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AUTOMATIC DEPENDENT SURVEILLANCE

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FOREWORD

The ICAO Council's Special Committee on Future Air Navigation Systems (FANS), in accordance with its terms of reference, carried out extensive studies aimed at identifying and assessing new concepts and new technology, including satellite technology, which may have future benefits for the development of international civil aviation. Automatic dependent surveillance (ADS) was defined by the FANS Committee as a function for use by air traffic services whereby aircraft automatically transmit, via data link, data derived from on-board navigation systems, including aircraft identification and three-dimensional position.

This circular has been prepared by the ICAO Secretariat with the assistance of an air navigation ADS Study Group comprising experts from ten Contracting States and five international organizations. It contains guidance material on ADS including information concerning the experience gained to date regarding development and planning of ADS, pre-implementation programmes and harmonization of air traffic services. The purpose of the circular is to provide information on a number of aspects of ADS that would benefit and harmonize its early world-wide implementation.

The introduction and operation of ADS will provide air traffic service units with the capability to extend automatic surveillance of aircraft beyond present radar coverage and to monitor air traffic operations over oceanic and land areas where procedural air traffic control is presently applied. It is envisaged that the implementation of ADS will have considerable impact on air traffic control procedures and that the guidance material presented herein will need to be supplemented in the light of experience. It is therefore recommended that States share with ICAO their experience concerning ADS with the objective of updating the guidance material contained in this circular.

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Chapter 1
BACKGROUND

1.1 OVERVIEW OF PRESENT AIR TRAFFIC SERVICES

1.1.1 Air traffic services include air traffic control (ATC) services, flight information services (FIS) and alerting services. The airspace where ATC service is provided is normally divided into control areas with a view to obtaining manageable portions of the airspace for the provision of ATC services and thereby achieving efficient air traffic operations. An increasing number of aircraft movements, and subsequent increased controller workload, necessitate the further subdivision of the control areas into a number of control sectors in which ATC services can be provided in an effective manner. However, such subdivision causes an increase in co-ordination between control sectors, which limits control capacity. This situation is exacerbated in areas where the level of automation is low.

1.1.2 The efficiency of ATC services is to a large extent dependent upon the available air-ground communications and surveillance capabilities. Several continental airspaces are covered by reliable air-ground communications and radar surveillance systems. However, in oceanic airspaces and continental areas where very high frequency (VHF) communications and surveillance installations are not practicable, ATC services are provided by means of high frequency (HF) communications, which have operational limitations, and procedural air traffic control.

1.1.3 Many flight information regions (FIRs) throughout the world rely on procedural systems for controlling air traffic, some with little or no automation support. This is particularly true in most oceanic FIRs where radar and VHF communications systems cannot be provided to cover vast areas of oceanic airspace. In addition, these systems are not usually employed in low traffic density remote areas because of cost-effectiveness. Instead HF voice communications are used, which are not restricted to line of sight but are subject to severe fading and interference. Moreover, there are no surveillance systems comparable to radar available in these regions. The application of procedural ATC ensures an adequate level of safety, at the expense of optimal flight profiles and system capacity. In general, flights must be planned via intermediate way-points rather than on direct routes, hence limiting the opportunity to obtain changes to cleared flight profiles. This has an adverse effect on aircraft operating costs.

1.1.4 Flights operating outside radar and VHF coverage at present are monitored on the basis of current flight plan (air traffic control clearance) and the pilot-reported position (air-report). The flight plan describes the assigned route along which the aircraft is expected to fly. The position reports, transmitted via HF at relatively infrequent intervals, enable the controller to monitor the aircraft's progress for conformance to its air traffic control clearance.

1.2 OPERATIONAL CONSIDERATIONS

1.2.1 Airspace environments around the world vary significantly in terms of traffic densities. In most regions where no radar coverage is available, traffic is relatively sparse; in some oceanic airspaces, however, congestion is already reaching critical levels. Although certain system capacity improvements have been achieved during recent years, ATC in many regions is still procedurally-based and therefore does not provide the flexibility required for economical flight operations.

1.2.2 Air traffic services (ATS) units responsible for providing services to users operating in non-radar environments employ varying degrees of automation and use different procedures for controlling traffic. As a result, pilots are required to be familiar with the individual control aspects of all FIRs their flights will traverse.

1.2.3 Long-range air navigation has reached a high level of reliability and accuracy through the use of modern long-range navigation systems. Data from accurate short-range systems such as VHF omnidirectional radio range/distance measuring equipment (VOR/DME) may also be used when available to update the on-board system. Today's aircraft can reliably navigate long distances across the oceans and vast continental areas and can expect at any time to be within a few nautical miles of the desired position. However, a small number of significant deviations from cleared track still occur. These are mainly attributable to human error such as ATC loop errors or aircraft navigation systems insertion errors.

1.3 POTENTIAL IMPROVEMENTS TO OPERATIONS

1.3.1 The procedural ATC described above is typical of that employed in many FIRs throughout the world. This method of control has been used for many years and has a proven safety record. Continuing increases in international travel and the need to reduce commercial air transport operating costs will require more efficient air traffic management techniques. ICAO and its Council's FANS Committee have recognized these needs and have actively pursued the identification and development of new concepts and new technology for the implementation of ADS on a global basis. Application of ADS in oceanic and other non-radar regions is normally expected to be satellite-based. Other data link media, such as VHF, may also be used.

1.3.2 An ADS function whereby aircraft-derived positional information would be transmitted automatically or on request to an ATS unit offers the potential for increