection of incapacitation and the take-over practices can be trained.</u> Incapacitation gates, consisting of announcement by PNF and answered by PF should be implemented like a certain speed in take-off roll and an altitude passed during approach. The two-communication-rule is applied: if the pilot flying does not answer, the call out will be repeated once, and with no reaction at the second call out, take-over occurs with the phrase "I have control" by the assisting pilot. Simulator missions offer good opportunities to train this even surprisingly after the PF has been briefed by the instructor.

The size of an airline also seems to be of a certain significance. Since it is difficult to judge the growth of an airline over the years we compared the size of 1988 with the number of losses this airline accumulated over the years and did this for the 30 years period as well as for the last 3 years. The results are almost identical. Comparing the productivity and the number of losses, the smaller companies have a relative high number of accidents, out of proportion to the exposure. The smaller the company, the higher the relative participation in accident numbers. Only beyond a fleet size of 50 aircraft this trend reverses.

It is alarming, that companies with only 2 % of aircraft (combined fleet size of all companies involved) produced nearly 40 % of the accidents of these companies. The same can be said of small freighter companies.

Included in the 20 operational losses of 1988 were 4 Boeing 707's, all operated by African companies, three as freighters. The two lost DC-8's were also operated by small freighter companies. A former study of the relatively bad South American record showed the same trend: while the big national airlines had a record comparable to equally sized companies in other parts of the world, the losses were mainly produced by small or mini-companies, whose resources did not allow them to pay high wages for best qualified and experienced pilots, who did not seek the support available from the manufacturer, who operated in less well regulated parts of the world and in higher risk environment, and to make things worse, often bought cheap old aircraft which were costly to maintain and therefore did not get the maintenance they principally needed. We learnt that the proneness to accidents of those companies is high.

Potential contributing factors could include the financial pressures due to increasing competition, take-over practices and the adverse economic position not only of companies but States. Regarding the year 1988 and its 20 losses it could be assumed that this applied to 14 of the companies or states involved. It can only be repeated to ICAO and the governments represented there that we urgently need national or supranational aviation supervision agencies, which are sufficiently staffed, budgeted, equipped and experienced to supervise the existing, but mainly the high number of newly founded companies with often limited resources. These are beginning to show in significant numbers under deregulation or liberalization. Due to lack of infrastructure on the ground and in the air a highly effective supervision by experienced authorities is more necessary than ever.

VII ACCIDENT INVESTIGATION

Since we started to analyze and categorize past accidents systematically with the help of computers, we know and are able to proof the definition of main areas of concern. But nevertheless it is mandatory, that future incidents and accidents must be by far more carefully analyzed as to the human performance factors, to produce tools to develop failure avoidance strategies, and to show how the duties were performed within a social, organizational and cultural context. Thereby the all too common search for someone to blame would hopefully end, since it would show that we all have to share that blame and indicating that a solution has to be found to avoid a repetition.

Insofar the National Plan to Enhance Aviation Safety Through Human Factors Improvement, published by ATA in April 1989, is a step into the right direction, since it requests among other activities a selection of relevant pilot error categories, the development of a human factors investigators checklist and a structured questionnaire, the implementation of a human error data base, to finally change design and procedures to reduce human error.

But our state representatives and authorities are also requested to change certain rules laid down in ICAO Annex 13.

It is absolutely mandatory, that the state's investigators in charge are requested to use to fullest possible extent the expertise and knowledge of the operator and its staff in investigating incidents and accidents. Especially large companies can offer assistance to an extent which is rarely available by other sources. It is hardly possible to investigate a human factor case in depth without the detailed knowledge of an operator. The present rule still allows the investigator in charge to exclude the operator on non-justified, barley subjective grounds, since the rights of the operators to participate are still non-existent.

States like Australia have drawn the consequences and granted officially the participation of the operator concerned in any investigation under their iurisdiction. This should be made general rule-making within ICAO.

VIII TRAINING

Our Training is dominated by aircraft behaviour and technical failures, but that is not our major problem. Personal- and intra-cockpit behaviour is our main concern, but training programs are either non-existent or lamentably underdimensioned, even in major airlines. If we wait for an ab-initio-student to grow up to an excellent pilot whose knowledge goes beyond the usual skills into the human factors field and who reacts accordingly, we wait too long and expose our companies to unnecessary risk. We can and have to train our people, or the usual blame will generally shift to airline management and state authorities.

The latter should be more open minded to allow companies with experienced and effective training departments to structure their training more effectively and to drop still required programpoints which can be regarded as completely outdated.

Insofar a more flexible attitude of the authorities towards companies of different background and resources is required.

IX RESPONSIBILITY

We will have to improve our knowledge further, but we do know enough already about human failures and the negative influences of our working environment, that we all carry the moral responsibility to do whatever possible to improve the situation: the manufacturer by better design in human engineering, the aviation administration by improving rule making and company-supervision, the company management in sufficient spending in selection, training and supervision of flight crews, reviewed procedures, sufficient support and an effective safety program which reports to the highest level, and last but not least the airman to improve his performance by personal fitness, mental preparedness, by a high level of theoretical knowledge and a good common sense, by vigilance, discipline and the willingness to listen to others who have bright ideas too.

Our Rules are not enforced, supervision is difficult in this profession. Our aviation administrations are understaffed and lacking experience, they are rarely independent and often under political instead of professional management. Our adjustment to new developments is too slow.

We have two choices:

- Accept the present loss rate, deny moral responsibility beyond the present standard, calculate the costs with the insurers, investigate only if a defined rate is surpassed, then decide, if something has to be done, or

- regard any loss as being too high. But this means that we have to improve our system at increasing costs, since labour costs will increase steadily and the environment requires enormous investments in the infrastructure. In pilot selection and training we should not try to create a new man, but to select carefully to agreed standards in intellect, flexibility, cooperation, communication, frustration resistance, independence and self-confidence. In our training we have to encourage independent thinking, decision and action to improve human redundancy and fight collective mistakes by recognizing and accepting, that man is faulty and to err is human.

We do know, that the safety standard can best, if not only, be raised by improving knowledge, motivation and performance of cockpit crews. We know what the deficiencies are and how to fight them, and still we seem to achieve very little, if any progress. We repeatedly, like a tibethan prayer mill, pointed out, what's wrong, but results are barley visible. Our drive must be harder, our warnings must be heard, our proposals must be followed, or we all expose ourselves to the accusation of being corrupt, meeting regularly, exchanging the same ideas, but getting nowhere. We are facing difficult times with safety standards likely to suffer from erosion under economical pressure, so safety, the cornerstone of public trust in our system, will cost relatively more money, for operators <u>and</u> supervisory agencies.

Aircraft-Accidents will also happen in the future.
Their probability has to be reduced.
Experience exists, how to manage that.
Man, though indispensable, is the main causal factor.
The main area of concern is identified.
It is the Duty of the State Aviation Administration, to control the risk by National Law and Initiatives published in Standards and Recommended Practices.
Authorities have the Responsibility to define, implement, supervise and enforce necessary rules -
or publicly declare their inability due to lack of resources (logistic, staff, experience, budget, competence) to provoke and initiate the necessary changes on the national and international field.

УЧЕТ ЧЕЛОВЕЧЕСКОГО ФАКТОРА ПРИ ПРОЕКТИРОВАНИИ САМОЛЕТА ТУ-204

Доклад на семинаре по безопасности полетов и человеческому фактору

Безопасность полета - основная цель, которая всегда стояла перед создателями самолетов, начиная с того момента, когда первый человек поднялся на аппарате тяжелее воздуха. По мере того, как авиация из экзотического метода передвижения превращалась в транспортную систему, эта проблема становилась все более многофакторной.

Статическая и динамическая прочность, устойчивость и управляемость, обеспечение приборного полета и, наконец, человеческий фактор.

Если посмотреть на относительно короткую по отношению к истории человечества историю авиации, перечисленные аспекты этой проблемы на разных этапах имели разные акценты.

Что, на сегодня решили уже все указанные вопросы, кроме последнего? Конечно, нет! Но по мере накопления опыта в проектировании летательных аппаратов были созданы инженерные методы расчетов, качественные модели оценки влияния внешних воздействий на функциональные системы самолета, которые позволили достаточно хорошо учесть неблагоприятные факторы и снизить их влияние на фатальный результат.

Сегодня по международной статистике 70% авиационных катастроф происходит по причине ошибок экипажа, что свидетельствует о том, что мы еще недостаточно хорошо научились учитывать человеческий фактор.

Причем, из оставшихся 30% минимум 29% приходится на ошибки человека, связанные с проектированием, обслуживанием и эксплуатацией.

В последние годы возрос интерес к исследованиям поведения человека в рабочей обстановке. Проблемам эргономики при проектировании и эксплуатации самолетов уделяется не меньше внимания, чем любым другим вопросам. Наиболее квалифицированные специалисты предпринимают настойчивые усилия для внедрения самых эффективных достижений в системы пилотажной техники и практики.

Если мы посмотрим на кабины самолетов конца 60-х начала 70-х годов и конца 80-х годов, мы увидим существенную разницу.

Немалая доля уже накопленных знаний реализована в компоновках кабин, технике управления и системах отображения информации.

В качестве примеров и подтверждающих реализаций мы будем рассматривать технические решения, осуществленные на самолетах ТУ-154 и ТУ-204. Один из них успешно эксплуатируется 11-ю авиакомпаниями и с учетом дешевизны, отлаженной эксплуатации и модернизации навигационно-пилотажного оборудования, связанной в основном с дополнительными требованиями ИКАО, будет эксплуатироваться и во втором тысячелетии.

Другой самолет проходит испытания и начнет эксплуатацию в ближайшее время.

На рисунках (слайдах) представлены компоновки и фотографии кабин и приборных досок пилотов.

Мы в своем докладе хотели бы показать, как решения, улучшающие удобство работы экипажа, уменьшающие вероятность ошибок, повышающие комфорт рабочих мест, вырабатывались на основе преемственности и опыта эксплуатации и в то же время, на базе развития электроники и цифровой техники, становились новыми, как по содержанию, так и по форме.

Мы, конструкторы самолетов, должны создать экипажу необходимые условия для успешного решения задач, определяемых полетом, с учетом его обязанностей и ответственности за соблюдение инструкций и наставлений по выполнению полета.

Прежде всего о рабочем месте экипажа – кабине.

Если мы обратимся к истории, то увидим, что конструкция кабины на первых самолетах была очень простой. Один пилот в условиях хорошей погоды успешно справлялся с полетом. Полеты в плохую погоду потребовали приборов, указывающих пространственное положение. На самолетах, летающих на маршрутах большой протяженности, включают в экипаж штурмана-навигатора, который мог использовать средства астронавигации.

В кабине самолета АНТ-25, совершавшего в конце 30-х годов трансконтинентальные беспосадочные перелеты в большей своей части над безориентирной местностью, сидело три человека: командир, штурман-навигатор и второй пилот.

Причем, первый самолет Чкалова был оборудован одним постом управления и летчики могли подменять друг друга, поочереди садясь на это место. Уже второй самолет Громова был доработан по опыту полетов и имел два поста управления.

Развитие радиосвязи и ее использование не только для передачи информации на землю, но и для навигации и управления воздушным движением, прибавило еще одного члена экипажа – радиста.

В послевоенные годы развитие и совершенствование самолетного оборудования, особенно на реактивной авиации, шло быстрыми темпами и одновременно по пути его усложнения.

Система генерирования и распределения электроэнергии; гидравлическое оборудование с большим числом силовых приводов, топливная система с перекачкой, закольцеванием, аварийным сливом топлива; система кондиционирования с приборами контроля и управления потребовали включения в состав экипажа бортинженера.

Кроме приборных досок пилотов, каждый член экипажа получил свое рабочее место.

Все это показывает, что "разрастание кабины" явилось следствием увеличения количества необходимой сигнализации, индикации и "ручного" труда членов экипажа при выполнении полетов. Но это одновременно привело к углублению разделения функций, недостаточному контролю действий каждого члена экипажа другими и отсюда к неблагоприятным последствиям ошибок.

Вопрос о числе членов экипажа поднимался и обсуждался на различных собраниях специалистов, семинарах научных и исследовательских работников, ассоциации пилотов и т.п.

И тем не менее, обсуждая проблему "человеческого фактора", нельзя не вернуться к этому вопросу.

Кабина самолета ТУ-154 была спроектирована для трехчленного экипажа: два пилота лицом по полету и бортинженер за боковой панелью. Но было предусмотрено еще два места: одно между летчиками, чуть сзади них, и второе - за левым пилотом, с разной степенью комфорта. Причины такой компоновки мы уже объясняли выше.

Конкретное число членов экипажа, эксплуатирующих самолет, дело авиакомпании.

Аэрофлот на этапе внедрения штатно разместил штурмана между пилотами и была разработана инструкция по летной эксплуатации для такого состава экипажа. В некоторых полетах за рубеж на пятое место подсаживают бортрадиста, лучше владеющего международным языком обмена.

Необходимость штурмана объяснялась слабым радионавигационным обеспечением большинства трасс при недостаточно точном автоматическом автономном навигационном счислении.

Авиакомпании БАЛКАН и МАЛЕВ эксплуатируют самолет ТУ-154 с трехчленным экипажем.

Влияет ли количество членов экипажа на вероятность ошибки? Несомненно. Особенно присутствие поверяющего. Как показывает практика, новый человек в составе экипажа, особенно поверяющий, потенциальный дополнительный риск. Этот феномен требует дополнительного изучения.

Развитие электроники и цифровой техники делает вполне реальным совершение полностью автоматического полета от взлета до посадки.

Не нужно ли вообще исключать человека из контура управления?

Мы думаем, такая постановка вопроса неправомерна и нереальна. Вряд ли кто из Вас сядет в самолет, если будет знать, что он управляется только автоматикой.

Есть много ситуаций, требующих нестандартных логических операций с использованием многочисленных источников информации, с которыми человек справится лучше, чем любая автоматическая система.

Следовательно, на самолете должен быть хотя бы один пилот, но, развивая идею дублирования систем, на пассажирских самолетах необходимо иметь, как минимум, двух пилотов.

Таким образом мы, проектировщики, пришли к минимальному составу экипажа. Кабина самолета ТУ-204 спроектирована в соответствии с этим требованием.

Что же сделано, чтобы при минимальном составе экипажа повысить безопасность полета?

Начнем с управления. Вопросы, связанные с управлением, всегда волновали и продолжают волновать специалистов.

Роль пилота и автоматики, вид и форма рычагов управления, способы вмешательства пилота при автоматическом управлении, методы и принципы индикации для предупреждения выхода за допустимую область полета, степень необходимой загрузки членов экипажа при длительных крейсерских полетах – вопросы можно продолжить и ответы, реализованные в конструкции, мы думаем, прямо влияют на учет человеческого фактора.

Самолет ТУ-154 был одним из первых гражданских самолетов, который имел необратимое бустерное управление всеми рулями. Это позволило, используя сравнительно простые системы загрузки рычагов управления, с помощью трехкратно резервированной системы обеспечения устойчивости и управляемости на всех режимах полета, вне зависимости от центровки и веса самолета, получить оптимальные характеристики управляемости.

При пилотировании вблизи границы по максимальной перегрузке или минимальной скорости заметное увеличение градиента усилий эффективно предупреждает пилота.

Отклонение руля высоты при автоматическом управлении от механизма триммирования и дифференциально подключенного к системе управления рулевого агрегата позволило обеспечить при необходимости безударное вмешательство пилота в управление на всех этапах полета.

Дальнейшее развитие система управления, создающая у пилота чувство легкости и удобства управления, получила на самолете ТУ-204.

Дистанционная электрогидравлическая система с миништурвалом, с легкими градиентами загрузки, с малыми усилиями страгивания позволяют реализовать желание пилота: надо только подумать, не прикладывая усилий, и самолет легко и плавно откликается на управление и делает то, что ты хочешь.

Автоматическая перебалансировка и совмещенное управление снимают с пилота необходимость многократных действий при установлении режима полета.

По нашему мнению, такой подход во многом решает вопрос компромисса между автоматическим и ручным управлением.

Много раздумий было и по поводу боковой ручки управления, практически идентичной широко распространенным в 50-е годы, особенно в военной авиации, совмещенным ручкам управления через автопилот. Правда, они делались для командира под правую руку. Но большой объем проведенных стендовых испытаний и полетов на летающей лаборатории ТУ-154, обсуждение с линейными пилотами привели нас, исходя прежде всего из преемственности и учета человеческого фактора, к двуручному миништурвалу, по характеристикам загрузки близкому к боковой ручке, но более понятному для пилотов.

Большие работы по оснащению ЭВМ навигационных и пилотажных систем, развитие электронной техники привели к установке на борт самолета ТУ-204 нового типа электронного оборудования с многоцветными дисплеями на приборных досках пилотов.

Новейшие средства навигационного и пилотажного оборудования способны представлять поток необходимой информации на разных этапах полета в более концентрированной форме.

На индикатор вертикальной обстановки выдается командный авиагоризонт, информация о скоростных режимах, высотах и траектории.

Аналогично этому на индикатор горизонтальной обстановки выводится информация о плане полета, промежуточных пунктах маршрута, радиомаяках, схема взлета, захода на посадку и текущее положение самолета.

Объединение в комплекс системы индикации плановой обстановки с воздушным движением существенно облегчит работу минимального экипажа и повысит безопасность полета.

Но внедрение автоматики и вычислительной техники, разгружающей пилотов, хорошо при высочайшей надежности этой аппаратуры.

Новый образ объекта управления не должен меняться при реконфигурации комплекса оборудования из-за отказов или неисправностей отдельных его элементов.

Что сделано для этого?

Комплексная информационная сигнализационная система, два цветных индикатора которой расположены на средней приборной доске пилотов, и встроенные системы контроля самолетных систем обеспечивают обнаружение дефектов, установление причин и выдачу рекомендаций по их устранению.

Система сбора и локализации отказов комплекса пилотажно-навигационного оборудования обеспечивает выработку интегрального сигнала готовности аппаратры к следующему вылету на основе контроля эксплуатационного состояния агрегатов.

Уверенность технического и летного состава в готовности самолета к вылету существенно улучшает его психологическое состояние и способствует решению проблемы человеческого фактора.

Каким бы надежным и хорошо подготовленным оборудование не было, отказа в полете не избежать. И тут нужно рассмотреть две стороны возможных последствий, которые обеспечивает современная цифровая аппаратура.

Отказ элемента не приводит к изменению режима работы системы и только снижает уровень резервирования. Информация регистрируется на магнитном носителе и, если отказ может повлиять на последующий полет, на бланке блока оперативного документирования для принятия мер наземным техническим экипажем.

Если последствия отказа требуют вмешательства экипажа, то за очень короткое время формируется краткая индикация, сопровождаемая конкретными указаниями о месте и порядке действий.

Системы тревоги и аварийной сигнализации стали "умными", они устанавливают приоритет сигналов и обеспечивают защиту от явно ложных "сбойных" ситуаций.

Основное, что, по нашему мнению, способствует уменьшению вероятности ошибочных действий, это концентрация информации о состоянии самолетных систем на индикаторах, что позволяет обеспечить один "выход", ибо человек при выполнении функций контроля ведет себя как процессор с одним входом, а контролировать приходится большое число устройств и условий.

Одновременно с сигнальным оповещением выводится на экран дисплея информация об отказе и порядок действий в данной ситуации.

Еще один вопрос, по нашему мнению очень важный, на который мы хотели обратить внимание. Порядка 30-40% всех тяжелых происшествий приходится на посадку.

Методика пилотирования и распределение обязанностей между членами экипажа при заходе на посадку и посадке всегда вызывали большие дискуссии специалистов. Внедрение известными нам компаниями метода так называемого "подконтрольного" захода на посадку организационно упорядочило этот этап полета, во многом стандартизировало действия всех членов экипажа.

Однако, по нашему мнению, остается целый ряд проблем, которые усложняют пилотирование при заходе на посадку и приземлении.

Дальнейшее расширение сети аэродромов, оборудованных инструментальными средствами посадки, позволяет считать, что заходы на посадку магистральных самолетов происходят в большинстве случаев с использованием курсоглиссадных радиомаяков.

Все эти самолеты по требованиям норм летной годности оборудованы бортовыми системами посадки, поэтому, можно считать, что вне зависимости от погодных условий заход на посадку с момента входа в курсовую зону радиомаяка совершается пилотами с использованием инструментальных средств в ручном или автоматическом режиме.

Конечно, при ясной погоде или, по крайней мере, при минимуме, позволяющем заходить по планкам положения, выбор режима пилотирования, да и соблюдение всех требований "подконтрольного" захода, достаточно свободное.

Однако, когда условия близки к минимумам погоды II и III категорий по классификации ИКАО, выполнение инструкций и наставлений должно быть чрезвычайно жестким.

Все, что между этими ситуациями достаточно не определено, и в некоторых случаях субъективное толкование порядка действий пилотов, не способствует уменьшению ошибок.

Считаем, что настало время рассмотреть ряд предложений, как в направлении регламентации действий летного экипажа, так и размещения дополнительного оборудования, обеспечивающего безопасность за счет снижения вероятности возможных ошибок.

Основные положения в виде тезисов.

<u>Первое</u>. Необходимо запретить пилотам переходить при совершении захода в автоматическом режиме на ручное пилотирование на излишне малых высотах. Например, ниже 30 м.

<u>Второе</u>. Запретить попытки исправлять допущенное отклонение, если оно не позволяет совершать приземление на высоте ниже установленной, например, 45 м.

Третье. Уход на второй круг должен стать для пилота одним из нормальных режимов пилотирования. При тренировках уходы с минимально допустимых высот, с учетом возможного касания полосы, должны быть тщательно отработаны.

Для обеспечения эффективного контроля траектории со стороны командира при выполнении "подконтрольного" захода предлагается:

Первое. Магистральные самолеты оборудовать индикаторами на лобовом стекле с обеспечением информации о направлении вектора скорости, линии крыльев, высоты, скорости.

Второе. Для стандартизации методов контроля при заходах на посадку в условиях низких минимумов, и обязательно для минимума ниже 30 метров, обеспечивать визуализацию полосы.

Наиболее просто это можно осуществить с помощью радиолокатора высокого разрешения.

Локационное изображение полосы в масштабе, соответствующем реальному изображению, нужно проектировать с помощью индикатора на стекло.

Теперь некоторые комментарии к вышесказанному.

Позднее включение командира корабля в процесс пилотирования может привести к более грубому приземлению и неточностям при управлении на полосе, особенно если она скользкая.

Стремление обязательно посадить самолет, даже если вертикальная скорость слишком большая или ошибочно заходили на параллельную соседнюю полосу, приводит, как мы знаем из практики, к катастрофе. Если есть малейшее сомнение в благополучном приземлении, командир или второй пилот обязаны уйти на второй круг, и после этого, спокойно разобравшись в причинах неудачного захода, принять правильное решение о завершении полета.

Индикаторы на лобовом стекле давно обсуждаются специалистами. На современных легких пилотажных истребителях они нашли широкое распространение, а на пассажирских самолетах нет. Почему?

Мы думаем, это связано с тем, что при высоких погодных минимумах высококвалифицированные пилоты магистральных самолетов считают и без них ошибку маловероятной.

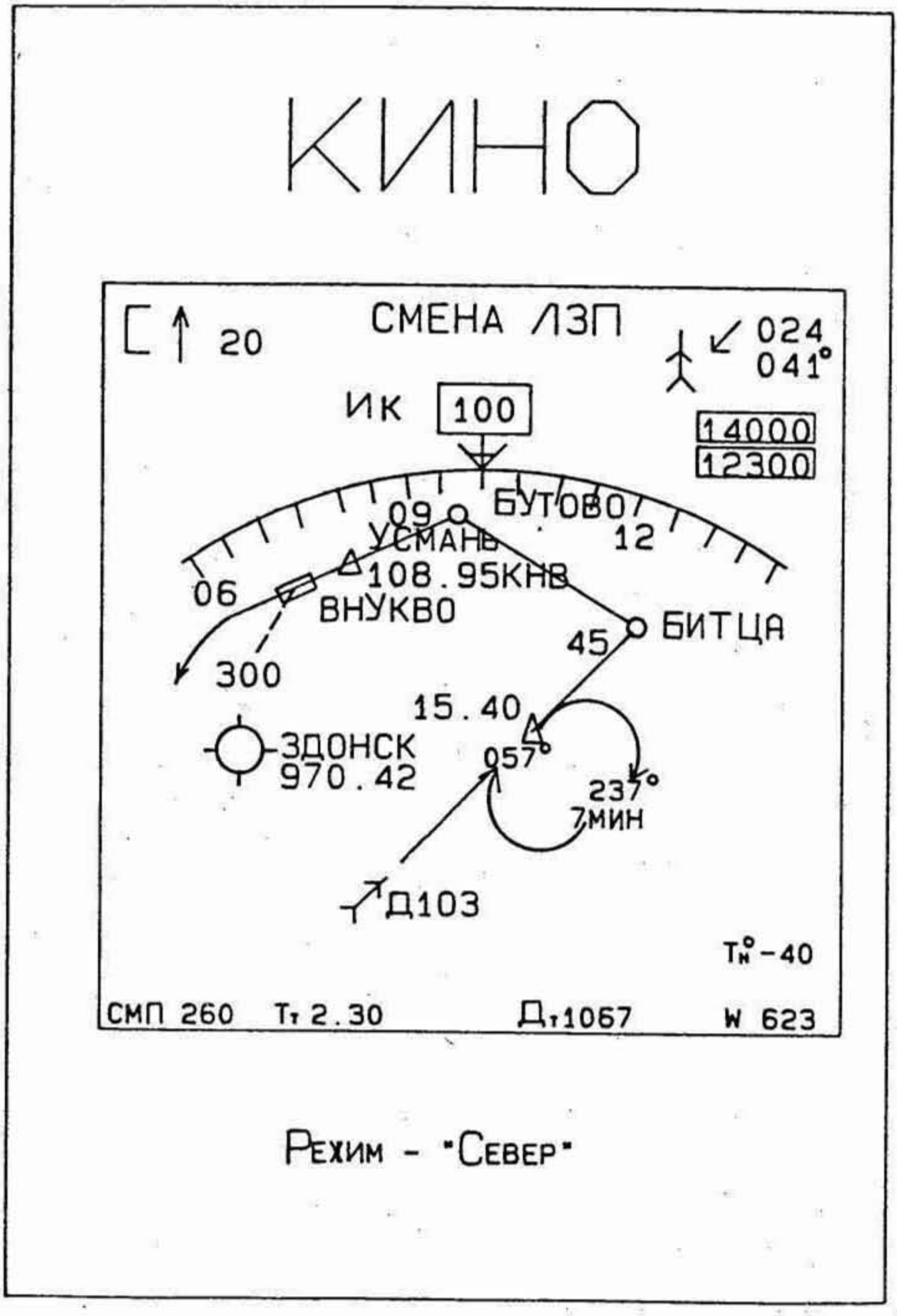
При минимумах, близких ко II категории, индикаторы должны быть очень эффективны при переходе от приборного полета к визуальному, но это время перехода очень мало.

Добавление к индикатору на лобовом стекле радиолокатора высокого разрешения делает методику захода, распределение обязанностей между членами экипажа стандартными, не зависящими от погодных условий.

На самолете ТУ-204 по желанию покупателя мы предусмотрели установку индикатора на лобовом стекле и радиолокатора "Видимость". В настоящее время эти приборы в стадии разработки и испытаний.

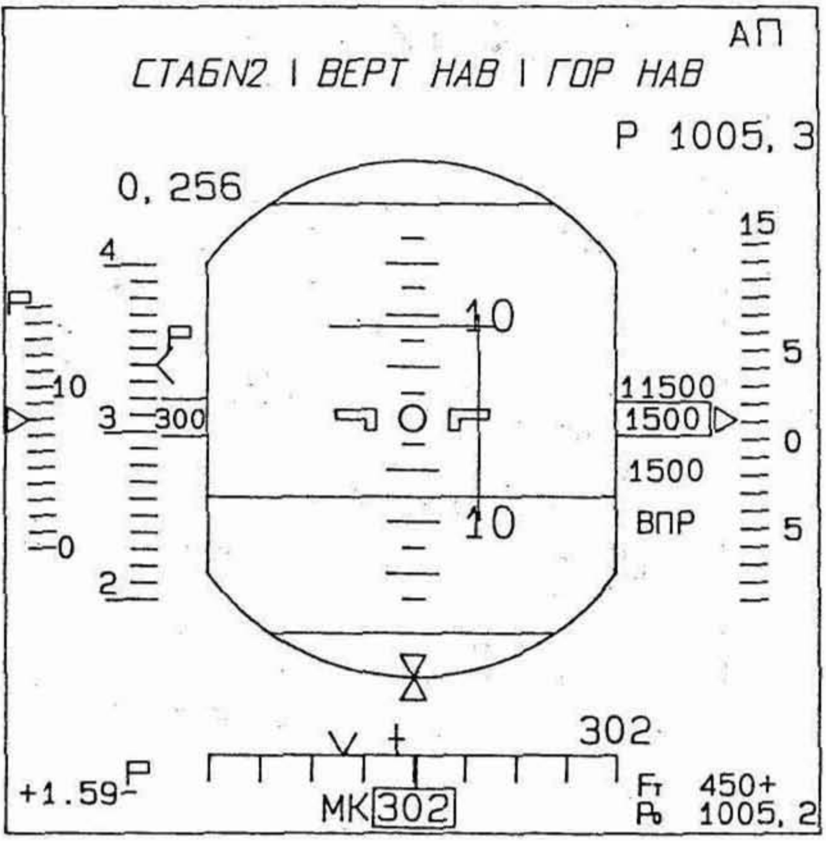
В кратком докладе мы постарались рассказать, как специалисты Туполевского конструкторского бюро учитывают человеческий фактор при проектировании самолетов.

Будем очень рады, если наши усилия дадут результаты и настроение летных экипажей после полета будет лучше, чем до него.



Режим - "Север"

КПИ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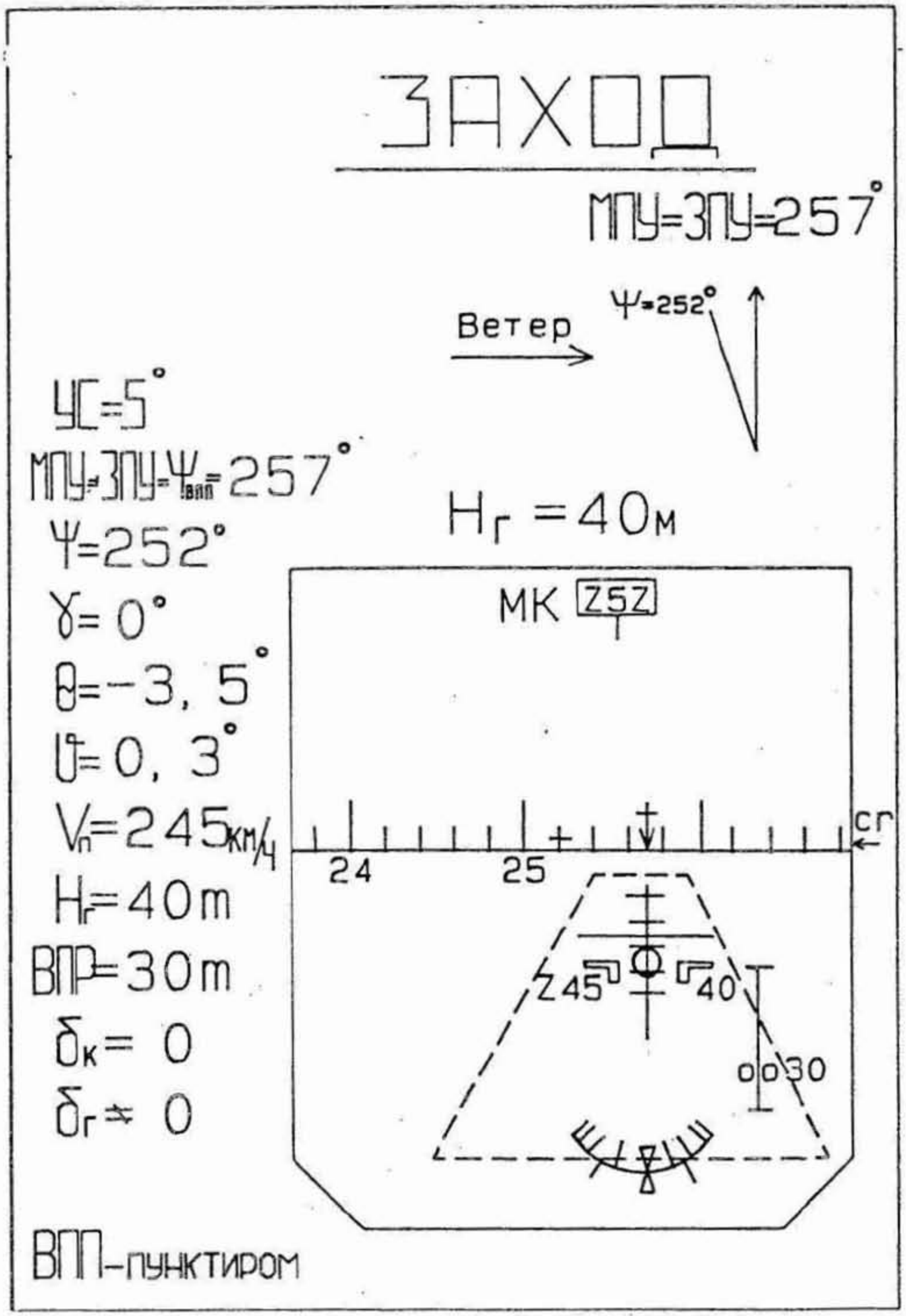
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Ветер
Ψ=252°
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МПУ=ЗПУ=Ψвпп=257°
Ψ=252°
γ=0°
θ=−3,5°
ϑ=0,3°
Vп=245км/ч
Hг=40m
ВПР=30m
δк=0
δг≠0
ВПП–пунктиром
Hг=40м
МК 252
24
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Некоторые вопросы контроля профессиональной подготовленности пилотов в целях профилактики и расследования авиационных происшествий.

(проект доклада)

Когда мы говорим о проявлении человеческого фактора в проблеме безопасности полетов, то вынуждены касаться широкого круга вопросов, среди которых центральным, по нашему мнению, является вопрос изучения закономерностей в системе "Экипаж – воздушное судно". Эта система, представляя собой единое целое, тем не менее допускает разделение на подсистемы "воздушное судно" и "экипаж".

Для подсистемы "воздушное судно" нас больше остальных ее свойств интересует так называемая "эргономичность", включающая в себя такие аспекты как приемлемость характеристик устойчивости и управляемости, полнота и качество отображения необходимой полетной информации, обеспечение гигиенических условий работы экипажа и др..

Для подсистемы "экипаж" мы вычленяем следущие основные проблемы:

а) достаточный (то-есть высокий) уровень профессиональных качеств каждого члена экипажа в отдельности;

б) достаточный (то-есть высокий) уровень профессиональных качеств всего экипажа в целом как производственного коллектива, усилия которого направлены на безопасное и качественное выполнение полета.

Указанные основные проблемы также поддаются детализации.

Так, высокий профессиональный уровень пилота включает в себя:

- умение своевременно и с возможно большей полнотой контролировать процесс полета, воспринимаемый как участие в единой системе воздушного движения и одновременно как результат функционирования комплекса сложных систем, составляющих в совокупности воздушное судно;,
- умение своевременно и адэкватно реагировать на отклонения в процессе выполнения полета с выработкой и реализацией оперативных решений посредством собственных действий или команд членам экипажа с учетом круга их обязанностей и наилучшими возможностями к действиям в конкретной обстановке;
- умение пилотировать, то-есть готовность и способность контролировать

большое число меняющихся во времени параметров полета и воздействовать на них посредством органов управления при том, что каждый из контролируемых параметров реагирует на орган управления по сложному динамическому закону.

Примерно то же можно сказать и о каждом другом члене экипажа, учитывая все-таки, что работа пилота-командира является наиболее сложной и ответственной.

Расследования авиационных происшествий, к сожалению, дают повод считать, что приведенные выше требования удовлетворяются не всегда и не полностью. И еще больше в практике случаев, когда драма или даже трагедия является следствием недостатков в деятельности экипажа, рассматриваемого, как единый коллектив, то-есть именно тогда, когда коллектив недостаточно един, несмотря на высокий профессионализм каждого его члена в отдельности.

Мы бы могли привести достаточное количество подтверждающих примеров. Вот два из них.

Пилот вертолета при выполнении захода на посадку получил указание диспетчера изменить расчет таким образом, чтобы приземлиться ближе на 400 метров от точки предварительного расчета. Его удаление от новой точки приземления и высота полета заведомо позволяли произвести безопасную посадку. Однако, недостаточный личный профессионализм привел к тому, что пилот продолжал заход по более пологой, чем теперь требовалось, глиссаде, а на завершающем участке, стремясь выполнить указание диспетчера, перешел на опасно крутую глиссаду, попал в режим "вихревого кольца", не справился с пилотированием и потерпел аварию. Это - типичный случай низкой личной подготовленности пилота.

Другой случай касается ситуации, когда оба пилота, каждый из которых обладал достаточно высоким уровнем личной подготовки, из-за несогласованности между собой допустили опасное снижение самолета в непосредственной близости земли, после чего спасти самолет уже стало невозможно и посадка закончилась катастрофой. Приведенные и многие другие примеры показывают, насколько важно максимальное удовлетворение требованиям, приведенным выше.

Пилот, приходящий на работу в авиацию, уже имеет прошлое. Он прошел отбор при поступлении в училище, закончил его полный курс и приобрел некий минимум знаний и навыков, который должен обеспечить его производственную деятельность. Однако, летная работа - это учеба всю жизнь, что хорошо знают добросовестные летчики. Их командиры знают (или должны знать), что кроме индивидуальной учебы пилота, существуют и другие проблемы, прямо относящиеся к безопасности полетов. В их числе чрезвычайно важно оптимальное комплектование экипажей с учетом индивидуальных качеств каждого его члена. Таким образом, мы имеем, как вывод, необходимость учета и контроля, как минимум, двух свойств пилота - его индивидуальные профессиональные качества и его качества, определяющие эффективность работы (и руководства) в коллективе.

Часть этих качеств (построение общей модели воздушного движения и его фрагментов, относящихся к своему в нем участию, выработка, и реализация оперативных решений, (восприятие и анализ) особенностей ситуации и способность управлять ею. с учетом качеств руководимого экипажа, эффективность работы в составе экипажа и т.п.) является предметом, который поддается исследованиям специалистов по инженерной и профессиональной психологии, социологии и т.д. Другие качества (навыки в технике пилотирования, распределения и организации резервов внимания) являются прерогативой инструкторов-наставников из числа лиц командно-летного состава. Летную работу пилота сопровождают два важнейших летных документа: его летная и медицинская книжки, в которых фиксируется текущее состояние его профессиональной подготовки и состояние здоровья. Эти два документа являются как бы паспортом пилота, который (в идеале) должен дать исчерпывающие ответы на все или почти все вопросы, связанные с его деятельностью.

Мы здесь не будем говорить о тех разделах медицинской книжки, где речь идет о динамике физиологических показателей, оставив это врачам. Но в последние годы, особенно с появлением при Госавианадзоре СССР Научно-исследовательского подразделения, изучающего проявления человеческого фактора, все чаще возникает вопрос о необходимости изучения и неформального, содержательного отражения в т.н. "паспорте" летчика его психологических качеств, определяющих названные выше его свойства. Эта точка зрения, к счастью, разделяется многими специалистами в области авиационной психологии: и в Академии Гражданской авиации, и в НЭЦ АУВД, и в других организациях. Мы предполагаем, что введение таких мер существенно облегчило бы комплектование экипажей, рациональную расстановку кадров летного состава.

Нельзя сказать, что сегодня ничего не сделано.

Существуют утвержденные методические рекомендации по комплектованию экипажей на основе психологических свойств его членов. К сожалению, конкретные условия работы авиационных транспортных предприятий, а главное - недопонимание их важности, затрудняют их использование.

И мы не можем сказать, какого числа несостоявшихся происшествий мы бы избежали, используя эти рекомендации, но из практики известно, что во многих происшествиях проявился их неучет. Эти рекомендации, возможно, недостаточно совершенны. Кроме того, они (будучи направлены только на комплектование экипажа) практически не учитывают всех остальных психологических аспектов, в том числе перечисленных выше.

Таким образом, нам кажется важной научной и практической задачей разработка и реализация методов создания "психологического портрета" члена летного экипажа (и в первую очередь - пилота) и его учет в практике.

Второй столь же важный проблемой является контроль и управление качеством работы пилота, что включает в себя, как указывалось выше:

а) уровень техники пилотирования;

б) навыки в распределении внимания и организации его резервов.

В практике авиации всех стран мира традиционно существует такая форма контроля профессионализма как контрольный полет с проверяющим (инспектором или инструктором).

Если проверяющий высокопрофессионален и доброжелателен, он заметит большую часть отклонений от идеала - погрешности в технике пилотирования, повышенную напряженность и загруженность процессом собственно пилотирования (что ограничивает резервы внимания летчика, необходимые для бдительного контроля за исправностью техники или оперативным изменением обстановки), недостатки в управлении экипажем. В результате всех этих замечаний он укажет проверяемому путь к совершенству. Однако, контрольные полеты выполнять ежедневно невозможно и большую часть полетов пилот выполняет без проверяющего. При наличии же информации о полете, полученной в результате регистрации полета самописцами типа МСРП, было бы расточительно ею не воспользоваться.

Так родилась и реализовалась идея анализа полетной информации для суждения о качестве работы экипажа и в меру наших возможностей мы пытаемся эту информацию использовать при экспрессанализе закончившегося полета.

Анализу этой уникальной информации, к сожалению, до сего дня еще недоступна такая всесторонность, которая может быть сделана присутствующим на борту проверяющим, и мы до сих пор результат регистрации параметров полета пропускаем через жернова обрабатывающих компьютеров, чтобы оценить "чистоту" пилотирования, получая те или иные числовые характеристики. Инженерам и командирам особенно нравиться на основе этой обработки расставлять летчикам отметки и ранжировать их по этим признакам. Они не учитывают при этом, что судят о многокомпонентной работе пилота по одному-единственному показателю. Прекрасно, если летчик умеет идеально выдержать режим полета и в то же время все видеть, быть непрерывно ориентированным в обстановке и управлять экипажем. Летчики-испытатели вынужденные в силу профессии пилотировать максимально точно, знают, что такое совмещение не может считаться типичным и встречается далеко не каждый день. Поэтому массовый пилот, стремящийся пилотировать как можно точнее, неизбежно проигрывает в остальных качествах. Оценки же по результатам полета составляются почти исключительно по признаку точности пилотирования, а летчик, как и всякий человек, хочет иметь хорошие отметки. Причем поскольку отметка ставится только за точное пилотирование по критериям отклонений от рекомендаций инструкций, постольку летчик вынужден жертвовать почти всеми другими аспектами своей работы для получений хорошей отметки, от которой в известной степени зависит его и социальное положение. Из сказанного не следует делать вывод о ненужности измерения и анализа материалов "черного ящика". Нужно сделать вывод о том, что необходимо возможно скорее научиться из этих материалов извлекать максимум информации о работе летчика, чтобы помочь ему в профессиональном совершенствовании, и пополнить наши знания о деятельности летчика в русле общей проблемы "человеческого фактора".

В нашей стране (в том числе и с участием автора) были предприняты попытки из т.н. "параметрической информации" извлечь сведения о резервах внимания летчика. Известны попытки оценивания уровня нервно-эмоционального напряжения по этой же информации.

Эти поиски построены на некоторых непротиворечивых гипотезах, которые проверялись в экспериментах на тренажере и в воздухе.

Методы исследований включали в себя разработку аппарата априорной оценки резервов внимания летчика и строились на теории марковских процессов, на использовании энтропийно-информационного подхода к задаче, на применении теории выбросов случайных функций, а также на интерпретации процесса пилотирования как непрерывного удовлетворения "заявок на обслуживание" в терминах теории массового обслуживания.

В ряде случаев результаты априорных аналитических исследований хорошо коррелировались с результатами прямых измерений резервов внимания пилота.

В других случаях, когда корреляция была слабой, делался вывод о неэффективности того или иного априорного метода.

Нам представляется целесообразным дальнейшее изучение проблемы текущего контроля качества пилотирования в указанных двух направлениях. Однако в случае успешности таких разработок, мы считаем, что оценки качества, адэкватные текущему состоянию натренированности в смысле техники пилотирования и резервов внимания пилота, должны быть поводом исключительно для профилактических методических мероприятий, таких, как дополнительная тренировка или отмена запланированной тренировки, предоставление профилактического отдыха или решение о продолжении деятельности и т.п. Но ни в какой мере эти оценки не должны применяться как повод для санкций к пилоту.

Дальнейшим наращиванием исследований могло бы быть изучение устойчивости этих оценок во времени для определения оптимальной периодичности контроля. Некоторые работы по этой проблеме у нас в стране выполняются.

Таким образом, мы считаем, что применение доложенных методов в виде создания некоего "профессионально-психологического портрета" летчика отраженного в сопровождающих его летную деятельность документах (летной и медицинской книжках), было бы полезно как при профилактике авиационных происшествий и инцидентов, так и при их расследовании, если, несмотря ни на что, они будут иметь место.

ФОРМИРОВАНИЕ ПРОФЕССИОНАЛЬНЫХ КАЧЕСТВ ПИЛОТОВ И ДИСПЕТЧЕРОВ УВД ПО КРИТЕРИЯМ НАДЕЖНОСТИ ДЕЯТЕЛЬНОСТИ

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Одним из важнейших показателей функционирования авиационной транспортной системы является безопасность полетов.

Несмотря на происходящие в последние десятилетия под влиянием научно-технического прогресса качественные изменения в надежности авиационной техники в мировой авиационной транспортной системе продолжают происходить авиационные происшествия и предпосылки к ним. Мировой опыт расследования и анализа этих событий показывает, что в большинстве случаев их причины связаны с"человеческим фактором". Именно поэтому усилия многих ученых различных стран направлены на поиски путей учета "человеческого фактора" при проектировании и совершенствовании таких сложных эргатических систем как атомные электростанции, атомные подводные лодки, системы управления сложными производствами и в том числе и авиационная транспортная система. Все задачи, решаемые в отношении развития *инфраструктуры этой системы в конечном итоге* направлены на безопасное и экономичное выполнение каждого конкретного полета. Влияние "человеческого фактора" при этом, естественно, следует ожидать не только от экипажа, но и от действий диспетчера, а также от их совместной деятельности. Это становится тем более важным, что в последнее время наблюдаются предпосылки к авиационным происшествиям (ПАП) и авиационные происшествия (АП), причины которых кроются именно в несогласованных действиях экипажа и диспетчера.

При этом цена ошибки летчика и диспетчера настолько возросла, что для некоторых стран последствия авиакатастроф являются национальным бедствием. Именно поэтому поиск эффективных путей повышения надежности человеческого звена в контуре управления воздушным судном и управления воздушным движением летательных аппаратов стал всемирной задачей.

В настоящее время можно выделить три главных направления поиска путей повышения надежности человеческого фактора в авиации (рис. 1):

- профессиональная подготовка членов летных экипажей и диспетчеров УВД;

- профессионально-психологический отбор летного состава и диспетчеров УВД;

- оптимизация профессиональной деятельности членов летных экипажей и диспетчеров УВД в ожидаемых условиях полета и особых ситуациях.

Именно в этих направлениях осуществляют научный поиск большинство наших ученых, авиационных специалистов, методистов летного обучения, психологов, медиков, инженеров и др. Анализ большого количества нормативных актов, литературных источников и научно-исследовательских работ показывает, что за последние I0 лет сделаны крупные шаги в разработке путей повышения уровня надежности человеческого звена, средств и методов летного обучения членов экипажа и диспетчеров УВД. В гражданской авиации существует большой отряд ученых и специалистов, которые внесли огромный вклад в решение проблемы повышения уровня надежности звена "экипаж" в системе "экипаж-воздушное судно-среда". Большие достижения в решении частных задач по проблеме повышения надежности человеческого звена обеспечили серьезные предпосылки для создания в гражданской авиации современной системы совместной подготовки летного и диспетчерского составов, базирующейся на критериях надежности их деятельности.

Однако на пути конструирования и внедрения такой системы профессиональной подготовки указанных специалистов лежат и нерешенные проблемы.

Исследования специальных источников и нормативных актов покаготовки летного и диспетчерского составов.

Исследованием такого интегративного плана является работа по конструированию системы "экипаж-диспетчер УВД". Это будет работа, которая позволит соединить дидактическую структуру подготовки двух видов специальностей, имеющих единую целевую направленность в стратегии исследований проблемы человеческого фактора.

Именно по этим причинам первостепенное значение в нашей Академии придается разработке языка системного подхода к профессиональной подготовке специалистов на первый взгляд несколько различного профиля. Поиск системообразующего фактора, который увязал бы тактику моделирования сложных педагогических процессов,- первостепенная задача наших ученых.

В сложной эргатической системе пилот и диспетчер представляют собой активные элементы, и их адаптационные механизмы играют исключительно важную роль в обеспечении надежного функционирования всей системы в полете. Характеристики надежности совместной деятельности пилота и диспетчера, которые обеспечиваются своевременностью и безошибочностью выполнения операций в ожидаемых условиях (ОУ) и особых ситуациях (ОС) полета, активно приобретаются и развиваются в процессе летной тренировки, и интенсивность развития адаптационного механизма до уровня динамического стереотипа зависит от совершенства системы профессиональной подготовки членов летного экипажа, пилота и диспетчера. Следовательно, современная система профессиональной подготовки должна базироваться на критерии надежности совместной деятельности экипажа и диспетчера в различных эксплуатационных условиях. Этим критерием являются своевременность и безошибочность выполнения операций в ожидаемых условиях полета и особых ситуациях, что определяет фундамент эксплуатационной направленности всей системы совместной подготовки зали, что формирование надежностных характеристик деятельности членов экипажа в ожидаемых условиях и особых ситуациях в полете и поддержание их на заданном уровне осуществляется в основном в системе подготовки членов летных экипажей гражданской авиации без учета их взаимодействия с диспетчерами УВД. Это коренится в отсутствии научно-обоснованных моделей выпускников учебных заведений и других видов обучения по требованиям отрасли, слабой научной проработке отбора содержания подготовки, выбора целенаправленных методов, средств и способов формирования надежных знаний, навыков и умений по эксплуатации ВС в особых ситуациях, а также в

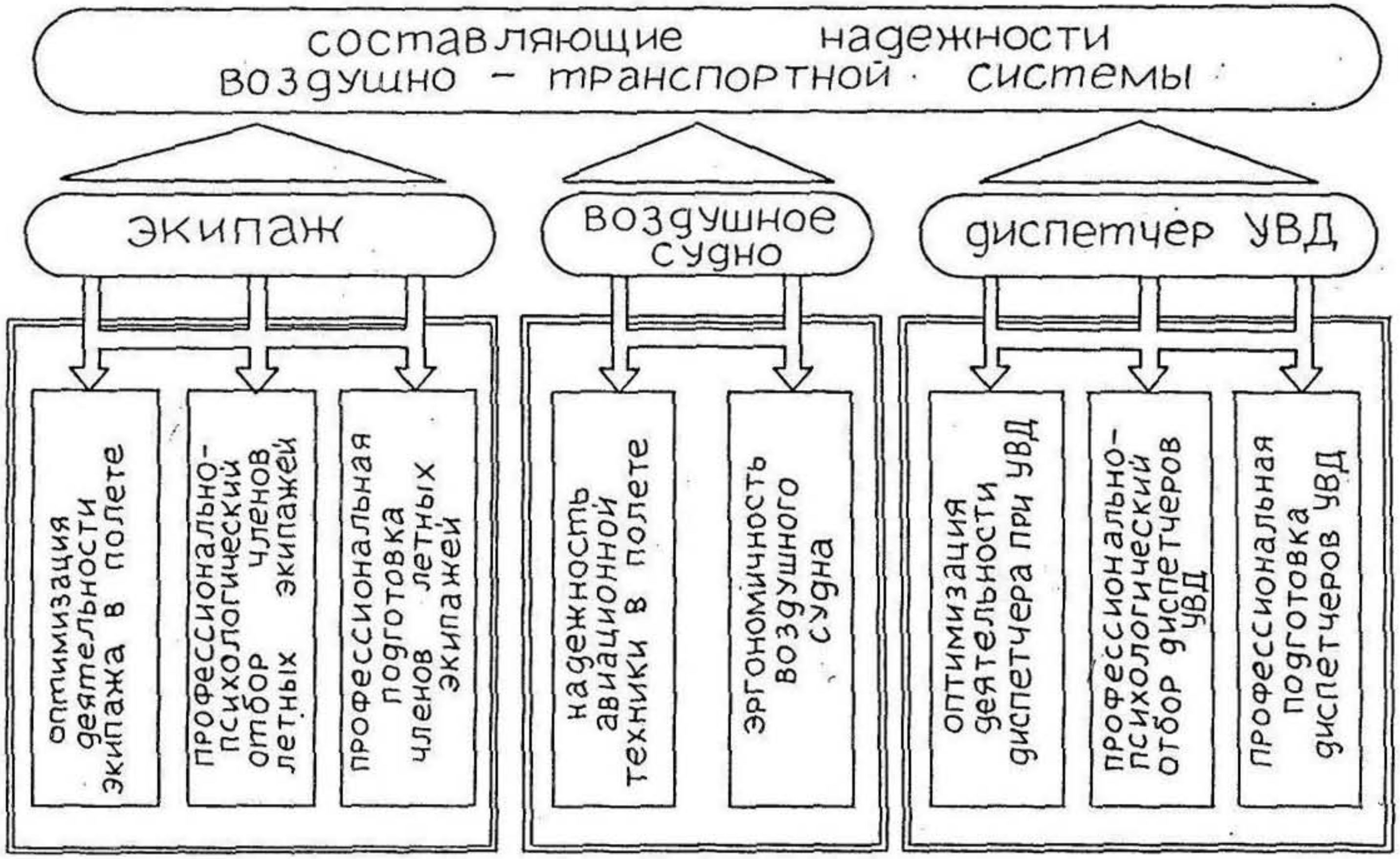

Рис. 1 Главные направления в повышении уровня безопасности полетов в эргатическом комплексе „экипаж – диспетчер"

отсутствии комплексных критериев оценки деятельности экипажа и в системном оформлении.

Все это требует поиска и осмысления новых путей подготовки авиаспециалистов в их взаимодействии, новых методологических подходов с позиций повышения надежности человеческого звена и эффективной эксплуатации воздушно-транспортной системы в различных эксплуатационных условиях.

Однако система летной подготовки - это лишь одно звено в обеспечении надежности человеческого фактора. Если внимательно посмотреть на каналы взаимодействия пилотов при выполнении полетного задания, то станет совершенно очевидно, что есть еще одна система, которая оказывает доминирующее влияние на надежность системы "экипаж-воздушное судно-среда". Это суперсистема "экипаж-диспетчер УВД" (рис. 2).

На практике эти две системы "экипаж-ВС" и "экипаж-диспетчер" находятся в тесном органическом взаимодействии, а при подготовке летного и диспетчерского составов создается по существу искусственное их разделение. Аварии и катастрофы по вине диспетчерского состава заставляют задуматься над созданием суперсистемы "экипаж-диспетчер", которая должна стать основой для проектирования совместной системы профессиональной подготовки летного и диспетчерского персоналов. Это обуславливает следующие узловые концепции на пути надежности человеческого фактора:

- единство целей в обеспечении надежности человеческого фактора;
- необходимость единого языка в оценке ситуаций;
- необходимость получения прироста качества надежности человеческого фактора за счет взаимопроникновения в сущность "соседней" профессиональной деятельности;
- необходимость в целях повышения надежности получения совершенства психологических механизмов взаимодействия в рамках суперсистемы.

1. Единство целей в обеспечении надежности ЧФ.
2. Единый „язык” в оценке ситуаций.
3. Прирост качества надежности ЧФ за счет „взаимопроникновения” в профессиональную деятельность.
4. Совершенство психологических механизмов взаимодействия.

Рис. 2 Суперсистема „экипаж – диспетчер”

В настоящее время разработка частных вопросов подготовки авиационных специалистов не удовлетворяет требованиям этапа ускорения научно-технического прогресса, традиционно сложилось, что подготовка летного и диспетчерского составов осуществлялась отдельно, в то время как на практике об"ективно существует единая суперсистема, созданная по потребностям практики априорно, без методологического упорядочения, а потому стоящая в стороне от интенсивных научных исследований.

Сегодня мы можем констатировать тот факт, что теоретические концепции целостного подхода к конструированию моделей профессиональной подготовки, аппарат системного анализа и другие ключевые проблемы нашими учеными раскрыты и осмыслены, а это позволяет в самое ближайшее время перейти к практической разработке сложных интегративных систем (суперсистем) профессиональной подготовки и, наконец, на научной основе построить систему профессиональной подлетного и диспетчерского персонала. Создание такой системы должно вестись по этапам (рис. 3).

На этапе исследования функций в совместной деятельности важнейшим вопросом является распределение ответственности между экипажем и диспетчером.

Вопрос о распределении ответственности, по-видимому, должен ставиться не только и не столько для того, чтобы определить кто должен отвечать за результаты действий, сколько для того, чтобы разумно в смысле надежности и экономичности были распределены отдельные функции в общей системе "экипаж-диспетчер".

Эти функции в первую очередь связаны с соблюдением установленных правил полетов, а конкретнее с учетом этих правил при принятии решений (например, при принятии решения на вылет учитываются правила вылета ВС и т.д.).

Принятие решения осуществляется на основе переработки информации об ограничениях на выполнение того или иного действия и поэтому для решения вопроса о том, кто и по каким ограничениям должен принимать решение, на наш взгляд, целесообразно учитывать следующие основные принципы: (рис. 4):

Рис 3. Основные этапы определения содержания совместного обучения летного и диспетчерского персонала

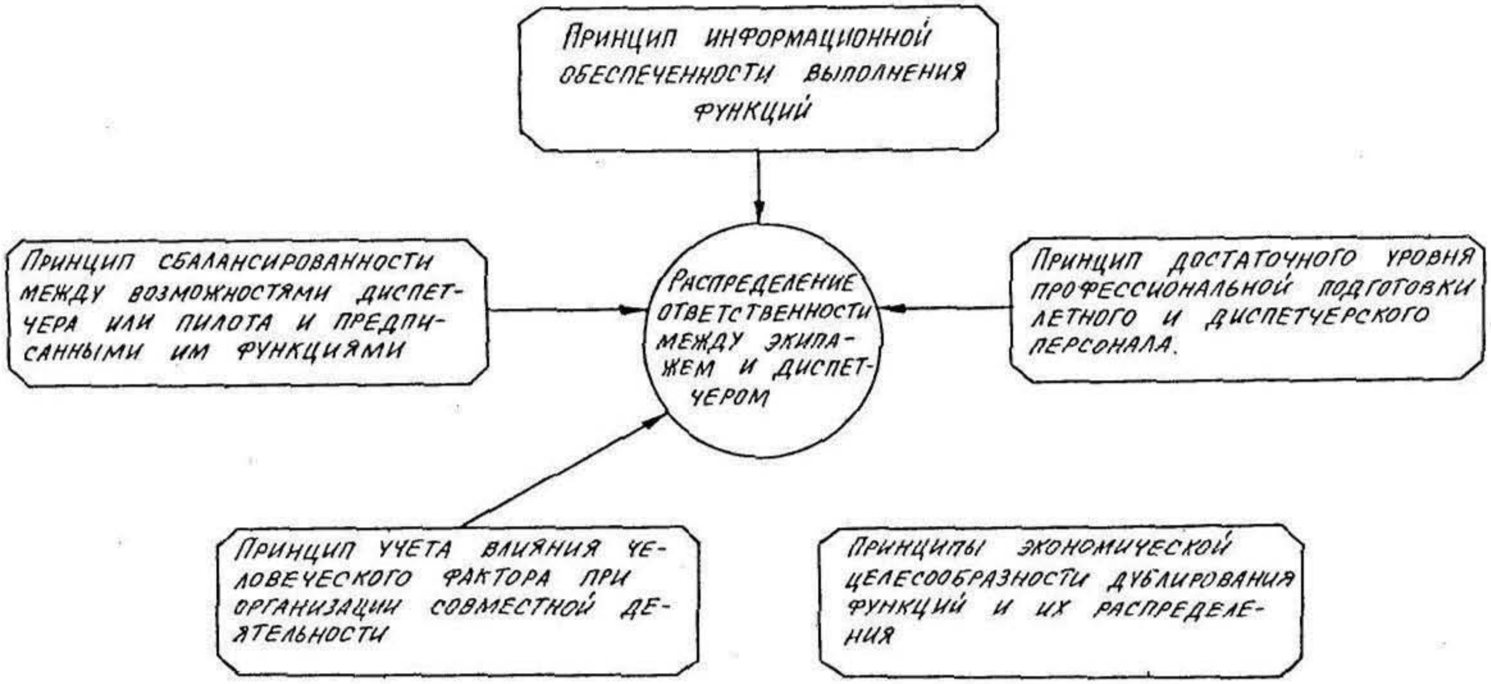

Рис. 4. Принципы рационального распределения ответственности между экипажем и диспетчером.

1. Принцип информационной обеспеченности, заключающийся в оценке количества, точности и своевременности представляемой информации о воздушной и метеорологической обстановке, а также об ограничениях на параметры этой обстановки.

2. Принцип сбалансированности между возможностями диспетчера или пилота и предписанными ему функциями. При этом сбалансированность определяется наличием средств и уровнем автоматизации обработки информации, а также показателями сложности алгоритма принятия решения.

3. Принцип достаточного уровня профессиональной подготовки летного и диспетчерского персонала. При этом особо необходимо учитывать ту часть профессиональных знаний и навыков, которую пилот или диспетчер приобретает в процессе непосредственной работы. Так, например, знания пилота об условиях выполнения полета на предпосадочной прямой при ограниченных значениях видимости и нижней границы облаков несравненно больше, чем знания об этом диспетчера.

4. Принцип влияния человеческого фактора на процесс принятия решения и на его результаты. Тут целесообразно ответить на вопрос - что эффективнее движет человеком при принятии решения - личная заинтересованность в безопасности у пилота или страх перед ответственностью у диспетчера. Другим аспектом влияния человеческого фактора является такое явление, когда два исполнителя одной и той же функции в ряде случаев не только в надежде друг на друга не выполняют этой функции, но и осуществляют взаимное влияние друг на друга, чтобы ее не выполнить.

5. Принцип экономической целесообразности при распределении функций и ответственности особенно важно учитывать при организации схемы дублирования (контроля) выполнения функций принятия решения. Так, например, в очень большой степени диспетчером АДП дублируется принятие решения на вылет командиром ВС, что требует достаточно больших материальных затрат.

Таким образом, процесс принятия решения и его результаты оцениваются показателями надежности и экономичности с учетом изложенных принципов и поэтому при выборе варианта распределения функций и ответственности между пилотом и диспетчером следует в первую очередь рассчитать или определить именно эти показатели.

Задача определения этих показателей является не тривиальной. В настоящее время нет рассчитанных значений показателей надежности для этих вариантов. Однако есть результаты опытной проверки различных вариантов распределения ответственности в различных странах.

Есть опыт использования двух вариантов и в нашей стране. Это вариант ИКАО, когда мы управляем рейсами иностранных авиакомпаний и наш вариант - использования правил распределения ответственности по НПП.

Есть опыт выполнения полетов нашими экипажами за рубеж, когда действует вариант распределения ответственности по стандартам ИКАО.

В целом оба эти варианта используются достаточно долго и поэтому являются рабочими для анализа и сравнения.

Существенной разницей между вариантом ИКАО и нашей отечественной системой распределения ответственности является степень дублирования функций по принятию решения.

В нашей отечественной системе количество дублированных функций больше, чем в системе стандартов ИКАО. Следует отметить, что у нас дублированными оказались наиболее важные функции экипажа по принятию решения, такие как принятие решения на вылет, на взлет, на снижение, на посадку, по выдерживанию безопасных высот, некоторых интервалов и т.д.

Обоснованием этого, по-видимому, являлось предположение о том, что дублирование или резервирование повысит надежность принятого решения. При этом, естественно, требовались и затрачивались дополнительные материальные ресурсы. Однако полного уровня безопасности полетов такая схема резервирования не дала. Примеры нарушений безопасности полетов широко известны (Алма-Ата - нарушение схемы снижения и захода на посадку). Однако и отрицать полностью эффективность такой схемы нет оснований.

Экспертный опрос летного состава, проходящего обучение в Академии ГА, дает основание считать в целом, что степень дублирования функций в нашей системе распределения ответственности все-таки слишком высока. При этом ни в коей мере не высказывается мнение о необходимости абсолютно полного разделения функций и ответственности. Примеры неудачного применения такого принципа также широко известны (катастрофа Б-747 в США при произвольном снижении ВС при заходе на посадку, когда диспетчер видел, что ВС снижается и не принял разумных эффективных мер по предотвращению снижения). Одним из основных принципов организации схемы распределения ответственности является принцип декомпозиции задач УВД и тщательный научный анализ конкретной задачи.

Такой анализ позволяет перейти к рассмотрению и определению основных путей повышения надежности деятельности летного и диспетчерского персонала (рис. 5), среди которых важнейшим является проектирование элементов системы профессиональной подготовки.

При прогнозировании развития системы "экипаж-воздушное судно-диспетчер" к настоящему времени учитываются следующие основные направления:

- создание государственной системы использования воздушного пространства и УВД, что существенно изменит функции диспетчеров и, по-видимому, внесет изменения в правила и процедуры выполнения полетов и УВД;
- разработка и внедрение современных автоматизированных систем УВД и принципов,и методов зональной и спутниковой навигации;
- существенное увеличение интенсивности международных полетов и расширение их географии на территории СССР, с чем связана проблема обучения летного и диспетчерского персонала английскому языку.

Общегосударственные требования к организации процесса подготовки кадров в СССР в настоящее время претерпевают серьезные изменения, в основу которых положены принципы демократизации общест-

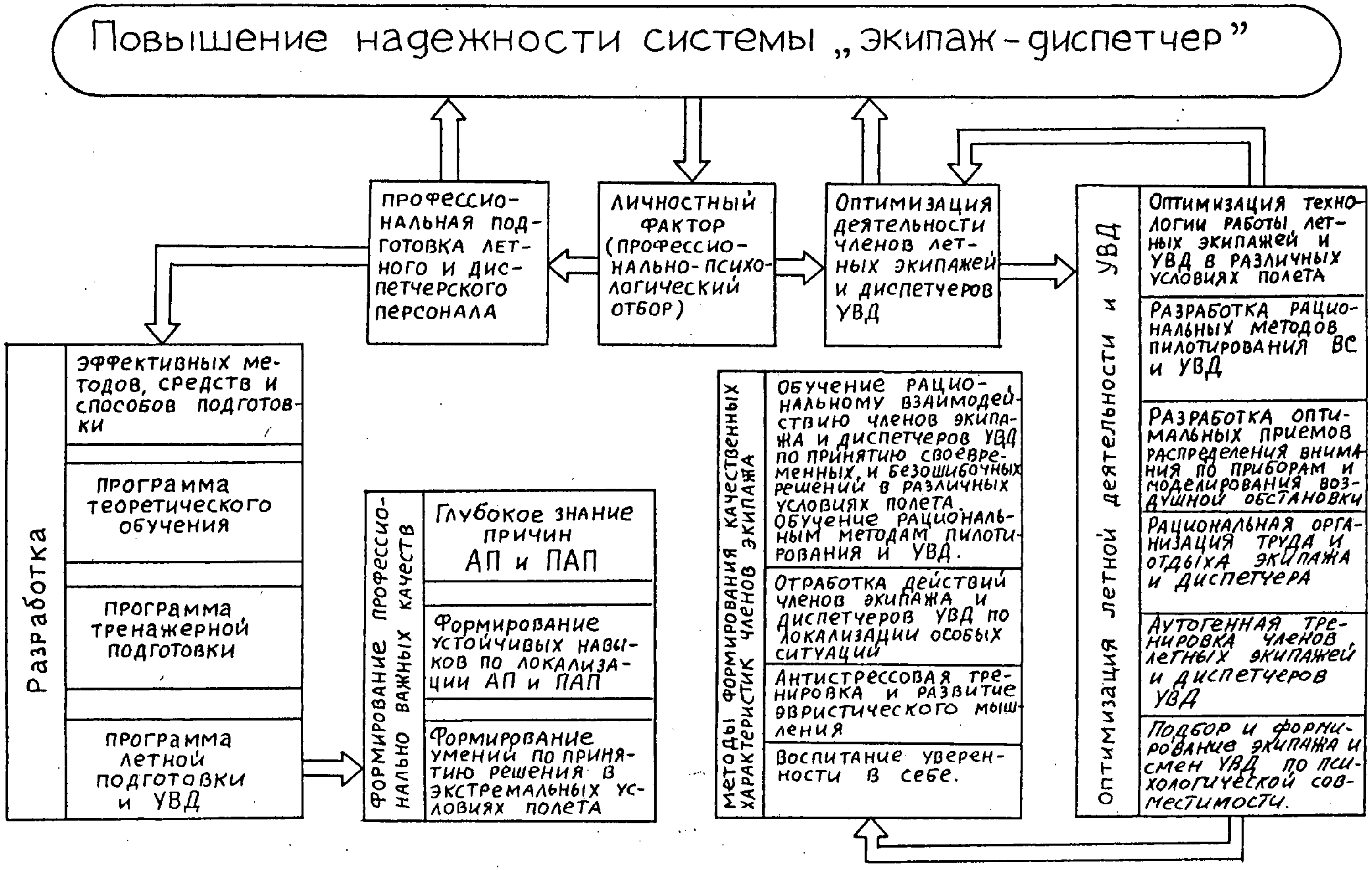

Рис. 5 Основные пути повышения надежности деятельности летного экипажа и диспетчера УВД

ва. Снимаются многие ограничения, отменяются инструкции, что делает систему подготовки более гибкой и позволяет учесть и применять стандарты и рекомендации ИКАО и опыт зарубежных стран в этой области.

Практика летной деятельности УВД показывает, что особенно в первое после окончания учебного заведения время диспетчеры часто берут на себя ответственность принимать решение без достаточных к тому оснований, а, с другой стороны, подобные ошибки проявляются у пилотов после переучивания с легких на средние и тяжелые самолеты, то есть когда совместная деятельность пилота и диспетчера переходит из области действия одних правил (например, ПВП) к другим (ППП). При этом в программах переподготовки пилотов огромное внимание уделяется вопросам пилотирования новой для него техники, а новое взаимодействие со службой УВД считается второстепенным.

Вот почему необходимо выделение, анализ и отработка таких ситуаций, в которых и пилот и диспетчер должны показать знания и навыки в принятии решений только тех задач, которые они должны решать, либо в координации совместной деятельности в тех случаях, когда этого требуют соответствующие летные законы.

Существенный эффект в приобретении таких знаний и навыков достигается за счет применения различных технических средств обучения, таких как процедурные тренажеры, работающие в режиме диалога, основой которых являются персональные ЭВМ. При этом эффективность во времени обучения на таких тренажерах по сравнению с комплексными выше в 10÷15 раз, а стоимость обучения ниже на порядок. Разработка такой системы процедурных тренажеров для персонала УВД проводится в Академии на основе научных исследований в этой области. Основной проблемой тут является идентификация и моделирование совместной деятельности пилота и диспетчера. К настоящему времени разработаны математические модели и соответствующее программное обеспечение для разделений имитации фрагментов деятельности пилота и диспетчера.

Но еще и на этом пути лежат нерешенные нетривиальные задачи, такие как адекватность модели, определение показателей эффективности и критериев качества деятельности в различных ситуациях и условиях.

Для разработки системы об"ективной оценки результатов совместной деятельности пилота и диспетчера необходимо:

I. Определить и детально описать цели, функции и действия пилотов и диспетчеров.

2. Определить и формализовать единицы измерения качества выполнения этих действий.

3. Разработать структуру оценок или параметров – они должны быть адекватны структуре реальной деятельности пилота и диспетчера.

4. Решить технические проблемы регистрации этих параметров и определить оптимальный уровень применения параметров с точки зрения цены, точности и надежности оценки.

5. Определить критерии для этих параметров. Существует множество научных методов для этого, но большинство из них основано на экспериментальных исследованиях деятельности диспетчера.

6. Определить метод построения комплексного показателя эффективности. Это типичная задача в теории принятия решений, методы которой и можно применять для этого. Интересным является подход, основанный на использовании методов теории распознавания образов.

Все это является ничем иным, как разработкой модели принятия решения инструктором о качестве подготовки персонала.

СНИЖЕНИЕ ВЛИЯНИЯ ЧЕЛОВЕЧЕСКОГО ФАКТОРА НА БЕЗОПАСНОСТЬ ПОЛЕТОВ С ПОМОЩЬЮ ЭКСПЕРТНЫХ СИСТЕМ

Н.Н.Сухих, С.М.Федоров

Влияние человеческого фактора на безопасность полетов складывается из ряда составляющих, среди которых можно выделить уровень подготовленности авиаспециалистов и степень автоматизации эксплуатируемой техники в смысле подготовки данных для последующего быстрого и правильного принятия решений человеком в особых ситуациях, в условиях необходимости переработки значительных объемов информации при дефиците времени. Настоящий доклад посвящен снижению влияния человеческого фактора согласно второго направления, т.е. за счет совершенствования информационного обеспечения авиаспециалистов.

Одним из основных путей решения данной задачи является разработка и внедрение на базе ЭВМ специализированных программных средств, каждое из которых является экспертом в некоторой узкой предметной области. Эти программы получили название экспертных систем (ЭС). Ядром любой ЭС является база знаний, которая накапливается в процессе её построения. Знания выражены в явном виде и организованы так, чтобы упростить принятие решения.

Сравнение компетентности авиационного специалиста и " искусственной компетентности ", получаемой с помощью ЭС, иллюстрирует таблица I.

Таблица I.

Компетентность авиаспециалистов	Компетентность экспертной системы
Ограниченная	Практически может быть достигнута в любом требуемом объеме.

Трудно учитываемая.	Легко учитывается путем накопления в базе знаний.
Трудно проявляемая в стрессовых ситуациях и в условиях дефицита времени.	Стрессовые ситуации практически не возникают, скорость проявления определяется быстродействием ЭВМ и структурой программного комплекса.
Дорогая.	Приемлемая по затратам.

Преимущества ЭС позволяют использовать их в ГА в следующих направлениях: бортовые системы управления полетом; системы УВД; расследование авиационных происшествий; различные наземные службы.

В докладе более подробно рассматривается первое направление. Место бортовой экспертной системы (БЭС) в составе пилотажно-навигационного комплекса современного воздушного судна (ВС) иллюстрирует рис. I. При этом бортовая ЭС может применяться экипажем для решения следующих задач: прогнозирование координат ВС; диагностика отказов бортового оборудования; выбор оптимальных режимов полета в смысле заданного критерия.

В качестве примера показано применение БЭС для выдачи исходных данных при прогнозировании допустимых отклонений координат ВС от заданной траектории при заходе на посадку на высоте принятия решения (ВПР). В первом приближении можно полагать, что область допустимых отклонений представляет собой " окно ", размеры которого ограничены максимальными значениями исправляемых отклонений в боковой и вертикальных плоскостях: $\pm Z_{max}$ и $\pm H_{max}$ (рис.2).

Размеры данного " окна " зависят от ряда факторов, среди которых можно выделить действующие возмущения на ВПР и ниже, а также характер управления после пролета ВПР. При этом характер управления оказывает существенное влияние при посадке по I и II категориям ИКАО, т.к. в этом случае на ВПР осуществляется переход на ручное пилотирование.

В докладе исследование производится на примере цифровой системы автоматического управления боковым движением одного из типов самолетов ГА [I] . Для упрощения задачи рассматривается только последний участок траектории захода на посадку - движение по предпосадочной прямой. Движение объекта описывается линеаризованной системой

$$\dot{x} = Ax + B\gamma_{\text{з}} + CW_z ,$$

где $x = (Z, \dot{Z}, \psi, \dot{\psi}, \gamma, \delta_H)'$. При этом величина Z характеризует уклонение центра масс самолета от оси Взлетно-посадочной полосы (ВПП), ψ - угол рыскания, γ -крен; к фазовым координатам относятся также скорости изменения этих величин $\dot{Z}$, $\dot{\psi}$, $\dot{\gamma}$; δ_H - отклонение руля направления. Предполагается, что вычислитель командного сигнала (заданного угла крена $\gamma_{\text{з}}$) реализует закон управления автоматической бортовой системы управления типа АБСУ-I54 [2] . К возмущениям, непосредственно действующим на самолет, относятся изменения боковой составляющей скорости ветра W_z [3] . База знаний данной БЭС содержит правила и факты в двух предметных областях:

- индивидуальные особенности пилотирования конкретным экипажем после пролета ВПР;
- ветровые возмущения в конкретном аэропорту посадки с учетом времени и сложившейся метеорологической ситуации.

В качестве примера можно указать фрагмент базы знаний БЭС в терминах правил продукций, используемых, например, в экспертной системе типа MYCIN :

ЕСЛИ пилотирует экипаж .... ТО τ = 0,6 с (0,9);
ЕСЛИ заход на посадку в аэропорту........ И лето И I2 часов
И скорость ветра у земли I0 м/с ТО p = 0,4 с (0,8).

В скобках указаны значения коэффициентов определенности, τ- время запаздывания конкретного экипажа, значение параметра p необходимо для прогностического расчета скорости ветра на заданной высоте H в соответствии с известной и переданной на борт экипажу скоростью ветра у земли $W_{\text{з}}$ согласно формулы $W = W_{\text{з}} (\frac{H}{10})^p$ [2] .

Использование БЭС позволяет определять допустимое боковое отклонение самолета на ВПР применительно не только к типу ВС, но и к конкретному экипажу и аэропорту посадки. Учет человеческого фактора с помощью программных средств ЭС приводит в данном случае к повышению вероятности успешного захода на посадку и, в конечном итоге, к повышению безопасности полетов.

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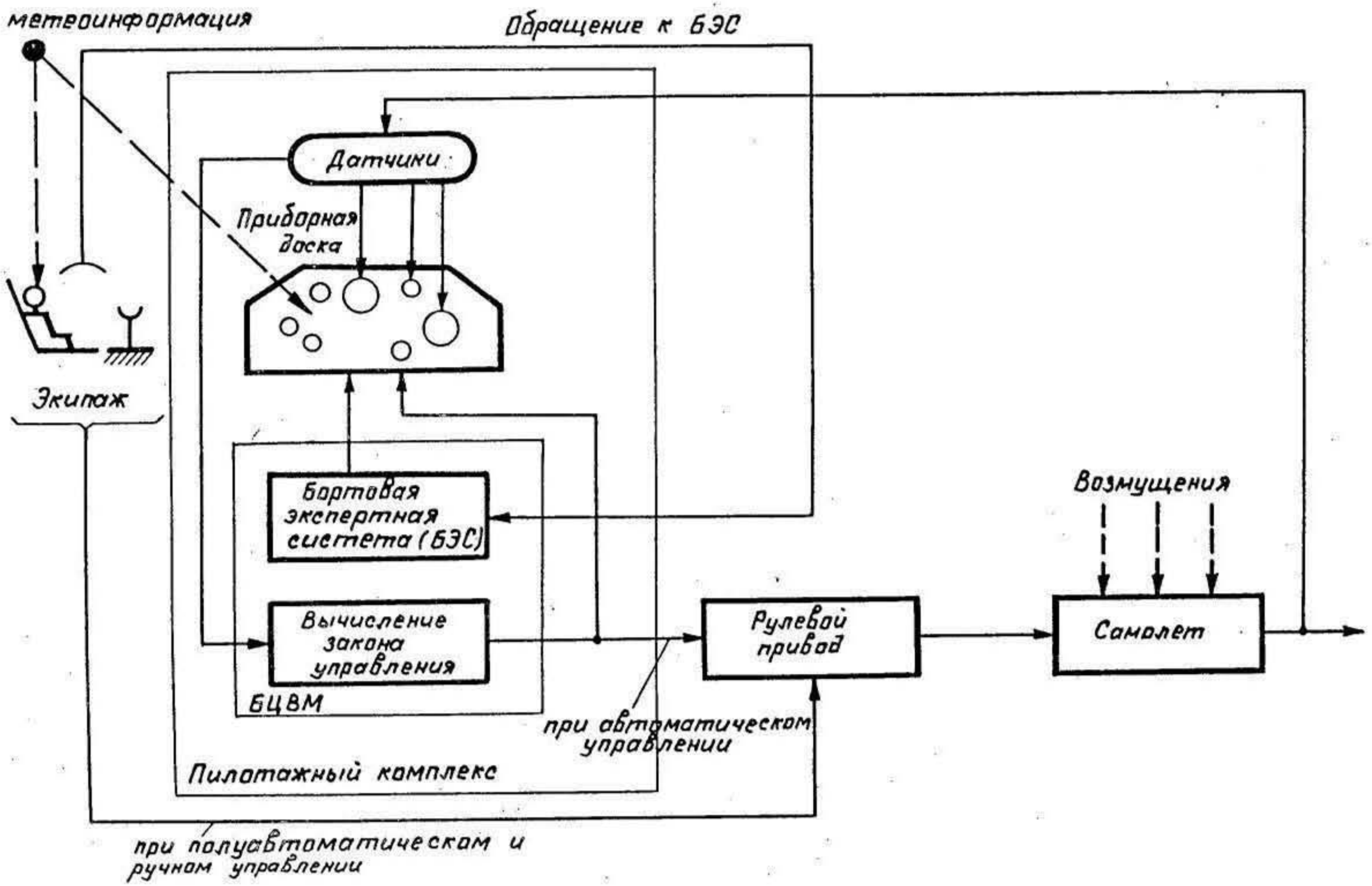
метеоинформация
Обращение к БЭС
Датчики
Приборная доска
Экипаж
Бортовая экспертная система (БЭС)
Вычисление закона управления
БЦВМ
Пилотажный комплекс
Рулевой привод
Возмущения
Самолет
при автоматическом управлении
при полуавтоматическом и ручном управлении

Рис. 1

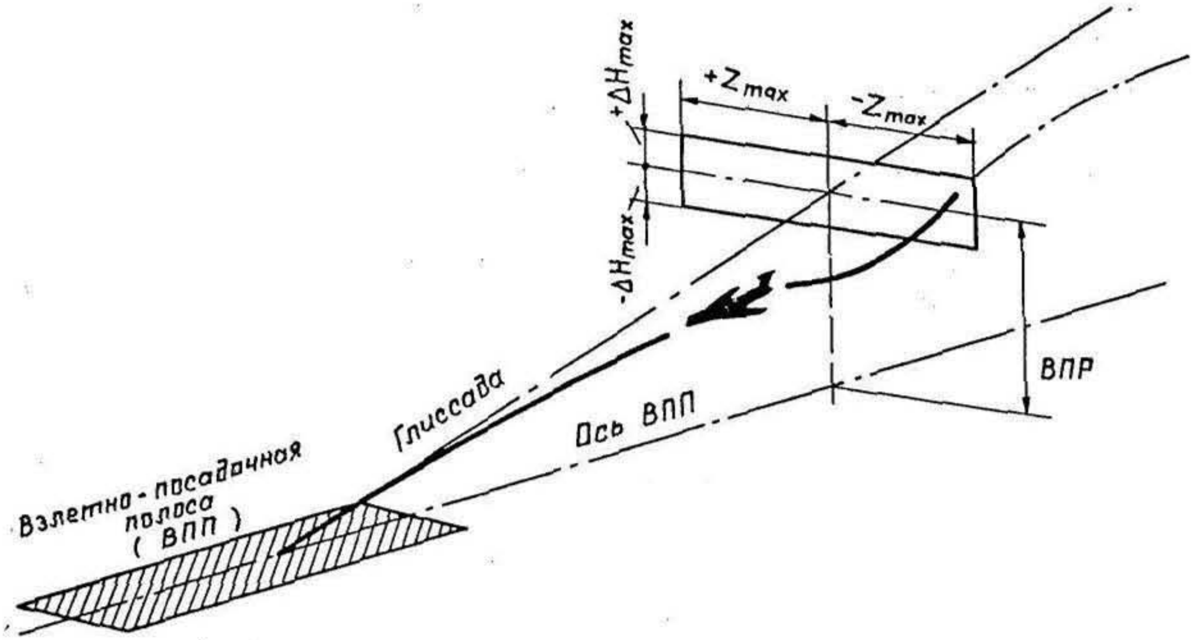
+ΔH max
-ΔH max
+Z max
-Z max
ВПР
Глиссада
Ось ВПП
Взлетно-посадочная полоса (ВПП)

Рис. 2

MAXIMUM DUTY TIME AND MINIMUM REST TIME FOR FLIGHT CREW MEMBERS

(Presented by the
International Federation of Air Line Pilots Associations)

The human body and its physiological functions are strongly controlled by the biological clock, a 24-hour day-night variation or cycle of body functions called circadian rhythm. This includes body temperature, alertness versus sleep, eating and appetite, hormone levels, performance, and behaviour. Mental performance and memory is high between 0800 and 1400 hours and then drops off during the afternoon. All of this simply means that at night the aviator is asked to perform at maximum capacity, when the body is saying "it's time to sleep - I'm not ready for work"[1].

The issues of flight crew rest and duty time have been intertwined with those of flight safety for decades. Although dramatic advances in aircraft design and air traffic control have resulted in a substantial decrease in the overall accident rate, a persistent 65 percent of all mishaps continue to result, at least in part, from flight crew error. Of course, a variety of human factors underlie these statistics, but fatigue has always been one which has attracted attention[2].

A study was performed with 74 crew-members operating B-737 and DC-9 aircraft primarily flying in the eastern half of the U.S. with no more than one time-zone crossing.

The results revealed that, in general, crews flying the short-haul routes under study obtained less sleep during layovers than at home, slept more poorly as the trip progressed, and become more tired. More specifically, the extent of these effects varied depending on a number of factors such as time-of-day and individual personality traits.

There was some suggestion that both activity and heart rate during sleep increased on successive trip nights, particularly in older subjects. Older subjects also rated their fatigue as significantly greater and their activation as significantly less at the end of each duty day in comparison to younger crew members. The emergence of an age-related effect in sleep disturbances would be consistent with the recent findings of poorer sleep in older crew members flying transmeridian routes.

The leading question is, of course, does lack of sleep and fatigue cause accidents?

Maybe. Certainly it is on the minds of pilots.

Last year the U.K. Confidential Human Incident Reporting Programme (CHIRP)[3] received a number of pilot reports of excessive fatigue, typical of which was:

> "The combination of long hours, multiple sectors, night flights, bad crew meals and no summer holidays makes you very fatigued. Something must be done soon to change this before there is an accident". (The same pilot *twice last year found his captain asleep at the controls*).

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[1] Flight Safety Foundation - "Flight Safety Digest" - September 1989 by T.P. Jensen

[2] R. Curtis Graeber: "Sleep and Fatigue in Short-Haul Operations - a Field Study."

Did fatigue cause the crash in 1979 of a Western Airlines DC-10 which landed on the wrong runway at Mexico City and collided with a cargo truck and building? Seventy-nine people were killed. It happened at 05.30 in the morning, a time when the crew from Los Angeles would normally have been in bed.

Accident Investigation Authorities are loath to implicate lack of sleep or fatigue in their reports. For example, in December 1977 three crew members died when their air freighter flew into a mountain near Salt Lake City. Investigators concluded that the crash was caused by unclear communications between the pilots and the controller and the crew's failure to adhere to prescribed holding procedures. What the investigators did not query was the controller's lack of sleep before the 01.38 a.m. crash nor the wearying cross-country schedule the captain had flown in the days before the accident.

Similarly, in September 1978 investigators blamed the crew of a B-727 for failing to keep a Cessna in sight near San Diego. The planes collided and one hundred and forty-four people died. The airliner crew, however, had worked both days and evenings during the previous four days.

The topic of Flight Fatigue is so delicate that never before have Pilots, Scientists, Airline Operators and Aviation Authorities discussed the problems more intensely than now.

Forty years ago the International Federation of Air Line Pilots Associations (IFALPA) produced the first proposal to regulate the Airline Industry in this regard. The basic figures for the policy haven't changed much though the pilots at the time didn't have the benefit of the scientific evidence that we have today.

At the time it was regarded as an "industrial" issue by the Management of the Airlines - just another claim by the "spoiled pilots". Unfortunately, that opinion hasn't changed much in the meantime. Economy has always been the driving force!

The scientific evidence is now so overwhelming that it is time to set things straight. ICAO Annex 6, paragraph 4.2.9.3 presents the following Standard:

> *"4.2.9.3 An operator shall formulate rules limiting the flight time and flight duty periods of flight crew members. These rules shall also make provision for adequate rest periods and shall be such as to ensure that fatigue occurring either in a flight or successive flights or accumulated over a period of time due to these and other tasks, does not endanger the safety of a flight. These rules shall be approved by the State of the Operator and included in the Operations Manual.*
>
> > *Note. - This Standard does not preclude a State from establishing regulations specifying the limitations applicable to flight crew members of aeroplanes registered in that State. Guidance on the establishment of limitations is given in Attachment A."*

and there is additional "green-page" guidance material in Attachment A to the Annex. For the sake of flight safety, it is considered that this material should be upgraded to include more specific quantitative provisions.

The IFALPA policy has basically been divided into a maximum duty time and a maximum flight-deck time (time at the controls). We have also made a strict distinction between two-pilot and three-crew operations.

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[3] "Pilot Fatigue. A Fatal Flaw" by Ian Anderson, San Francisco.

The basis data are shown in Figures 1 and 2.

Despite our conscious effort to be very Flight Safety-minded, we realize that expensive new two-pilot operated aircraft will be flown to their maximum range. It is therefore very essential that the importance of fatigue with reduced crew numbers must be closely monitored.

Fatigue is a factor in all crew complements. A degraded performance by one individual in a three or four-man crew is of obvious concern, but a degraded performance by one individual in a two-man crew is critical, as the balanced distribution of workload and the important monitoring and cross-checking functions so vital in these operations can be grossly eroded. This erosion is a potential aviation safety hazard[4].

However, with the proliferation of two-crew aircraft and the concurrent broadening of their scope of service from essentially regional to intercontinental operations, aircraft manufacturers and airline management will have to be prepared to increase their efforts to ensure that the fatigue-producing factors on two-man crews are minimised. Again, fatigue may be experienced in any crew concept but the effect on a two-crew cockpit may be catastrophic.

Degraded performance by one pilot in a two-pilot crew not only reduces the effectiveness by 50 percent, it also increases the work load on the remaining pilot by 100 percent.

If we accept that all aircraft crew, irrespective of size, suffer from fatigue, it becomes obvious that fatigue amongst two-pilot crew operated aircraft is more critical.

Looking deep into oneself trying to analyse the reasons for one's tiredness and trying to quantify the causes, one may wonder, could there be a better way to improve the situation?

In IFALPA we believe there is a way, but it takes understanding of the problems and ICAO should be co-ordinating an approach to all concerned to minimise the effects.

Within our pilot-circles we have an expression: "Flying a passenger-airplane is long hours of boredom with occasional seconds of terror", a quotation aptly summing up our industry.

To improve Flight Safety when using augmented crew, IFALPA has developed a policy shown in Figures 3, 4, 5 and 6 with one and two augmented crew-members. Note again the clear distinction between two-pilot and three-crew operations.

In 1982 the Commission of the European Communities (EC DG VII - Transport) asked a private consultant company to make a report concerning Flight Duty and Rest Time with recommendations to harmonise the rules within the EC States, with specific emphasis on Flight Safety and <u>the Social aspect</u>[5]. The report was published in 1984.

The Commission expects a final regulation covering all EC States to be approved by the Council in June 1990. If so, it will be "law" within the Community within a maximum of 18 months, and a decision of that kind will undoubtedly influence the world aviation industry.

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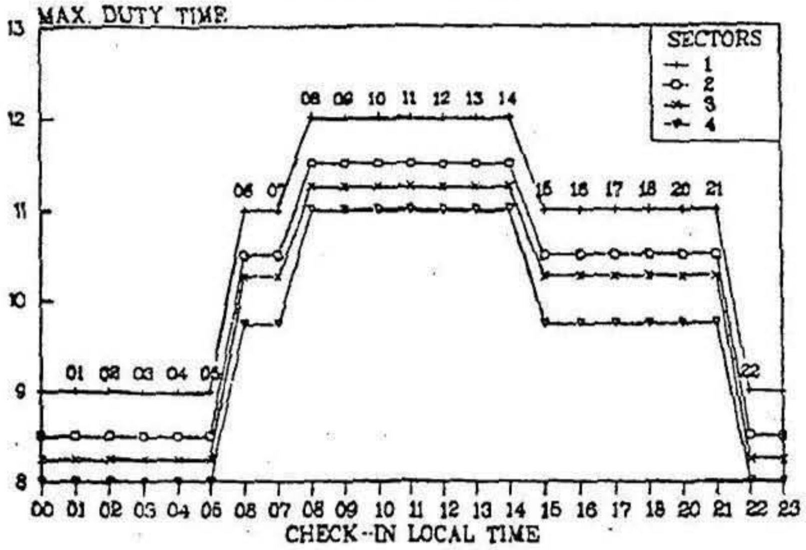
[4] Flight Safety Foundation - "Flight Safety Digest" - September 1989 by T.P. Jensen

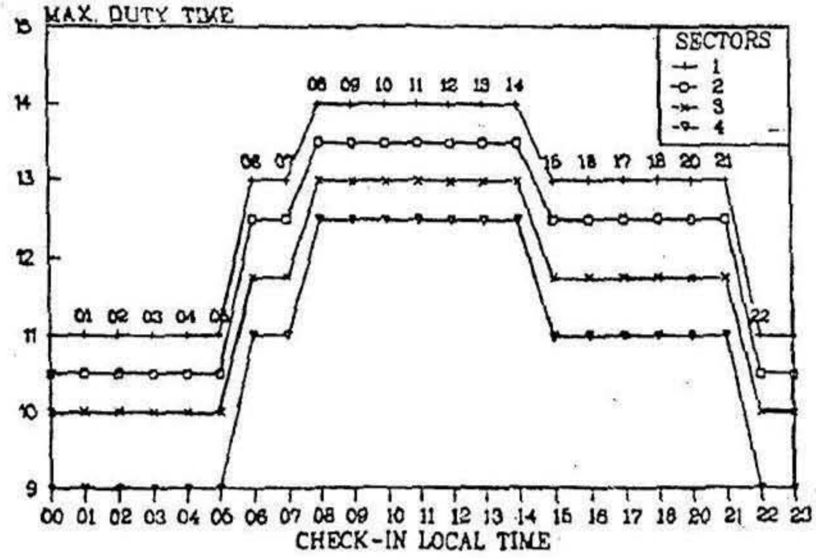
[5] Bossard Consultants, 12 Rue Jean-Jaures 92807 Puteaux Cedex, France.

IFALPA POLICY



2 PILOT OPERATION

FIGURE 1



3 CREW OPERATION

FIGURE 2

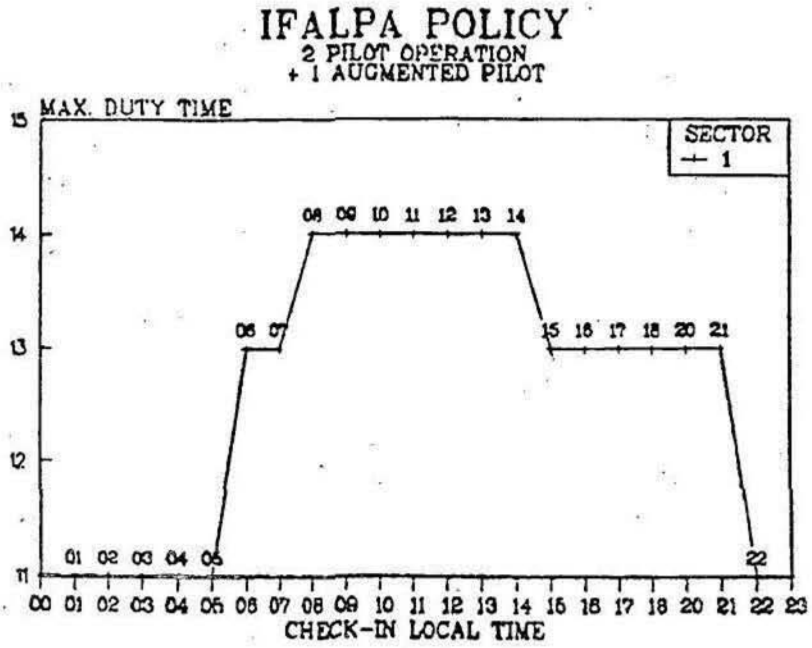

IFALPA POLICY
2 PILOT OPERATION
+ 1 AUGMENTED PILOT

FIGURE 3

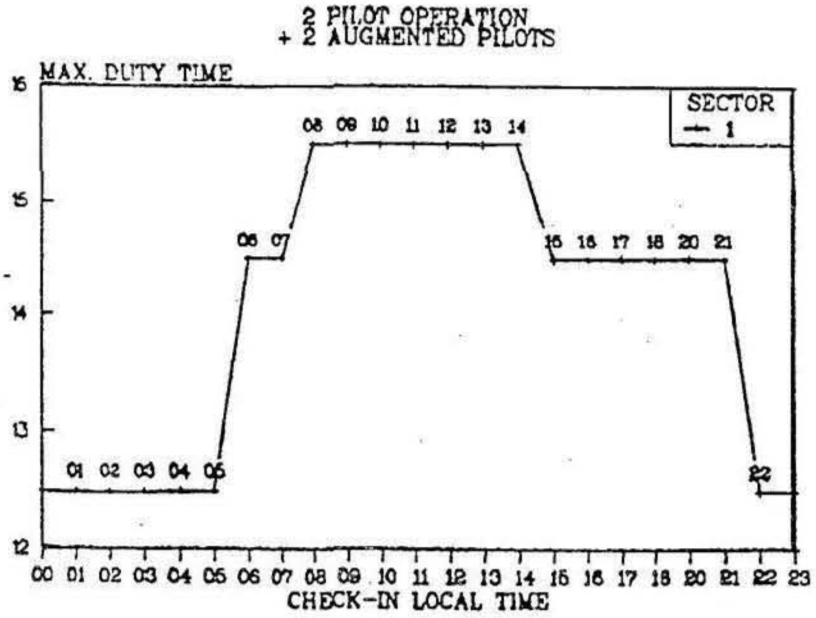

2 PILOT OPERATION
+ 2 AUGMENTED PILOTS

FIGURE 4

IFALPA POLICY

3 CREW OPERATION
+ 1 AUGMENTED CREWMEMBER

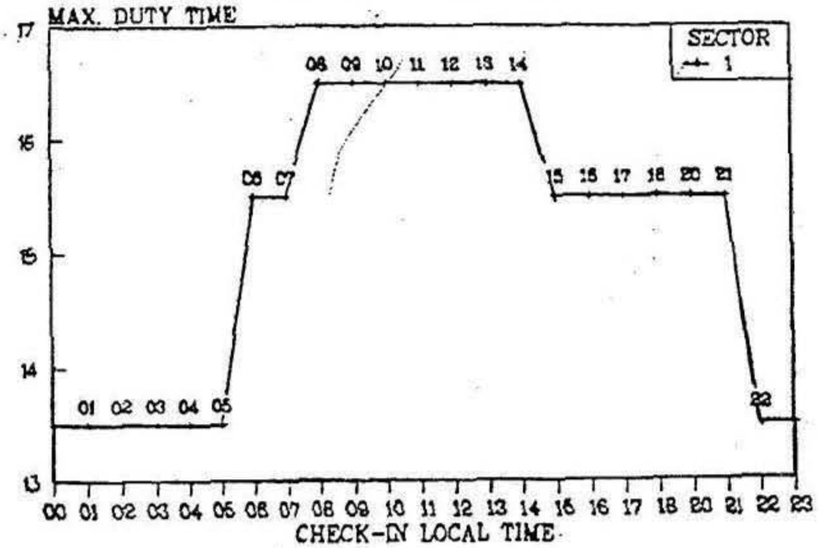


FIGURE 5

3 CREW OPERATION
+ 2 AUGMENTED CREWMEMBERS

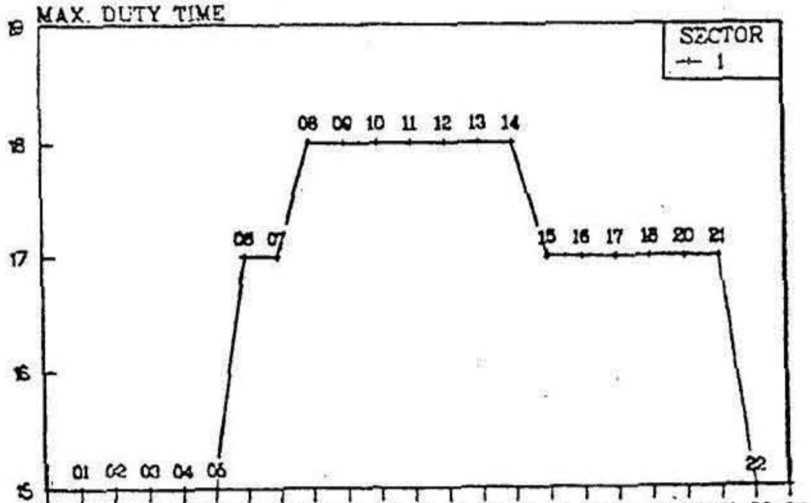


FIGURE 6

Conclusions

Today we can have cockpit crews having a duty-time of up to 21 hours and no minimum rest time in between duty periods. Working and rest conditions of that magnitude must be unacceptable for passenger safety and certainly also for the crews involved.

Due to the fierce competition amongst the airlines it is now more important than ever to have a world-wide maximum duty time and minimum rest time regulation.

IFALPA is happy that ICAO, with the ANC task No. OPS-9001, has taken steps to work on a Flight and Duty time system. It will be a tremendous task, but we pilots are looking forward to the world-wide implementation and the experts of IFALPA are ready to participate fully in the work to be accomplished.

A NEW GENERATION OF CREW RESOURCE MANAGEMENT TRAINING

DR. NEIL A. JOHNSON
CAPT. DAVE H. SHROYER
MR. JAMES B. GREWE

HERNANDEZ ENGINEERING, INC.

INTRODUCTION

As most of the readers of this paper will know, the concepts of Cockpit Resource Management (CRM) have been around since the mid-seventies, and formal steps were taken to institute CRM training programs in civil aviation beginning with the NASA workshop in 1979. As employees of United Airlines in 1979, the authors were pleased to be a part of the pioneer work with NASA, both on CRM and on Line Oriented Flight Training (LOFT). Since that time my colleagues and I have been a part of the development effort for several CRM programs developed by United Airlines Services Corporation and currently, by Hernandez Engineering, Inc.

In the past year the term "Third Generation" program has been increasingly used as a reference to the fact that CRM programs have shown some evolution over the last ten years. This "evolution" raises some questions. What exactly has evolved? What remains to be done? How do we best implement a new generation of CRM programs? The nature of that evolution and the current capability of CRM programs is the subject of this paper.

FIRST GENERATION CRM

The first generation of CRM consisted of a series of research studies, industry working groups, and NASA/Industry Workshops which produced certain themes from which the concepts of CRM were derived. One consistent theme noted by Lauber (1979), was pilot's dissatisfaction with the non-technical aspects of their training. New captains in particular were concerned with skills like decision-making, leadership, and communication. The accident and incident statistics supported these findings (Cooper, White, and Lauber, 1980; Murphy, 1980). The classic Ruffell Smith study (1979) solidified the belief that much of the wide variation in the performance of crews in a full-mission simulation scenario was due to the variability in the crews' use of all of their available resources.

One of the strongest contributions to the first generation of CRM was an outgrowth of the Coordinated Crew Training being conducted by Captain Tom Nunn of Northwest Airlines. Captain Nunn's program coupled with the Ruffell Smith results proved the value of full-mission simulation as an opportunity to practice CRM skills in a non-retribution environment. The result was that Line Oriented Flight Training LOFT) actually preceded formal CRM programs by several years.

Finally, with the first generation of CRM and LOFT activities came the initial description of the major dimensions of cockpit resource management. Such concepts as leadership and followership, crew communications, situation awareness, decision making, prioritization and assignment of tasks, and monitoring and cross-checking, were beginning to receive attention from a number of sources including American, United, and Northwest Airlines, and of course NASA.

Put into proper perspective, the first generation products of cockpit resource management served to raise the level of awareness of the civil aviation industry at large regarding the importance of CRM skills to aviation safety. The only detractor to all of this positve work was that even though we talked about them, we failed to emphasize strongly enough, the value of program evaluation and the importance of using non-cockpit resources when necessary and available. In spite of these minor criticisms, the first generation of CRM proved to be a catalyst for change in the airline industry.

SECOND GENERATION CRM

As a result of the Portland accident, United Airlines formed a working group to study safety issues. Coupled with the suggestions of that group, the 1979 NASA workshop helped to focus the issues and guide the development of United's Command, Leadership, and Resource Management program which was implemented in 1981. This pioneer CRM effort involved extensive self-study preparatory work (prework) followed by a 4 day workshop and a 4 hour LOFT session. Many similar CRM programs were developed in this time frame, all of them structured along the same lines.

Following the 1981 NASA LOFT workshop, the evolution of CRM took a quantum leap when airlines began to integrate their LOFT and CRM programs. This integration provided a way to reinforce CRM concepts in a recurrent training program. The Second Generation of CRM had fully arrived by the time of the 1986 NASA/Military Airlift

Command workshop. It is important to note that one of the key presentations at the 1986 workshop focused on the importance of baseline data and the need for evaluation of the effectiveness of CRM/LOFT.

The 1986 workshop had four objectives: 1) Define the essential elements of an optimal CRM training program; 2) Identify the strengths and weaknesses of current approaches; 3) Identify the best ways of implementing CRM training; and 4) Suggest ways to measure the effectiveness of CRM training (Foushee,1986). The manner in which we addressed those objectives has guided us toward the third generation of CRM programs.

Define the essential elements. The working group participants provided long lists of topics to be covered in any CRM program, however, the number of absolutely essential elements amounted to seven. These include crew communications, situational awareness, problem solving/decision making/judgement, leadership and followership, stress management, interpersonal skills, and critique. There was near unanimous agreement on these major categories.

Identify strengths and weaknesses. Because of a lack of evaluation data, this question could only be partially addressed. It was agreed that most programs in existence had face validity. The techniques used varied from program to program, however, it was generally agreed that some type of academic instruction coupled with group exercises was the best approach.

Identify ways of implementing CRM. The three biggest lessons learned were: 1) Get early and significant support from the management structure; 2) train the instructors, evaluators and check airmen first; and 3) conduct awareness briefings for the crew members prior to implementation.

Suggest ways to measure CRM. The conclusion here was that effectiveness of CRM training had been judged on face validity alone. That is, we were providing CRM training on the skills that everyone agreed are the known weaknesses. There was also considerable anecdotal evidence from pilots, check airmen and management.

In the intervening four years little new has been accomplished other than the implementation of additional second generation programs. A review of Second Generation programs leaves us with some good news and some bad news. The good news is, the essential elements of CRM appear to be in the curriculum of existing programs and the techniques we use, while varying from program to program, appear to be getting the job done. The bad news is, evaluation is still largely missing from the programs in existence and most programs are still oriented to the cockpit while neglecting many of the other resources that can have an impact on the flight deck. One final note from a psychologist's perspective is that instructional techniques used in current CRM programs could be more firmly grounded in learning theory, for example, fewer instructor-centered activities and much greater emphasis on providing a variety of learner-centered experiences geared to the acquisition of CRM skills. This brings us to a look at what the next generation of CRM programs can bring in the way of improvements.

The "THIRD" GENERATION OF CRM.

Perhaps the most efficient way of presenting ideas for improving the next generation of CRM programs is to simply list our suggestions. These suggestions are based on objectives not fully met during the last NASA workshop, from lessons learned over two generations of CRM and LOFT programs, and on the results of a recent survey we conducted.

1) Broaden the scope of CRM training to include operational effectiveness in addition to safety. At a minimum, involve all flight deck crewmembers, and to the extent possible, anyone else in the system who can be considered a resource. In fact, we suggest dropping the term "cockpit" from the title of CRM programs.

2) Survey the population you are going to train to establish their perception of their needs. Also, at this time let the target population know what to expect from the program in general terms.

3) Train the existing instructors, evaluators, check airmen, and operations management first.

4) If possible, select and train a cadre of instructors/facilitators whose sole purpose is CRM training.

5) Build in an evaluation program that includes program evaluation as well as evaluation of individual and crew CRM performance. It is imperative that the latter evaluation be non-punitive. Use the evaluation data to make timely modifications and updates to the program.

6) Deliver the basic knowledge of CRM concepts via a self-directed series of lessons that first provide a model for proper behavior and then an opportunity for the learners to begin individually applying their new knowledge in an interactive environment (e.g., interactive computer-based lessons or interactive video disk).

7) In the beginning, keep the number of concepts presented to an absolute minimum (first time exposure to prework, workshop and LOFT), and provide a "rule of thumb" for those elements you most want to be retained. Gradually build on these during recurrent training. For example, you can teach the essentials of crew communications (basic sending and receiving of messages) without requiring the crew members to remember, for example, serial distortion). With this heuristic approach, the number of essential concepts to be taught will be between five and seven.

8) Make the workshops largely student-centered with a facilitator present to guide overall activities. The activities should make maximum use of an experiential model of learning. Within the workshop, make extensive use of video tape and provide time for participants to view themselves in group activities. This approach lays the foundation for the all-important critique process.

9) In designing LOFT scenarios, be very careful not to force errors. In fact, it is usually the insidious problem which causes the crew to create major problems for themselves. To the extent possible, require the crew to critique their own performance under the guidance of an instructor/evaluator.

10) Constantly introduce fresh, challenging material into the program. This requires planning so that the program is flexible enough to accept changes.

We are currently implementing a Crew Resource Management program which incorporates all of these items. In approximately the July timeframe, we will have a significant amount of data concerning the short term effectiveness of this training. Long term evaluation is also being designed into this program. If past generations of CRM are any measure, the next generation should provide us with answers to many as yet unanswered questions.

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K. VANWONTERGHEM

I.N.E.R.E.C.
M. RABIT

1 LA PROBLEMATIQUE ERGONOMIQUE

L'ergonomie peut être définie brièvement comme l'étude de l'homme en activité de travail. Elle utilise un ensemble de connaissances interdisciplinaires.

La physiologie, la psychologie, la sociologie, l'ethnologie, la technique et l'économie sont les facettes qui constituent son champ de connaissance, mais ce qui la rend autonome c'est son objectif : l'étude de l'opérateur.

Comme le dit P.CAZAMIAN l'ergonomie veut explorer un objet hétérogène : "le travail humain représente un objet composite par excellence puisqu'il associe, par des liens qu'on ne peut rompre hommes et matériels"

Cette hétérogénéité se situe à des niveaux hiérarchiques différents. En effet l'opérateur est un être cognitif et social à support biologique, c'est une entité psycho-biologique son objectif est d'assumer et d'assurer la finalité de sa tâche.
Ses activités cognitives et son comportement doivent être interprétés à travers les représentations de différents niveaux :

-technique: la nature des outils, leur mode de fonctionnement, le choix lié à la conception du système technique et la filière technologique

- psycho-physiologique; l'état fonctionnel de l'opérateur dépend de ses limites physiologiques et psychologiques

- ethno-sociologique; la projection de l'opérateur dans son devenir professionnel mais aussi l'acquisition de ses compétences dans les situations passées.

Ces différents niveaux s'enchevètrent mais ils n'ont pas le même statut épistémologique.

1.1. LA METHODOLOGIE ERGONOMIQUE

La pratique méthodologique est une problématique clinicienne (analogue à la pratique médicale) : elle utilise des systèmes de lecture se référant à des champs scientifiques spécifiques, elle construit l'unité de sa démarche en cherchant la signification de la situation complexe observée qui rend alors intelligibles et cohérents les différents fragments collectés lors de l'étude ergonomique.

La situation ergonomique est "une", chaque cas est unique. Le terrain d'étude relève de lois existantes hors de son champ spécifique - comme la chronobiologie, les régulations sociales ethniques..- mais il génère aussi des lois qui lui sont propres. Cette ambivalence structurelle implique une rigueur méthodologique tant au niveau des recueils des données que dans l'interprétation des symptômes recueillis. Le passage d'une situation locale circonstancielle à l'élaboration d'un modèle général impose la clarification des signes rencontrés qui sont apparemment multiformes, voire discordants.

Seule l'intelligibilité des faits observés situés dans la situation étudiée permet cette approche et justifie le modèle interprétatif que l'on construit a posteriori.

Cette démarche impose à l'ergonome la compréhension de la situation dans sa globalité et sa complexité, que cela soit une simulation ou une situation réelle de travail.

1.2. L'ANALYSE DU TRAVAIL

L'analyse du travail doit se centrer sur les deux approches complémentaires du modèle de M. de MONTMOLLIN.

- l'analyse des exigences du travail définie par l'organisation : la tâche
- l'analyse de la conduite des opérateurs: l'activité

Cette double lecture permet la reconnaissance de la difference entre le travail réel, (travail informel, conduite des opérateurs) et le travail prescrit, (travail formel, fixé par l'organisation).

Le travail prescrit est le niveau des exigences de la tâche commune à tous les opérateurs. On leur fournit des outils et des procédures de fonctionnement et d'utilisation afin d'assurer les performances exigées voire des normes- dans un cadre donné. Les connaissances requises pour assumer cette tâche sont dépendantes de l'apprentissage et des situations antérieures rencontrées par l'opérateur.

Les activités rendent compte du travail réel fait par les opérateurs. Seule l'étude in situ et en continu des procédures utilisées, des conduites intelligentes observées et des comportements émergeants permet de mettre en évidence les distorsions qui existent entre le travail prescrit et le travail réel. L'intelligibilité des faits renvoie à la stratégie choisie volontairement par l'opérateur avec ou sans contrainte.

Les conduites des opérateurs sont caractéristiques et dépendent des apprentissages antérieurs, des situations de travail qui sont spécifiques et uniques et de l'état fonctionnel du sujet.

A noter que la connaissance du métier des opérateurs permet une lecture plus précise et intelligible des procédures et conduites observées.

Il existe des relations entre les résultats de l'activité et les conduites qui les engendrent mais il n'y a aucun lien de prédictibilité entre les performances exigées et les performances réalisées. DE MONTMOLLIN déclare de même : qu'aucun indice physiologique ne peut être érigé en critère d'une hypothétique "charge mentale de travail dont il permettrait de définir une échelle absolue". Seule une interprétation réflexive des variables physiologiques permet de donner sens aux faits observés comme nous le montrerons ultérieurement.

Il ne peut y avoir de connaissances quantitatives de l'astreinte, seule une connaissance qualitative permet la description, la compréhension et l'explication des phénomènes observés. De l'étude d'un phénomène local nous essayons de déduire des lois générales.

1.3. LES FACTEURS DE CONTRAINTES - L'ASTREINTE

Les facteurs de contrainte* (stress) du travail tant celle de l'environnement que de la tâche prescrite dans son enveloppe organisationnelle vont se traduire pour l'opérateur par une astreinte* (strain) ou coût psychophysiologique.

L'étude des facteurs de contraintes est réalisée en partie par **une enquête technique** centrée sur le poste de travail et les ambiances environnantes.

- L' étude du poste de travail : l'anthropométrie statique et dynamique permet de construire un poste de travail répondant aux exigences de la tâche et à la configuration anthropométrique des opérateurs : localisation des outils dans des zones de moindre inconfort.

- L'étude des ambiances lumineuses, thermiques et sonores permet l'aménagement d'un environnement confortable.

A cette étude technique s'ajoute l'étude des activités physiques, psychosensorielles et mentales. Un double décrytage est nécessaire: en effet l'organisation du travail par son schéma temporel, par la durée des postes et la rotation des équipes impose un cadre fonctionnel aux opérateurs, de plus l'évolution technologique introduisant de nouveaux outils de présentation des informations, modifie les facteurs de contraintes.

La surveillance d'informations visuelles rigidifie les postures et entraîne une fatigue visuelle par sollicitation persistante de l'accommodation convergence, de plus la présentation sur des écrans lumineux doit faire rechercher des signes d'intolérance à la lumière.

Mais l'évolution technique et la logique des systèmes interviennent principalement sur la charge mentale, point qui sera développé ultérieurement.

Interpréter les relations qui s'établissent entre les contraintes et l'astreinte doit prendre en compte les caractéristiques de la structure humaine, les contraintes internes de fonctionnement. (l'activité diurne et le sommeil nocturne), **il n'y a pas d'adaptation au non-respect de la logique du vivant.**

Quand les contraintes sont physiques, l'opérateur peut continuer sa tâche aux dépends de sa santé. Le temps devient pour lui la mesure de toutes les perturbations qu'il a reçues. L'espérance de vie traduit ce phénomène.

Paradoxalement, l'étude des variables de l'astreinte dans une situation donnée risque de mettre en évidence le seul maintien de la structure biologique, la déstabilisation ne s'exprime pas encore... ou plutôt nos moyens objectifs de l'appréhender ne sont pas suffisamment pertinents.

Dans le cas des activités mentales, le non-respect de la logique du vivant se traduit par une détérioration des capacités mentales des opérateurs; la performance n'est pas continue, on en observe des fluctuations brutales et réversibles. Il y a maintien des apprentissages, mais dans une situation nouvelle, l'opérateur risque d'avoir un comportement stéréotypé non adapté au problème spécifique posé. **Le non respect de la logique du vivant est un des facteurs responsables de la non-fiabilité des systèmes sociaux-techniques.**

Le problème fondamental est bien l'activité mentale, cognitive des opérateurs, à quelles lois obéit-elle?

Historiquement la charge de travail mental a été appréhendée dans l'optique de la description d'état limite et de l'évaluation quantitative par une échelle qui étalonnerait la détérioration progressive de la tâche.

La fatigue mentale est alors considérée comme un état de fatigue consécutif à un travail complexe mettant principalement en jeu les activités mentales. Elle se traduit par une détérioration de la performance et des modifications de l'Electroencéphalogramme.

Pour PTERNITIS , GRANDJEAN c'est un état fonctionnel qui varie. L'électroencéphalogramme permet d'enregistrer l'activité électrique du cerveau et objective cet état.

Cette démarche statique de "description d'état" ne prend pas en compte toute la problématique dynamique et qualitative du problème complexe du maintien de la vigilance et du traitement des informations.

2 - LA PROBLEMATIQUE DE L'ERGONOMIE COGNITIVE

2.1. LE TRAITEMENT DES INFORMATIONS ET LA STRUCTURE TEMPORELLE.

La structure fonctionnelle temporelle de l'homme présente des périodicités "invariantes" (variations circadiennes dont la période est de 24 H et ultradiennes dont la période est de 100 mn). La capacité fonctionnelle de l'homme fluctue avec le temps et se modifie sous l'effet cumulatif de l'activité. Le non-respect de la structure fonctionnelle entraîne l'apparition de signes de dysfonctionnement qui se traduisent par une astreinte accrue et par une altération des capacités de traitement des informations.

La vigilance est un des aspects cette structure. Toute activité mentale, fonction différenciée, orchestrée par le cerveau se réalise sur un fond général d'activité tonique qui est le niveau de vigilance. Ce rythme circadien est modulé par un rythme ultradien; des phases d'hypovigilance apparaissent toutes les 100 mn. L'état de concentration des opérateurs dépend de l'état fonctionnel, c'est à dire du niveau d'activité du cerveau. Les activités mentales ne peuvent pas se poursuivre sans discontinuité. Quand ces activités sont passives - restitution d'un savoir acquis antérieurement ou présentation par autrui d'un problème- on peut ne pas respecter ces rythmes ultradiens pendant un certain temps. Mais le non- respect à terme de la logique fonctionnelle temporelle se traduit par la détérioration des performances et des capacités des opérateurs. Ces états sont objectivés par la survenue d'états "paradoxaux" de la vigilance, états réversibles et significatifs à l'électroencéphalogramme.

Si la structure temporelle peut être violée pour les activités cognitives syntaxiques, ce n'est plus le cas dans les activités cognitives sémantiques. Ces points seront développés ultérieurement.

2.2. L'ELECTROENCEPHALOGRAMME - LES INDICES CORTICAUX DE L'ACTIVITE CEREBRALE

L'électroencéphalogramme permet d'enregistrer l'activité électrique du cerveau. Les électrodes détectent et enregistrent les ondes du potentiel électrique du cortex cérébral. Le tracé obtenu permet d'étudier les variations d'amplitude du spectre fréquenciel.

Les caractéristiques intra et interindividuelles

Les indices biologiques présentent des variations interindividuelles. Lavaleur énergétique de l'électroencéphalogramme dépend de la résistivité de la peau des sujets, celle-ci est fortement dispersée.

- Le **morphotype temporel** est une caractéristique individuelle. Seule une interprétation réflexive des signaux biologiques a un sens. Le pattern ou la fluctuation de l'indice observé doit être interprété par référence au sujet étudié, la valeur absolue n'a aucune signification. Toute activité neuronale (les neurones sont les cellules du cortex cérébral) engendre des courants électriques qui traversent la boîte cranienne et donnent naissance à des potentiels transitoires qui peuvent être captés au moyen d'électrodes sur le cuir chevelu. L'activité électrique des milliards de neurones est enregistrée dans sa globalité au moyen de l'électroencéphalogramme. L'amplitude du signal est de l'ordre de 5 à 100 microvolts. Elle est faite d'un complexe d'ondes pseudo sinusoïdales dont le spectre est compris entre 0 et 200 Hz.

L'activité de la vigilance est le niveau général tonique de l'électroencéphalogramme, elle présente les "invariants" décrits au paragraphe 2.1

Pendant l'accomplissement de tâches mentales, extériorisé ou non par un comportement, on observe une variation de l'activité électrique des groupes de neurones dans le cortex cérébral. Cette activité électrique peut moduler le rythme tonique de la vigilance.

On retrouve une localisation spatiale hémisphérique en relation avec les différentes activités mentales psychosensorielles et comportementales. L'activité d'une zone cérébrale se traduit par une modification de la répartition du spectre fréquentiel, il y a désynchronisation et glissement des fréquences vers les rythmes rapides.

Béta 1	16 à 20 Hz
Béta 2	20 à 35 Hz

Les phases d'hypovigilance "invariantes" ou induites "états paradoxaux" par le non-respect de la structure temporelle fonctionnelle se traduisent par l'augmentation de la puissance énergétique des signaux électriques dans les fréquences de 4 à 12Hz (fréquences lentes) et par une diminution des fréquences rapides.

Le rythme alpha de fréquence pure est compris entre 8 à 12 Hz, son amplitude est de 40 à 50 microvolts. Il apparaît classiquement lorsque le sujet ferme les yeux ou lorsqu'il est placé dans l'obscurité, sur la zone pariéto-occipitale et il est usuellement plus grand sur l'hémisphère droit.

Le traitement de l'électroencéphalogramme spontané par l'analyse de FOURIER donne de nombreuses informations.

Les critères d'amplitude, de fréquence moyenne peuvent être étudiés en fonction du temps et en fonction des différents types d'activités. On peut les comparer, les analyser, les sommer ...

Seule une **interprétation qualitative** de l'électroencéphalogramme est possible, l'objet, ici les variables énergétiques, doit être structuré dans un contexte dynamique et fluctuant prenant en compte les invariants fonctionnels sur lequel se greffent les différents processus cognitifs des opérateurs.

2.3. LES ACTIVITES MENTALES , LA LATERALISATION HEMISPHERIQUE

La charge mentale est assimilée au coût du maintien des activités mentales. Le cortex cérébral présente une dualité fonctionnelle des hémisphères: la latéralisation hémisphérique s'objective-t-elle à travers l'interprétation de l'électroencéphalogramme? Cette hypothèse mérite d'être testée. L'activité d'une zone cérébrale se traduit théoriquement par l'augmentation des rythmes rapides.

L'hémisphère droit muet, atemporel est globalisant, il régente l'espace en tant qu'image une et univoque, il réalise des synthèses rapides et complexes. Il est le siège de l'heuristique. Seule la stratégie heuristique permet la prise de décision dans un contexte mal systématisé. Elle est la propriété émergente des activités mentales. C'est l'expression des mémoires opératoires.

L'hémisphère gauche est analytique, séquentiel, il déroule ses raisonnements déductifs dans le temps, il permet des repérages temporels et spaciaux, il est algorithmique, déductif, logique, formel. Le traitement algorithmique est l'ensemble de raisonnements ou d'opérations conduisant à la solution d'un problème.

2.4. LA CHARGE MENTALE LES ACTIVITÉS MENTALES

"Le terme de charge de travail pourrait être réservé pour désigner l'ensemble des réactions de l'homme au poste de travail. La charge de travail résulte des contraintes de travail mais également des contraintes auxquelles le travailleur est soumis en tant qu'homme" H.MONOD, F.LILLE .

Mais comment cerner l'astreinte qui résulte de ces contraintes? Que peut-on déduire des variations observées ? Chaque paramètre biologique dans une situation observée suit des fluctuations liées aux contraintes de la tâche de travail, et des variations dues aux systèmes ambiants, non maîtrisables par l'observateur. De plus, ces relations ne sont pas spécifiques, l'interprétation de ces paramètres doit prendre en compte les variations du système ambiant et de la tâche de travail, de plus les invariants fonctionnels influent sur les variables physiologiques. L'activité électroencéphalographique n'est que le reflet de l'activité corticale, et doit être comprise comme le résultat de la confrontation de différents facteurs :

- le niveau de vigilance du sujet, c'est à dire sa structure endogène fonctionnelle qui règle naturellemment les variations globales d'activité
- le comportement évolutif et/ou les activités mentales (qui ne se manifestent pas nécessairement par un acte) de l'opérateur en réponse aux exigences de la situation de travail.

L'activité humaine traduit la notion dynamique de processus mentaux dont les caractéristiques temporelles et qualitatives enrichissent la notion plus simple de charge mentale, qui peut n'être perçue que comme statique et quantitative, restreignant de ce fait la définition donnée par MONOD et LILLE.

2.5. ETAT DE LA QUESTION

Nos recherches antérieures sur les activités mentales ont mis en évidence plusieurs phénomènes que nous résumons.
Les activités de perception-action ne peuvent être maintenues en continu. La simple détection simple d'un signal lumineux en fonction du temps montre que tous les sujets présentent des détériorations de la performance conjointes à des désactivations de l'électroencéphalogramme. L'occurence de ces évènements augmente proportionnellement au non-respect de la structure fonctionnelle des sujets.

L'opérateur peut ne pas respecter sa structure biologique fonctionnelle tout en continuant sa tâche,quand il y a comportement passif de celui-ci: restitution de connaissances, activité psychomotrice antérieurement apprise, l'information présente une structure uniquement syntaxique.

Dans toutes les situations où il y a, soit apprentissage de règles syntaxiques, soit compréhension du sens d'un problème ou d'un incident en temps réel, le respect de la structure temporelle

fonctionnelle devient une nécessité afin de permettre aux opérateurs de garder leur capacité de traitement des problèmes nouveaux.
Mais il est toujours possible de sauter une phase d'hypovigilance!

Ces processus décrits sont des tendances qui doivent être nuancées: l'état de fatigue mentale est induit quand il y a non-respect de la logique temporelle de l'homme et/ou quand les activités mentales ne sont pas de nature à respecter le mode de fonctionnement du cerveau humain.

Dans les activites d'un contrôleur aérien, la fatigue mentale est provoquée par un travail sensoriel intensif et prolongé, sollicitant des processus cognitifs. Elle devient de plus en plus un problème dans les activités de contrôle, le volume du trafic aérien s'intensifie de façon importante et les perspectives reférent à un accroissement considérable, on peut s'attendre à une astreinte plus élevée.

Celle-ci peut influencer la qualité du travail, menaçant la sécurité du personnel volant et des passagers. L'impact du comportement du contrôleur, résultant du système de traitement d'information humain, donc d'une activité cérébrale, est par conséquent déterminant.

Dans le but de caractériser la fatigue mentale chez les contrôleurs aériens des tests furent effectués dans des conditions de simulation :

- une première tentative fut effectuée (BEEK 1986) avec un système d'enregistrement des mouvements oculaires, des signaux E.E.G. et E.C.G. . Les signaux présentés sous forme analogique montraient des variations des bandes de fréquence "Alpha" entre 8 à 12 Hz, pendant les activités. La comparaison des signaux E.E.G. et des mouvements oculaires présentaient des discordances.
- un deuxième test (Bretigny/Orge, 1987) montrait des variations de la résistance électrique cutanée intéressantes, mmais la mise en concordance avec les signaux encéphalographiques débouchait sur des difficultés d'analyse systématique des signaux, en relation avec le déroulement de la tâche et des activités.
- un troisième test (Brétigny /Orge, 1987) sur une simulation standardisée (Kennedy Approach) est analysée au moyen d'un NIHONKOHDE, a permis de constater deux patterns évolutifs des réactions cérébrales, en fonction de la durée de l'exercice.
- la survenue de bouffées d'onde Alpha, dont le nombre augmente en fonction de la durée du test (le test est continu, on recherche "l'état limite du contrôleur"), et qui est suivie après un certain délai de signes électroencéphalographiques indiquant une réactivation cérébrale. Ce pattern est il l'objectivation d'une difficulté au maintien du traitement des informations en fonction du temps ?
- le changement de dominance hémisphérique droite vers l'hémisphère gauche des ondes Alpha obtenu pendant les périodes de repos (avant et après l'exercice traduit-il une variation des traitements des informations en fonction du temps ?

Ces patterns sont-ils des signes objectifs d'une fatigue mentale?

Sur la base de ces tentatives l'étude du mois de mai 1988, O.D.I.D. II (Brétigny/Orge) fut organisée afin de confirmer, voire d'infirmer les résultats et les hypothèses formulées.

3. LA MÉTHODOLOGIE ETHO-ELECTROPHYSIOLOGIQUE

Conjointement au receuil des données physiologiques, une observation systèmatique des contrôleurs et du travail est assurée. Le procédé de recueil et traitement des données est analogique et numérique avec un prétraitement des données pendant l'acquisition.

3.1 LE MATÉRIEL D'ENREGISTREMENT DES SIGNAUX

Les électrodes utilisées pour recueillir les signaux biologiques permettent des enregistrements de longue durée (de 10 à 13 h). Les électrodes pour E.C.G., E.O.G., sont à collerettes et les capteurs de l'E.E.G., des cupules argentées collées au collodion sur le scalp. Ces électrodes gardent une bonne adhésion pendant tout l'enregistrement au poste de travail.
La pâte conductrice électrolytique n'augmente pas l'impédance de la source des signaux recueillis (5000 ohms maximum pour l'E.E.G.)

Pour les analyses digitales des paramètres physiologiques nous avons utilisé:

- 1 télémesure SFENA, type 1 P 06, à six voies
- 1 enregistreur magnétique analogique Tandberg, à 4 voies
- 1 oscilloscope de contrôle

Les montages des appareils sont les suivants:

- un contrôle visuel en continu des signaux biologiques se fait sur l'oscilloscope rémanent à quatre voies,
- les données électrophysiologiques sont stockées sur bande magnétique et traitées ultérieurement en laboratoire. L'enregistreur analogique à quatre voies conserve l'électroencéphalogramme (E.E.G.) (voie 1 et 2), l'électro-oculogramme (E.0.G.) (voie 3) et l'électrocardiogramme (E.C.G.) (voie 4).

La télémétrie permet la transmission à distance des paramètres physiologiques et minimise la gêne occasionnée à l'opérateur par l'expérimentation.

Elle se compose :

- d'une chaîne d'émission qui se présente sous la forme de différents modules regroupés dans un boitier fixé à la taille des sujets par une ceinture
- d'un récepteur qui permet de capter les signaux issus de l'émetteur. Ce récepteur est placé en dehors du champ d'action et de surveillance du sujet afin de ne pas le perturber.

Le tableau suivant récapitule le réglage des différentes voies :

	filtre	constante de temps
E.E.G.	50 Hz	0,03 s
E.O.G.	5 Hz	0,03 s
E.C.G.	15 Hz	0,7 s

Un recueil de bonne qualité de la fréquence cardiaque et des mouvements oculaires a été plus facilement obtenu en raison de la plus grande amplitude des signaux. L'enregistreur magnétique Tandberg offre un contrôle visuel des prises d'information de chaque piste. La faible vitesse de déroulement 15/16 in/s (2,86cm/s) autorise une bande passante de 0,2 Hz à 156 Hz et permet des enregistrements continus de longue durée (7 heures) en employant des bandes de 1000 mètres.

3.2. LES PARAMETRES ÉLECTROPHYSIOLOGIQUES

Les paramètres électrophysiologiques étudiés sont les suivants:

- L'électroencéphalogramme

Les capteurs de potentiels électriques corticaux, espacés de 6 centimètres, sont fixés au niveau de la zone occipitale - voie E.E.G. voie gauche 1 , voie droite 2

- L'électrooculogramme

Les électrodes recueillent la différence de potentiel qui existe entre la polarité négative de la rétine et celle de la cornée. Le dipôle dont l'extrémité négative se trouve au fond de l'orbite varie avec les mouvements oculaires des yeux. Les électrodes oculaires sont placés sur les tempes en regard de la fente palpébrale privilégiant les mouvements latéraux.

- L'électrocardiogramme

Les signaux E.C.G. sont captés par des électrodes situées dans la région précordiale.

- La température cutanée

Les électrodes sont collées sur l'omoplate gauche.

- La résistance électrique cutanée

Deux électrodes sont collées à une distance de 5cm à l'intérieur de l'avant-bras.

Les artéfacts.

En raison de l'enregistrement sur les lieux même du travail, nous constatons des perturbations qui se traduisent par des artefacts sur nos tracés, perturbations dues :

- à la présence de parasites, à la fréquence industrielle (50 Hz), produits par l'environnement électrique et les consoles de visualisation

au décollement des électrodes

- au contact de l'antenne de l'émetteur avec une partie métallique etc...

Ces artéfacts se manifestent par des tracés inexploitables temporairement ; grâce à la surveillance des signaux sur l'oscilloscope nous pouvons intervenir immédiatement.

3.3. APPAREILLAGE NUMÉRIQUE

Il est constitue pour l'essentiel d'un MINC 1103 de Digital Equipement et d'une imprimante matricielle. Le MINC comporte les élements classiques d'un mini-calculateur : console de visualisation, clavier, unités centrales de calcul (PDP 11/03) et deux disquettes de 8 pouces assurant ensemble une mémoire d'environ un méga-octet et un "rack" de mesure présentant un convertisseur analogique digital multi-voies et une horloge.

Le convertisseur a une précision correspondant à 12 bits sur des signaux analogiques de - 5 volts à + 5 volts. L'ensemble offre une cadence d'échantillonage maximale de 20 Khz.

3.4. TRAITEMENT NUMÉRIQUE

Plusieures méthodes d'analyse sont utilisées ; l'une, gelée, est mise en oeuvre en temps réel pendant la prise des données et concerne ordinairement les paramètres E.E.G. , d'autres, plus souples, sont effectuées en temps différé, acceleré ou non, sur les enregistrements analogiques. Enfin la conservation sur disquettes de divers résultats numériques permet des analyses et représentations variées.

- Traitement numérique "in situ"

Le calculateur fonctionne en double tâche, d'une part, il échantillonne les deux voies que l'on veut analyser et, d'autre part, il effectue les T.F.R. (Transformée de FOURIER rapide) sur ces mêmes paramètres.

Plus précisément, si l'on considère les instants successifs le calculateur échantillonne les deux voies entre t_{n-1} et t_n conserve les valeurs obtenues et effectue les T.R.F. de t_n à t_{n+1}. On obtient ainsi un spectre de puissance toutes les 5 s sur chaque voie, la moyenne est effectuée sur 8 spectres (toutes les 40 secondes) le spectre moyen obtenu est conservé sur disquette. On obtient ainsi 180 spectres par voie pour deux heures d'enregistrements.

L'échantillonnage est effectué à 100 Hz avec 512 échantillons, ce qui conduit à un spectre toutes les 5,12 s. Cela permet d'effectuer une T.F.R. sur 256 points par entrelacement en utilisant le fait que les points sont réels. Le spectre est calculé de 0,2 à 50 Hz sur 256 points. On peut remarquer ici que la moyenne sur 40 secondes, c'est à dire sur 7,8 spectres, n'est en réalité effectuée que sur 7 spectres car l'ensemble des temps de calcul, d'échantillonnage et de mise en mémoire est trop long. Un spectre sur 8 est "perdu". L'étude à démarrage aléatoire d'un même enregistrement a montré que cela ne conduisait à aucune différence.

Enfin l'expérimentateur a la possibilité d'introduire, quand il le veut, une ligne de commentaire qui permet de noter le comportement des contrôleurs et l'évolution de la situation observée..

- Traitement numérique "in situ" en temps différé

Sur place les expérimentateurs peuvent lancer un certain nombre de programmes de traitement de spectres enregistrés de façon à se faire une idée de la qualité des mesures et orienter la campagne de recueil des données dans les directions qui semblent les plus intéressantes.

On peut ainsi sur chacune des voies E.E.G. obtenir une représentation temporelle des bandes de fréquence. L'analyse automatique de l'E.E.G. permet de visualiser l'évolution de l'énergie de n'importe quelle bande de fréquences. Nous avons réparti le spectre fréquentiel en six bandes pour lesquelles nous avons utilisé la dénomination classique des patterns de l'électroencéphalographie. Un indice est ici l'énergie d'une bande de fréquences dont les bornes sont :

- indice Delta de 0,3 à 3 Hz
- indice Thêta de 3 à 7 Hz
- indice Alpha de 8 à 13 Hz
- indice Spindles de 14 à 16 Hz
- indice Bêta 1 de 16 à 20 Hz
- indice Bêta 2 de 20 à 45 Hz

Deux formes sont possibles, l'une dite normée, qui représente le rapport de l'amplitude moyenne du signal dans la bande considérée à l'amplitude moyenne sur tout le spectre, l'autre, dite non normée, qui représente cette amplitude moyenne directement.

Enfin une transformée de FOURIER effectuée sur les bandes précédentes permet la recherche de périodicités éventuelles dont les périodes détectables sont comprises entre 2 mn et 30 mn. La limite inférieure est liée à la durée sur laquelle la moyenne est effectuée (40s) et la limite supérieure est due à la longueur de l'enregistrement .

- Traitement en laboratoire en temps différé.

Les enregistrements électroencéphalographiques sont analysés par la méthode décrite. Les bandes de fréquences sont déterminées par l'expérimentateur. Cette méthode n'est pas spécifique des signaux E.E.G. mais peut être employée sur tous les signaux biologiques enregistrés sous forme analogique. Les enregistrements cardiaques sont étudiés de façon spécifique. On mesure le temps qui s'écoule entre chaque battement ce qui fournit la période (ou la fréquence instantanée). On en déduit la fréquence cardiaque moyenne sur 40s. Cette étude est faite en vitesse accélérée (16 fois). Le risque de ne pas comptabiliser certains battements, à cause des fluctuations du niveau du signal exige une surveillance continue du niveau de déclenchement sur un oscilloscope. Les "erreurs" de déclenchement sont exclues par voies de programme en bornant les périodes cardiaques.

3.5 AUTRES PARAMETRES PHYSIOLOGIQUES

La température cutanée, la fréquence cardiaque et la résistance électrique cutanée furent enregistrée au moyen du système MEMOLOG 500. Les données recueillies toutes les 15 ou 30 secondes sont stockées in-situ dans une mémoire CMOS et analysées ultérieurement sur un I.B.M P.C XT.

3.6. CONCLUSION

L'ensemble de nos méthodes d'enregistrement et de traitement s'est, à l'usage, avéré efficace, fiable et de maniement sûr. L'intérêt le plus évident réside dans la possibilité d'effectuer de très nombreux essais de traitements et de n'utiliser que ce qui à un moment donné est intéressant. Il permet de conserver une masse de données qui s'avère utile quand on veut tester une nouvelle hypothèse sans avoir à refaire une autre campagne de mesures.

4. LA CAMPAGNE DE MESURES O.D.I.D.2

4.1 PRESENTATION DE LA RECHERCHE.

La campagne de mesures qui a été faite à Eurocontrol en mai 1988 se proposait de rechercher des variations de paramètres électrophysiologiques chez des opérateurs contrôleurs aériens, en simulation.

Deux séquences identiques sont prévues, de quinze jours environ. La séquence I du 2 mai au 11 mai, la séquence II du 16 mai au 27 mai. Entre les séquences, il y a changement des équipes de contrôleurs. Deux secteurs sont étudiés, Bruxelles-Ouest et Francfort-Est. Sur chaque secteur deux contrôleurs sont présents, ils travaillent en équipe. L'un est contrôleur organique, l'autre contrôleur radar. Ils alternent à ces deux postes mais l'alternance n'est pas systématique. Trois exercices sont éxécutés par jour.

Pour pallier aux caractéristiques individuelles des sujets, les deux systèmes de recueil de données PDP 11 télémétrie, NIHONKOHDE, restent focalisés sur le même contrôleur quelle que soit sa fonction et cela pendant toute la séquence. En effet, la résistivité de la peau, le morphotype temporel de la vigilance sont des données qui influencent la valeur absolue des signaux électroencéphalographiques, l'interprétation des résultats ne peut être que comparative.

L'observation des deux secteurs a une alternance journalière, de ce fait nous ne pouvons recueillir que la moitié des exercices de chaque secteur. L'étude des secteurs n'est pas continue, l'échantillonnage est bi-quotidien. Les résultats quantitatifs fournis par le système de PARIS I, comme ceux qualitatifs de Cergo ne représentent donc pour chacun qu'un quart des données totales, deux contrôleurs sur quatre sont étudiés.

Aux variabilités inter et intra individuelles rencontrées lors de la simulation - quatre opérateurs spécifiques sont étudiés pendant chaque séquence, les fonctions aux postes contrôleur organique et contrôleur radar ne sont pas systématiques - s'ajoutent les variations dues à la problématique de la simulation.

Lors de la simulation deux systèmes d'organisation sont testés, de plus, deux types d'exercices sont effectués.
La tâche de travail est qualitativement différente entre organisation I et organisation II.

L'organisation I repose sur une **démarche explicite** entre les coordinateurs organiques contrôlant les secteurs aériens.

L'organisation II renvoie à une **démarche implicite.** Le contrôleur organique recevant une proposition de prise en charge d'un avion renvoie un message de coordination au contrôleur organique qui a émis la proposition quand il y a problème.

La charge de travail est différente pour les contrôleurs organiques entre organisation I et organisation II. Il y a moins de communications entre les contrôleurs organiques en organisation II, à la prise en charge d'un avion, il y a une perte de la redondance de l'information.

La tâche du contrôleur radar est théoriquement identique en organisation I et en organisation II.

A cette différence qualitative observée s'ajoutent des variations quantitatives de la tâche entre les niveaux T2 T3. Si le nombre d'avions est relativement stable durant l'exercice, celui ci est différent pour chacun d'eux. Théoriquement, dix avions sont sous contrôle pendant l'exercice T2, quinze avions pour T3. Il y a une augmentation linéaire de la charge de travail que l'on peut assimiler au nombre d'avions de l'exercice.

De ces faits nous voyons que les situations observées sont rarement identiques.

4.2. L'EXERCICE O.D.I.D 2: DESCRIPTION DE LA CAMPAGNE DE RECHERCHE

Après une période théorique d'apprentissage lors des "training"" les opérateurs vont faire des exercices mesurés de la simulation. La première séquence comprend 5 "training"" et 5 exercices mesurés.

La deuxième séquence comprend 5 ""training"" et 12 exercices mesurés. 17 exercices sur 32 prévus ont été retenus, le critère de sélection choisi est la durée : l'exercice de simulation doit être de l'ordre de 60 minutes.

Le tableau ci-dessous récapitule pour chaque exercice le profil spécifique de la tâche de travail des opérateurs lors des deux séquences (opérateurs étudiés par Paris I).

Séquence 1

OPERATEUR BRUXELLES I (3 exercices mesurés)

poste de contrôleur radar organisation I niveau T2
poste de contrôleur radar organisation II niveau T2
poste de contrôleur radar organisation II niveau T3

OPERATEUR FRANCFORT I (2 exercices mesurés)

poste de contrôleur radar organisation I niveau T3
poste de contrôleur radar organisation II niveau T2

Séquence 2

OPERATEUR BRUXELLES II (5 exercices mesurés)

poste de contrôleur radar organisation I niveau T2
poste de contrôleur radar organisation I niveau T2
poste de contrôleur radar organisation I niveau T3

poste de contrôleur organique organisation II niveau T2
poste de contrôleur organique organisation II niveau T2

OPERATEUR FRANCFORT II (7 exercices mesurés)

poste de contrôleur radar organisation II niveau T2
poste de contrôleur radar organisation II niveau T3
poste de contrôleur radar organisation II niveau T3

poste de contrôleur organique organisation I niveau T2
poste de contrôleur organique organisation I niveau T2
poste de contrôleur organique organisation I niveau T3
poste de contrôleur organique organisation II niveau T2

4.3. LA TACHE DE TRAVAIL- LES ACTIVITES

Nous avons présenté les différents profils théoriques de la tâche de travail.

L'observation in situ lors de la recherche a montré la nécessité d'une étude approfondie des activités de travail des opérateurs. L'équipe de chaque site a présenté des différences comportementales et dès stratégies opératoires qui varient en fonction du type d'organisation et de l'apprentissage des opérateurs. Seules les plus explicites ont pu être relevées en raison de la méconnaissance du métier de contrôleur aérien. Par exemple, nous avons constaté dans une des séquences et seulement sur un des sites que certaines décisions opératoires étaient données oralement au contrôleur radar par le contrôleur organique en organisation I, ce comportement n'existe plus en organisation II. Il est évident que dans ce cas les activités de travail du contrôleur radar et du contrôleur organique sont différentes de celles attendues. Cette perturbation liée au dérogations à la règle, volontairement choisie par les opérateurs, montre qu'il est vain de croire que deux situations sont théoriquement identiques et justifie la démarche ergonomique.

La description de la tâche de travail ne préjuge en rien des activités réelles des opérateurs.

D'autres perturbations extérieures à la simulation ont été rencontrées. La survenue de visiteurs et des dialogues explicatifs donnés par les contrôleurs ont perturbé les tâches de travail des opérateurs, donc en finalité leurs activités mentales.

De ce constat nous présentons une description analytique de chaque situation. La démarche est clinicienne : de l'étude de ces cas locaux nous allons rechercher des invariants électrophysiologiques dont l'intelligibilité renvoie à la connaissance des activités mentales des opérateurs, activité qui modulent une "porteuse" dont le nom est vigilance.

4.4 LES DONNEES ELECTROPHYSIOLOGIQUES

Les activités des opérateurs étant visuelles, le choix du recueil des deux voies de l'électroencéphalogramme se situent sur les zones occipitales droite et gauche en regard du bord supérieur de l'oreille.

Nous ne présentons que les variations des indices Alpha (8 à 12 Hz), Béta 1 (16 à 20 Hz) et Béta 2 (20 à 35 Hz). Les comparaisons se font entre la valeur de l'indice de la voie droite et la valeur de l'indice de la voie gauche.

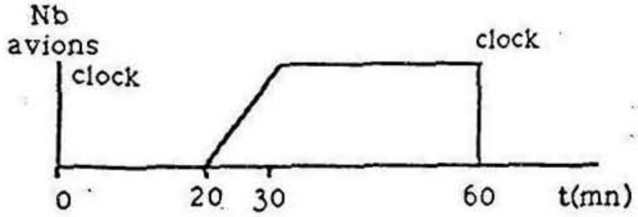
Ces variations relatives permettent

- d'éliminer l'effet de la vigilance sur l'électroencéphalogramme
- de négliger la résistivité spécifique de la peau des opérateurs qui influe sur la valeur absolue des signaux.

- d'éliminer les artéfacts liés à l'activité musculaire qui parasitent le signal à partir de 20 Hz, l'activité musculaire est généralement symétrique.

4.5. DESCRIPTION THEORIQUE D'UN EXERCICE

Après le clock du départ de la simulation vingt minutes s'écoulent environ avant l'apparition des avions sous contrôle. La montée en charge du système est de l'ordre de 10 minutes. Les trente dernières minutes présentent une tâche de travail relativement stable.
Le schéma ci-dessous récapitule la situation :



Pour chaque exercice sont présentées les variations des index Alpha Béta1 et Béta2 de la voie droite et de la voie gauche pendant les trente dernières minutes.

Sont notées par référence les variations des indices Alpha, Béta1, Béta2 pendant 5 minutes pris durant la période d'attente Le comportement des opérateurs est ici plus aléatoire ; ils ferment ou ouvrent les yeux, parlent, rient, bougent, fument ou consomment des boissons..

5 - DESCRIPTION ET INTERPRETATION DES RESULTATS ANALYTIQUES

5.1.Les électroencéphalogrammes

La valeur des indices électroencéphalographiques traduit la variation de la bande de fréquence considérée. Nous présentons les résultats des indices alpha Béta1 et Béta2 pour la voie gauche (1) et la voie droite (2).

La désactivation cérébrale se traduit théoriquement par l'augmentation des ondes alpha et la diminution des ondes Béta2.

Résultats

- La dominance énergétique de la bande Alpha chez les opérateurs au repos sur l'hémisphère droit ne semble pas être confirmée. En effet, nous ne la retrouvons que dans 3 cas. Dans 8 cas les indices ne se différencient pas, dans 6 cas nous avons une latéralisation hémisphérique gauche (le seuil retenu est de 5%).

- L'étude comparative des variations des indices Alpha, Béta1, Béta2 entre les cinq premières minutes et les trente dernières minutes de chaque exercice met en évidence: une diminution de l'indice alpha et une augmentation des indices Béta1 et Béta 2 pendant les trente dernières minutes et cela pour 9 exercices sur 17.

- Nous ne trouvons pas de relation entre les évolutions temporelles des indices alpha, Béta1 et Béta2 et les variations des flux aériens.

- La "perte des images" n'est pas objectivée à l'électroencéphalogramme mais nous avons trop peu de cas.

- Chez les contrôleurs organiques nous constatons une prépondérance hémisphérique droite de l'indice Béta 2 quand ils regardent l'écran des contrôleurs radar et cela est systématique.

Conclusion

" Le non-respect des invariants temporels"

La détérioration de la performance associée à des phases d'hypoactivation de l'E.E.G. n'a pas pu être retrouvée lors de la simulation. Les opérateurs travaillent pendant 40 minutes et cela trois fois par jour, on ne peut pas trouver d'effet cumulatif de la durée du travail, les exercices étant suivis de longues périodes de récupération ; les variations de l'activité cérébrale traduisant les phases naturelles d'hypovigilance ou celles induites par le non-respect de la structure fonctionnelle n'ont pu être objectivées.

" La latéralisation hémisphérique "

Quand les contrôleurs organiques observent l'écran radar, apparait conjointement une prédominance hémisphérique droite des valeurs énergétiques des rythmes rapides.

Comparaison avec les résultats des simulations antérieures.

Concernant les signaux analogiques en temps réel NIHONKOHDE nous n'avons pas pu mettre en évidence les hypothèses formulées après la simulation Kennedy Approach (apparition de bouffées d'ondes Alpha suivies d'une hyperactivité des rythmes Béta). De même la variation hémisphérique des ondes Alpha au repos n'est pas retrouvée. La structure temporelle des tests O.D.I.D. II ne peut mettre en évidence la détérioration temporelle des capacités de traîtement des opérateurs.

5. 2. Fréquence cardiaque

La fréquence cardiaque moyenne par exercice est de 86,5 battements par minute.(bt/mn) ce qui représente une augmentation de 11,2 bt/mn par rapport à la fréquence de repos.
Les variations inter et intra individuelles sont relativement importantes (fréquence de repos la plus basse 60 bt/mn, la plus élevée 100,bt/mn, les fréquences moyennes des exercices s'étagent entre 75 bt/mn et 106 bt/mn). Les valeurs obtenues représentent une charge cardiocirculatoire faible.

Les augmentations instantanées (dfc = 13,2 bt/mn) sont fréquentes. Elles caractérisent les activités des contrôleurs planeurs, et peuvent être interprétées comme la charge de l'astreinte lorsqu'il faut réagir à un signal auditif ou visuel. Nous avons constaté ce phénomène à plusieurs reprises chez les téléphonistes et les télégraphistes.

La différence entre la hausse de la fréquence cardiaque chez les contrôleurs radar et les contrôleurs organiques est significative (p = 0,01), quoique relativement faible (dfc = 14,37 - 9,39 = 4,98 bt/mn).

5.3. Température cutanée

Il n'y pas de variation significative au cours de l'exercice ce qui est normal vu les conditions climatiques du local. Un augmentation de 0,5° a été constatée lors des différentes séances avec un cas exceptionnel de 1,36° le 25 Mai, pour lequel nous n'avons pas d'explication.

5.4. Résistance cutanée.

Des ennuis techniques liés à l'équipement du système a entrainé l'arrêt des mesures.

6 ETUDE DES VARIATIONS HEMISPHERIQUES PENDANT LES TRENTE DERNIERES MINUTES DE L'EXERCICE

Les comparaisons des indices cérébraux Alpha et Béta2 se font entre la valeur de l'indice de la voie droite et la valeur de l'indice de la voie gauche. La valeur relative permet de détecter la latéralisation hémisphérique de l'électroencéphalogramme et de rechercher les situations où elle apparaît.

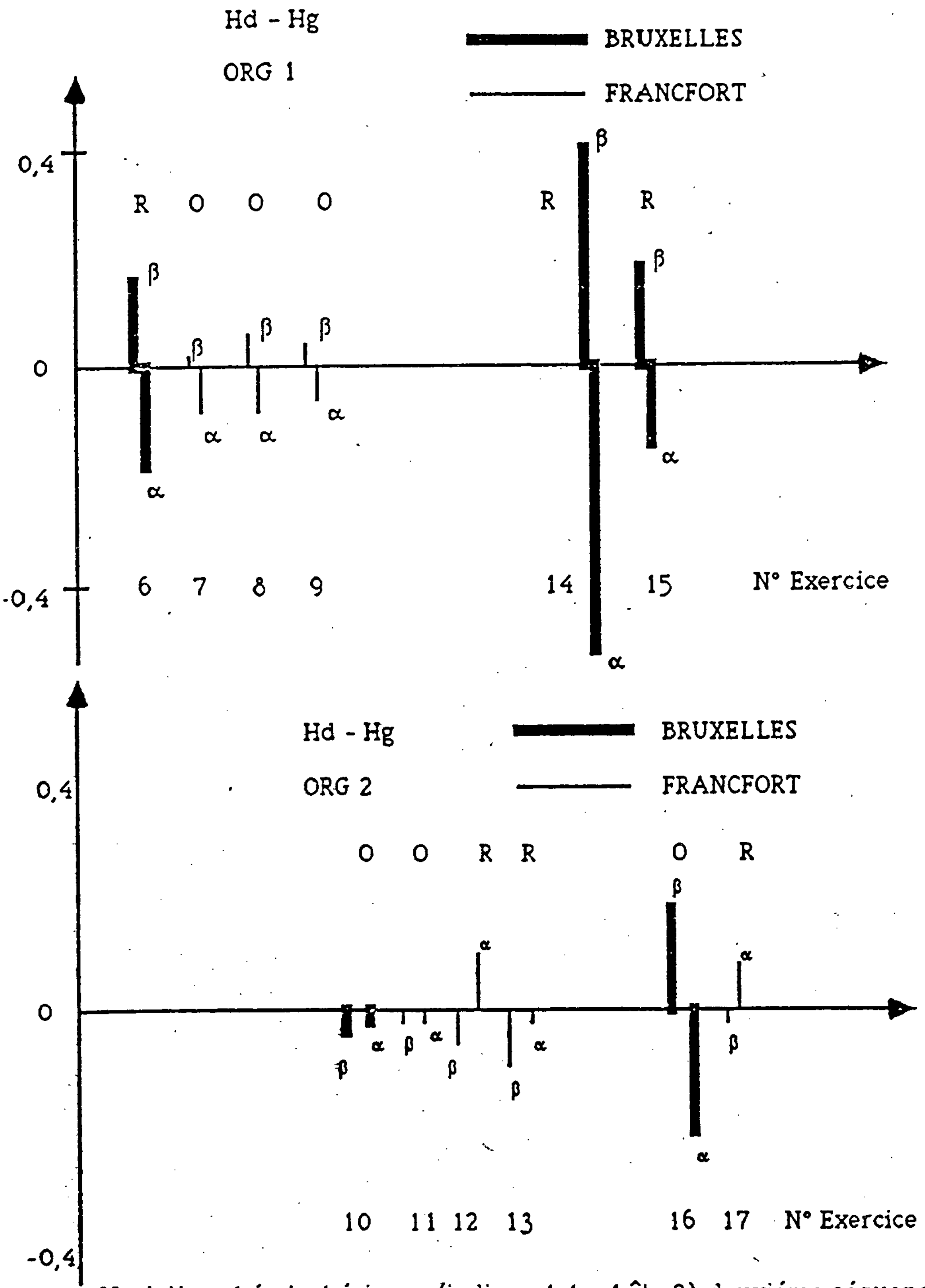
6.1 Etude des valeurs relatives alpha-Béta2

Ces valeurs relatives évoluent en sens inverse pour 13 exercices sur 17. Les amplitudes de variations sont de même ordre de grandeur pour 12 exercices.

Chez les contrôleurs du secteur de Francfort la valeur relative de l'alpha est supérieure à la valeur relative de Béta2 pour 6 exercices sur 9.

Le schéma suivant présente les variations de la valeur relative de l'alpha et de Béta2 obtenues chez les opérateurs durant la deuxième séquence (F.II, B.II) soit de la 6ème situation à la 17ème.

Ce schéma montre que nous ne pouvons étudier les différences d'apprentissage entre les opérateurs du secteur de Bruxelles Ouest et ceux du secteur de Francfort Est, ni voir de différences entre les organisations, les situations sont temporellement trop disparates.



Variations hémisphériques (indices alpha, bêta 2); deuxiéme séquence

Les indices relatifs Alpha et Béta 2 évoluent en sens inverse sauf pour la situation 10 et la situation 13.

- *Situation 10* : *le contrôleur organique (O) est sur le secteur* Bruxelles Ouest les deux indices sont négatifs mais leurs valeurs sont très faibles;

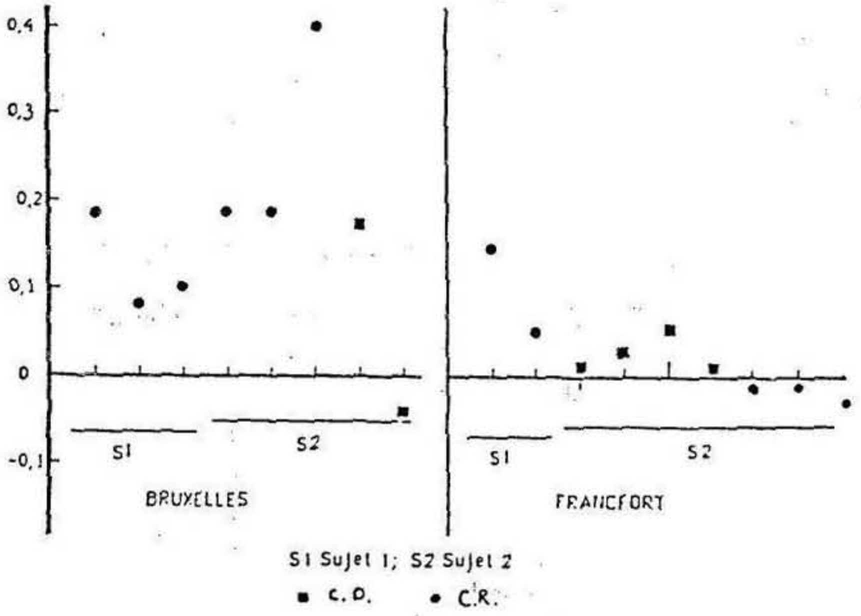
  Alpha= 0,02 Béta2 = 0,04

- Situation 13 : le contrôleur radar (R) est sur le secteur de Francfort Est:

  Alpha = 0,001 Béta2 = 0,019

La valeur des indices relatifs Alpha et Béta2 sont nettement plus importants chez les contrôleurs du secteur de Bruxelles.

6.2 ETUDE DES VALEURS RELATIVES BÉTA2



La valeur relative Béta 2 est fortement positive pour 6 exercices sur 8 chez les contrôleurs du secteur de Bruxelles Ouest ; la moyenne est de 0,2.

Tous les postes de contrôleurs radar ont une valeur relative Béta2 positive.

Pour les deux exercices où ces valeurs sont moins importantes, les contrôleurs présentent des signes de lassitude, confirmés à l'interrogatoire.

Aux postes de contrôleurs organiques la prédominance hémisphérique droite est retrouvée quand l'opérateur regarde l'écran du contrôleur radar, et quand, il discute de la simulation avec des visiteurs.

La valeur relative Béta2 chez les contrôleurs du secteur de Francfort Est est faible, la moyenne est de 0,04.

Il n'existe pas de différence entre les contrôleurs organiques et les contrôleurs radar. Seul un contrôleur radar en organisation 2 a un indice relatif de 0,14. Il discute sur sa tâche de travail.

6 .3 CONCLUSION ET INTERPRÉTATION

Les contrôleurs radar de Bruxelles Ouest présentent une prédominance hémisphérique droite de l'indice Béta2, ce phénomène *n'est pas retrouvé chez les contrôleurs radar de* Francfort Est.

Avons-nous objectivé à l'électroencéphalogramme une différence de traitements d'informations ? nous ne pouvons le certifier, mais l'hypothèse ne peut plus être exclue.

7. DESCRIPTION ET INTERPRÉTATION DES RÉSULTATS ÉLECTROPHYSIOLOGIQUES NIHONKOHDE.

Le traitement des signaux biologiques est fait par analyse de FOURIER. La représentation est visuelle et d'aspect tridimensionnel. Aucune interprétation quantitative ne peut être donnée. Le mode *particulier de représentation utilisé privilégie la mise en évidence* de la survenue d'un événement, d'un pattern, aux dépends de l'interprétation des phénomènes continus et évolutifs.

Résultats concernant les contrôleurs de FRANCFORT.

-Le contrôleur FRANCFORT 1.

Deux exercices sont sélectionnés selon le critère retenu. L'exercice a une durée de 60 mn environ. Le sujet est au poste de contrôleur organique en organisation 1 pour le premier, en organisation II pour le second.

- Les images de l'électroencéphalogramme montrent une augmentation énergétique dans les bandes de fréquences élevées Béta 1 et Béta 2 (15 à "30 Hz) au niveau de l'hémisphère gauche.

-Le contrôleur FRANCFORT 2.

7 exercices sont sélectionnés.

- Les images de l'électroencéphalogramme montrent une augmentation énergétique dans les bandes de fréquences élevées Bèta 1 et Béta 2:

- au niveau de l'hémisphère gauche pour les trois exercices du 20 Mai alors que l'opérateur est au poste de contrôleur radar..
- au niveau de l'hémisphère droit pour les trois exercices du 25 Mai que l'opérateur soit au poste de contrôleur radar ou organique.

L'expérimentation est quelque peu perturbée par la *présence* de visiteurs: le contrôleur aérien discute , fait des photos et prend un certain plaisir à provoquer volontairement l'apparition d'ondes alpha en fermant les yeux.

- La dominante hémisphérique droite pour les rythmes rapides est moins nette le 27 Mai alors que le sujet est au poste de contrôleur organique.

La dominante hémisphérique gauche est trouvée dans cinq exercices sur neuf. Les perturbations de la simulation doivent être prise en compte dans l'analyse et l'interprétation de ces résultats.

Résultats concernant les contrôleurs de BRUXELLES.

- Le contrôleur BRUXELLES 1.

Trois exercices sont sélectionnés . Le sujet est au poste de contrôleur organique. Les images électroencéphalographiques ne montrent pas de dominance hémisphérique droite dans les rythmes rapides.

- Le contrôleur BRUXELLES 2.

Cinq exercices sont sélectionnés. Le sujet est au poste de contrôleur organique. pour trois exercices Les images électroencéphalographiques montrent une dominance hémisphérique gauche dans les rythmes rapides.
L'opérateur est au poste de contrôleur radar pour deux exercices .
Les images électroencéphalographiques montrent une dominance hémisphérique gauche dans un exercice. Les images électroencéphalographique de l'autre exercice montrent des bouffées intermittentes des ondes rapides dans hémisphère droit.
La dominance hémisphérique gauche est trouvée au cours de quatre exercices dont trois au poste de contrôleur organique.

Conclusion

Les résultats obtenus par le système NIKONKHODE vont dans le même sens que ceux trouvés par le traitement numérique précédent (PARIS 1).

A FRANCFORT on retrouve une dominante hémisphérique gauche pour les rythmes rapides quand les situations ne sont pas perturbées.

A BRUXELLES les contrôleurs aériens sont six fois sur huit au poste de contrôleur organique ; alors on n'observe pas la dominance hémisphérique. droite des rythmes rapides qui est trouvée chez les contrôleurs radar.

8. CONCLUSION

Les variations de l'électroencéphalogramme ne sont pas artéfactielles, une interprétation logique a été donnée cas par cas, mais aucune validation statistique n'est possible : il y a 17 exercices mesurés et aucune situation ne peut être comparée à une autre ; les opérateurs, les postes de travail, les processus d'apprentissage, la présence de visiteurs entraînent trop de disparités.
Pourtant les résultats trouvés ouvrent des perspectives et posent des interrogations fondamentales.

Les contrôleurs radaristes du secteur de Bruxelles Ouest présentent une prépondérance hémisphérique droite de l'indice Béta2. Ce résultat n'est pas trouvé chez les contrôleurs radaristes du secteur Francfort Est, il n'y a pas de dominance hémisphérique.
Les contrôleurs organiques ne présentent pas de dominance hémisphérique.
Les contrôleurs organiques du secteur Bruxelles Ouest, quand ils regardent l'écran radar, présentent conjointement une augmentation de l'indice Béta2 sur l'hémisphère droit et cela est systématique.
A ce constat objectivé mais non validé statistiquement, les données acquises en neurophysiologie proposent de fournir une description symbolique des activités mentales des contrôleurs.

La tâche de travail des contrôleurs radar est différente de la tâche des contrôleurs organiques.

Les activités de lecture d'étiquettes de vol écrites en langage formel seraient l'appanage de l'hémisphère gauche. Cette lecture est séquentielle et analytique.

Les contrôleurs radar de Bruxelles n'assument pas leur tâche de travail comme ceux de Francfort, les activités mentales sont différentes. A Bruxelles la perception de l'espace aérien semble être globalisante., activité de l'hémisphère droit Les stratégies des opérateurs sont dynamiques, multiformes et réfèrent plus au mode de prise de décision, à une activité mentale auto-créatrice, heuristique. Il y a anticipation dans le traitement des vols, les contrôleurs semblent maîtriser le temps.

A Francfort, la séparation de l'espace aérien en couloir unidirectionnel permet un repérage des vols aériens séquentiel, matérialisé par la distance sur l'écran entre deux avions. Il y a optimisation d'un processus mental qui répond à une logique algorithmique plutôt rigide, activité de l'hémisphère gauche. Les opérateurs semblent être dépendant du temps.

Nous avons pu établir une passerelle entre un domaine phénoménal donné, les indices électroencéphalographiques et une explication symbolique des traitements des activités mentales, mais cette passerelle n'est pas du domaine de la causalité. Nous avons mis en rapport deux modes d'explication distincts, ils ne peuvent être réduits l'un à l'autre.

L'analyse des électroencéphalogrammes ne permet pas de dégager une suite de relations de cause à effet qui peut expliquer les phénomènes cérébraux sous-jacents aux traitements des informations mentales. Mais en soulevant le couvercle "de la boîte noire", elle souligne la complexité cérébrale que des modèles trop simplistes ont tendance à occulter. La cognition est une dimension essentielle dans la compréhension des activités des opérateurs, elle n'est pas que résolution de problèmes, elle est aussi activité autonome auto-créatrice.

L'évolution technique en simplifiant les activités des opérateurs ne va-t-elle pas à l'encontre de sa finalité qui est d'assurer une meilleure fiabilité du système ? sans répondre avec certitude à cette question, le choix des logiques techniques influence les activités mentales. La "sur-opérativité" des opérateurs ne risque-t-elle pas de se faire aux depends de la plasticité cérébrale, c'est à dire de la capacité d'apprentissage, donc de la performance à long terme.

PROSPECTIVES THEORIQUES

L'interprétation neurophysiologique du dialogue homme-ordinateur permet de réfléchir sur les pistes suivantes :

- comment se constitue le savoir opératoire ? à quels processus mentaux fait-il référence ? comment évolue-t-il ?
- à l'étude de changements des traitements des informations en fonction de la durée du travail et des variations qualitatives et quantitatives de celui-ci.
- à l'impact des choix technologiques sur le traitement des informations,
- à la fiabilité du système homme-ordinateur quand on est en situation usuelle et lors de la survenue fortuite d'un incident.
- à la recherche de modèles de traitement de l'information se référant à l'asymétrie cérébrale.

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Вопросы повышения эффективности взаимодействия членов экипажа воздушного судна при выполнении ими профессиональных функций

Принимаемые на протяжении большого периода времени попытки уменьшить отрицательное влияние человеческих факторов на безопасность полетов методами, основанными на обобщении результатов изучения и анализа всевозможных ошибочных действий летного состава, оказались недостаточно продуктивными, вследствие существенных различий психологических и психофизиологических свойств отдельных специалистов летной профессии, объединенных в экипаж. "Блокировка" ошибок человека техническими средствами нарушает сбалансированность соотношения между числом автоматических и ручных операций, что в свою очередь, порождает лавинообразный поток новых, непредвиденных ошибочных действий.

Таким образом, возникает как бы порочный круг, разорвать который традиционными техническими мерами становится все труднее.

Повидимому, с человеческими ошибками следует бороться человеческими способами, к числу которых относятся методы совершенствования взаимодействия членов экипажа за счет правильной организации их совместной работы, основанной на реализации межличностных свойств человеческого общения.

Этой проблематике и посвящен доклад, составленный по результатам исследований действий экипажей воздушных судов в особых ситуациях полета, проводимых в Научно-исследовательской лаборатории при Госавианадзоре СССР на фактуре материалов расследования авиационных происшествий и инцидентов.

I. Ошибки "взаимодействия".

Из анализа поведения членов экипажа в процессе возникновения и развития аварийной ситуации, причиной которой явились человеческие ошибки управления, установлено, что ряд ошибочных действий, допущенных одним из членов экипажа при выполнении какой-либо технологической операции, могли бы быть предотвращены другими, если бы они проявили некоторую активность, предприняв определенные "параллельные" действия, направленные на выполнение той же самой технологической операции или на исправление ошибки. Здесь под "параллельными" понимаются действия всех видов: мыслительные, сенсомоторные и речевые.

Неадекватные ситуации "параллельные" действия (или бездействия) определены нами как ошибочные и названы ошибками или нарушениями "взаимодействия", иначе ошибками корректировочных действий.

Оценку безинициативной работы члена экипажа можно приравнять к часто высказываемой оценке спортивного комментатора, выставленной вратарю хоккейной команды, – "Он выполнил свои функции достаточно не плохо, но не помог команде".

С точки зрения профессионала, кажутся нелепыми и абсурдными многие из ошибок "взаимодействия", несмотря на то, что они явились одной из причин тяжелых авиационных происшествий.

Вот их неполный перечень:

- необнаружение неверной установки на всех высотомерах заданного барометрического давления;
- необнаружение преждевременного снижения или ухода воздушного судна под глиссаду на конечном участке захода на посадку;
- одновременное и противоположное воздействие двух членов экипажа на один и тот же рычаг управления;
- пренебрежение командиром воздушного судна разумными советами других членов экипажа;
- решение командира воздушного судна доверить пилотирование в сложных метеоусловиях менее опытному второму пилоту;
- отсутствие или невыполнение необходимых команд или докладов.

Ошибки "взаимодействия", возникающие в полете, когда совместные действия членов экипажа были недостаточно согласованы, отмечаются, примерно, в 30 % авиационных происшествий.

2. Причины возникновения ошибок "взаимодействия".

Типичным симптоном нарушения "взаимодействия" является недостаточная слетанность "аварийного" экипажа, косвенно характеризующаяся тем, что, во-первых, время совместной работы входящих в экипаж специалистов, в большинстве случаев, было невелико и не превышает полугода, во-вторых, в этих экипажах нередко находился проверяющий из контингента командно-летного состава, имеющий, как правило, высокий уровень притязаний.

Следует выделить две группы причин, в значительной степени определяющих эффективность взаимодействия – это характер взаимоотношений и уровень организации распределения функциональных обязанностей в экипаже.

По оценке летного состава взаимоотношения в экипаже являются одним из главных условий надежной работы экипажа.

Социально-психологическая и психофизиологическая несовместимость, преобладание неофициальных отношений над официальными, непризнание в командире или проверяющем лидера, наличие в экипаже двух лидеров (формального и неформального) приводят к эмоциональной напряженности и нарушению взаимопонимания, особенно в экстремальных условиях.

Ко второй группе причин относятся недостатки нормативно-технической документации, регламентирующей порядок выполнения обязательных технологических процедур, которая по существу является основой для формирования у летного состава концептуальных моделей действий, а также представляет собой юридический документ, определяющий ответственность членов экипажа за соблюдение правил безопасности полета.

Так, некоторые из них предписывают выполнять специалисту несвойственные ему функции, например, бортинженеру – управление скоростью, другие не учитывают в полной мере численный и персональный состав экипажа, его психофизиологические возможности, эргономические особенности организации рабочих мест в пилотской кабине и ряд других факторов, характеризующих закономерности межличностных отношений людей, занятых групповой деятельностью.

Эти недостатки непосредственно влияют на надежность работы экипажа при возникновении особых ситуаций, или же являются их косвенной причиной.

3. Пути совершенствования взаимодействия членов экипажа.

Непостоянство персонального состава экипажа, как фактора аварийности, требует, на первый взгляд, принятия мер по созданию эффективных способов комплектования экипажей по критериям совместимости в производственных условиях. Однако, несмотря на имеющиеся уже в этом вопросе рекомендации, их реализация практически невозможна из-за особенностей производственной деятельности летных подразделений, требующих, порой, в незапланированном порядке формировать экипажи в новом составе.

Поэтому, этот путь, нам кажется, не достаточно перспективным. Компенсировать отсутствие методик комплектования экипажей должны методы отбора специалистов летного состава, которые могут учитывать их коммуникативные способности.

Наиболее перспективным, на наш взгляд, является подход, связанный с улучшением организации выполнения экипажем процедур управления воздушным судном, для чего нами разработаны общие принципы рационального взаимодействия, представляющие собой исходные положения, определяющие структуру информационных связей в экипаже и порядок координирования и контроля его действий в полете.

Предлагается пять принципов:

1. Принцип "лидера", устанавливающий порядок субординации членов экипажа в полете исходя из типов коммуникативного поведения людей, к которым относятся: обособляющий, ведомый, лидер и сотрудничающий.
2. Принцип "ролей", закрепляющий определенные функциональные обязанности за каждым членом экипажа в соответствии с занимаемым им в полете рабочим местом.
3. Принцип "информированности", определяющий содержание и форму информационного обмена между членами экипажа, обеспечивающего знание текущего состояния процессов, протекающих на борту воздушного судна.
4. Принцип "приоритета", определяющий первоочередность и порядок выполнения технологических операций и отдельных действий.
5. Принцип "взаимоконтроля", устанавливающий порядок действий членов экипажа по взаимному контролю за выполнением технологических операций и отдельных действий.

Апробация этих принципов показала их достаточную результативность и возможность использования в качестве основы при совершенствовании нормативно-технической документации, регламентирующей действия экипажа в полете, и программ группового обучения и тренировок летного состава.

Не принижая главенствующей роли командира воздушного судна *в руководстве работой экипажа, который по официальному статусу* является "лидером-руководителем", несущим юридическую ответственность за безопасность полета в целом, одним из решающих факторов повышения эффективности взаимодействия является профессиональное мастерство всех членов экипажа. Блестящим подтверждением этому является ответ командира экипажа, космонавта Комарова В.М. на вопрос журналистов: "Как Вы осуществляли свои функции командира?", заданный на прессконференции, посвященной первому космическому полету трех человек в целях исследования работоспособности и взаимодействия группы, - "Командовать не пришлось, каждый отлично знал и выполнял свои функциональные обязанности".

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ФАКТОР ЧЕЛОВЕКА В ПРОБЛЕМЕ АВАРИЙНОСТИ ВЕРТОЛЕТОВ

Многолетние статистические наблюдения за причинами аварийности вертолетов убедительно свидетельствуют о преимущественной роли ошибок человека в снижении уровня безопасности полетов и возникновении авиапроисшествий.

Концепции современной инженерной психологии позволяют рассматривать деятельность пилота в системе управления вертолетом как пример сложной "человеко-машинной системы". Широкий диапазон условий эксплуатации и конструктивные особенности вертолета предъявляют повышенные требования к уровню профессиональной подготовки и знаниям пилота. Пилот вертолета должен знать особенности аэродинамики и динамики полета вертолета и понимать физическую сущность процессов, происходящих на различных режимах, высотах и скоростях полета и уметь целенаправленно создавать необходимые аэродинамические моменты для оптимального управления полетом. Необходимым условием успешности деятельности пилота вертолета является понимание им законов совместной работы силовой установки и несущего винта вертолета. Он должен знать особенности возмущающих воздействий на устойчивость и управляемость вертолета и уметь целенаправленно парировать их. Он должен уметь ориентироваться на местности, рационально распределяя внимание между процессом ориентировки и пилотированием вертолета и при этом визуально точно оценивать расстояния, высоту препятствий и размер площадок. Обладать подвижностью центральных нервных процессов и психологической устойчивостью уметь принимать правильное решение в условиях дефицита времени и правильно его реализовывать. И при всем этом иметь пластичные и устойчивые навыки выполнения совмещенных действий.

Этот перечень далеко не исчерпывает необходимых требований к пилоту вертолета. Но, вместе с тем он достаточно нагляден для понимания того, что ошибки пилотов в системе управления вертолетом могут возникать на любом из перечисленных уровней деятельности и состояния человека.

Разработка проблемы деятельности человека в системах управления сложными многомерными объектами сформировала инженерно-психологический подход к оценке действий человека, как компонента целостной системы "пилот- вертолет - внешняя среда". Это означает, что ошибка человека и глубинные причинно-следственные связи ее возникновения должны рассматриваться в контуре законов управления полетом вертолета, его устойчивости и управляемости, эксплуатационных ограничений и реальных условий эксплуатации. При этом должны объективно оцениваться достоинства и недостатки техники, ее эргономичность и соответствие психофизиологическим возможностям человека. Всякий иной подход, упрощая понимание причин и условий возникновения ошибки пилота, не позволяет разрабатывать действенных рекомендаций для предупреждения авиапроисшествий и инцидентов.

С позиций инженерной психологии, ошибочное действие пилота определяется как неправильное или несвоевременно выполненное действие по управлению воздушным судном или его оборудованием без намерения действовать в нарушение установленных правил. Системный подход позволяет выделить две основные категории ошибок: случайные и закономерные. Анализ показывает, что частота возникновения случайных ошибок крайне незначительна и они составляют не более 2% от общего количества ошибок пилота. Такие ошибки носят неустойчивый характер и наблюдаются как при выполнении сложных, так и простых отработанных действий.

Из приведенного определения следует, что категорию ошибок необходимо рассматривать в качестве составной части деятельности человека, направленной на получение заданного результата. А это значит, что к анализу ошибки пилота нельзя подходить односторонне и считать ее только результатом недостатков обучения, здоровья или свойств личности. Это положение хорошо иллюстрируется примерами анализа причин аварийности вертолетов при выполнении авиахимработ, при столкновении с линиями электропередач и проводами телефонной связи, с обьектами на поверхности земли и т. д.

АХР являются классическим примером сложной профессиональной деятельности в крайне неблагоприятных санитарно-гигиенических условиях ее осуществления. И, казалось бы, при анализе причин аварийности должна учитываться высокая вероятность снижения уровня работоспособности человека в результате острого или хронического отравления высокотоксичными химическими соединениями. Транспортировка химикатов в кабину возможна не только при нарушении технологии заправочных работ на земле. По-видимому более эффективным ее способом является воздушный путь, возникающий при обработке небольших участков челночным методом, при котором существует реальная возможность входа вертолета во взвешенное химическое облако, не успевшее осесть на землю при отсутствии ветра и малой скорости движения воздушных масс.

Токсическое действие ядохимикатов на организм человека носит комплексный характер. Но едва ли не самым важным для практики пилотов является центральное действие этих соединений, проявляющееся в нарушении пространственной ориентировки человека и появлением диплопии изображения.

Влияние подобных состояний пилота на безопасность полета не требует каких либо комментариев. И поэтому, например, случаи столкновения ВС с землей в результате потери высоты и скорости полета при выполнении разворота после выхода из гона, нельзя избирательно обьяснять только ошибками в технике пилотирования или невнимательностью и неправильным распределением внимания. Это значит, что могут остаться в тени истинные причины авиапроисшествий на АХР.

Зависимость работоспособности человека от эмоционального состояния, здоровья, динамических факторов полета и факторов производственной среды хорошо известно не только специалистам в области психофизиологии летного труда, эргономики и инженерной психологии. Общеизвестно, что аварийная ситуация может явиться фактором не только дезинтеграции поведения и действий человека, что бывает достаточно часто, но и повлечь за собой повышения уровня работоспособности человека. Поэтому нельзя считать правомерным ограниченное применение в практике расследования АП иИ методов, позволяющих получить объективные данные о состоянии и действиях человека в катастрофической ситуации. Практика подтвердила эффективность медико-трассологических, гистологических, гистохимических и биохимических методов в оценке состояния, а их комплексирование с методами инженерно-психологического расчета и моделирования в оценке действий пилота. Этот подход приобретает особое значение в условиях отсутствия на борту ВС средств обьективной регистрации параметров полета и при недостаточном обьеме регистрируемых параметров.

Столкновение вертолетов с ЛЭП - достаточно широко распространенное событие в практике полетов на малых высотах. Происшествия такого рода обьясняют, как правило, невнимательностью, недисциплинированностью и грубым нарушением правил производства полетов. Обоснованность таких выводов не вызывает сомнений, поскольку АП происходят в хороших метеоусловиях, при солнечном освещении и осведомленности пилотов о наличии ЛЭП в районе полетов. Инженерно-психологический анализ позволяет в ряде случаев объяснить причину невнимательности пилота. Объясняется она ограниченными возможностями зрения человека в восприятии объектов малых угловых размеров из кабины движущегося ВС. Ухудшению условий восприятия способствует засветка глаз прямыми или отраженными солнечными лучами, изменяющими контрастную чувствительность, а также загрязненность, запыленность и потертость остекления кабины экипажа. На характеристики восприятия может оказать влияние стробоскопический эффект, возникающий при вращении НВ.

Проведенный нами опрос показал, что примерно для 15% респондентов столкновение было неожиданным и они не предпринимали никаких мер для его предотвращения. Остальные респонденты отметили позднее обнаружение провода, когда практически не оставалось времени на выполнение управляющих действий или его выполнение не предотвратило столкновения. Анализ структуры столкновений свидетельствует, что они наиболее часто происходят после выполнения разворота, т.е. в тех случаях, когда ЛЭП находилась в поле периферического зрения и не воспринималась пилотом активно.

Достаточно часто столкновения происходят на взлете и посадке, т.е. в тех случаях, когда внимание пилота сосредоточено на пилотажной задаче и контроль за выполнением дополнительных условий недостаточен даже при незначительном усложнении условий деятельности.

Разнообразие причин столкновения ВС с ЛЭП требует разработки универсальных профилактических мероприятий. Это может быть разработка средств внутрикабинной сигнализации. Возможен вариант маркировки ЛЭП в местах интенсивных полетов вертолетов. Считал бы необходимым высказать мнение, возможно для некоторых специалистов спорное, об эффективности средств разрыва проводов. Безусловно приемлемое для разрыва проводов небольшого сечения, оно может оказаться непригодным для предотвращения АП при разрыве провода большого сечения. Но такое решение может быть принято в результате ошибок в оценке диаметра провода. Более того, ошибки могут возникать по другим причинам, т.к. применение этого способа требует учета и других факторов: скорости полета, угла тангажа, угла столкновения с проводом и даже расстояний между опорами ЛЭП. Не исключены ошибки психологического контекста, т.к. пилоту необходимо принять осознанное решение и, тем самым, затормозить рефлекторные действия, направленные на предотвращение столкновения . Кратковременная растеренность может стать причиной возникновения АП.

Пилотирование вертолета- процесс сложной исполнительной деятельности человека, требующий врожденных и приобретенных способностей и навыков, координации движений, соразмерности и точности их выполнения. Особенности структуры, формирования навыков выполнения совмещенных действий и их разрушения в экстремальных условиях изучены еще недостаточно. Это существенно ограничивает возможность анализа ошибок пилотирования и не позволяет создать научно обоснованную систему подготовки летного состава к действиям в особых ситуациях полета.

Резкие рефлекторные действия играют большую роль в аварийности вертолетов. Они могут быть целесообразными лишь в узком диапазоне ситуаций, возникающих при отказе техники и требующих стабилизации пространственного положения вертолета. Во всех остальных случаях резкие движения могут рассматриваться как ошибочные, вызывающие рассогласование в работе силовой установки и несущего винта вертолета. При полете на малых высотах такие ошибки особенно недовустимы, т.к. пилот практически не располагает временем для парирования возникающих моментов и восстановления нормальной работы двигателя и несущего винта. Нарушения тонкой координации управляющих действий,темпа перемещения и соразмерности движений составляют основную категорию ошибок пилотов вертолетов.Их анализ позволяет сделать вывод что в основе многих из них лежит недостаточное понимание пилотами законов практической аэродинамики вертолета. Именно этим можно объяснить тот факт что некоторые пилоты рассматривают резкие движения органами управления динственно возможным методом достижения максимальных характеристик маневрирования. Ошибки могут отражать уровень пофессиональной подготовки летного состава и появляться в недостаточном учете особенностей устойчивости и управляемости вертолета на различных высотах и скоростях полета, эксплуатационных ограничений, внешних условий, характеристик приемистости двигателя и запаздывания управления, правил пилотирования при возникновении возмущающих воздействий и т.д..

Практика расследования АП и И свидетельствует о значительной роли ошибок восприятия в возникновении ошибок пилотирования. Ошибки в оценке удаленности,высоты полета и размеров посадочных площадок нередко встречаются у недостатояно подготовленных пилотов. Эксперименты показали, что наибольшие ошибки в оценке высоты допускаются при полетах над безориентирной подстилающей поверхностью. Выполнение разворотов при заходе на посадку без должного контроля высоты по радиовысотомеру, может сопровождаться потерей высоты и привести к столкновению с поверхностью земли. Такие случаи не единичны. в практике полетов и в них может отчетливо проявляться тенденция к " зарыванию " вертолета в процессе выполнения левого разворота без достаточного контроля за скольжением. Потеря высоты в этих случаях часто остается незамеченной пилотами из-за неправильного распределения внимания и отсутствия взаимодействия членов экипажа в контроле пилотажных параметров.

Позитивное отношение пилотов к высоким маневренным характеристикам вертолетов общеизвестно. Более того, именно в этих характеристиках многие пилоты видят наиболее привлекательную сторону своей профессиональной деятельности. Но далеко не все из них представляют, что максимальное использование пилотажных возможностей сопряжено с проявлением особенностей и необычным поведением вертолета при выходе на критические режимы,которые ставят недостаточно подготовленного пилота в очень сложное положение. И еще меньшая часть пилотов знает, что в этих условиях становятся возможными непреднамеренные и неправильные действия рефлекторной природы, которые могут явиться причиной АП. Известное опасение вызывает укоренившееся среди части летного состава мнение, что при полетах на малых и средних высотах у пилота есть время на принятие решения и исправление ошибок, и лишь предельно малые высоты маневрирования и наличие препятствий ограничивают возможности пилотов. Полеты на малых высотах предъявляют повышенные требования не только к качеству пилотирования. Обеспечение безопасности полетов становится возможным при условии знания эксплуатационных ограничений и их зависимости от различных факторов. Пилот должен предвидеть возможность непреднамеренного выхода за ограничения. Важно уметь по поведению вертолета распознать возникшее отклонение и своевременно определить порядок выполнения необходимых действий. Выявление таких факторов является важнейшей задачей инженерно-психологического анализа причин возникновения ошибок летного состава.

Статистика аварийности вертолетов свидетельствует о распространенности ошибок пилотов при выполнении посадок на подобранную с воздуха площадку. Достаточно часто это могут быть ошибки в оценке высоты в сочетании с неправильным решением по выбору метода зависания в зоне влияния воздушной подушки или вне ее. Итогом ошибок является потеря ориентировки в снежном или пылевом вихре. Ряд неудачных посадок сопряжен с недостаточным учетом характера экранирующей поверхности и ее уклонов. Выполнение посадок по вертолетному может сопровождаться ошибками типа резкого увеличения угла тангажа на величину более 10 градусов после выведения вертолета из угла планирования. Энергичное увеличение угла тангажа приводит к установке НВ на положительные углы атаки и росту его оборотов при сбросе мощности двигателей. При завершении выравнивания из-за быстрого уменьшения скорости в момент отклонения РЦШ от себя начинают падать обороты НВ и возникает самопроизвольное снижение вертолета, сопровождающееся порой разворотом из-за падения тяги РВ. Психологическая неподготовленность пилота к такому развитию событий, как правило, сопровождается задержкой с увеличением общего шага несущего винта. Резкое и запоздалое его перемещение может привести к перетяжелению НВ со всеми вытекающими отсюда последствиями.

Создание значительных углов тангажа на посадке является одной из причин повреждения рулевого винта вертолета. Распространенность таких случаев в практике эксплуатации вертолетов общеизвестна. Анализ показал, что происхождение ошибок пилотов в определенной мере может быть связаны с нарушением установленных правил по выдерживанию высоты и скорости захода на посадку и использованием ими наиболее эффективного способа гашения поступательной скорости,- торможения несущим винтом. Возникающее при этом интенсивное опускание хвостовой балки не исключает повреждения РВ о препятствия в районе посадочной площадки.

Таковы некоторые типичные по,нашему мнению, причины ошибочных действий пилотов вертолетов,создающие благоприятные условия для возникновения авиапроисшествий и инцидентов. Меры профилактики должны основываться на знании пилотами причин возникновения ошибок и условий, способствующих их возникновению.

APPENDIX B

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International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

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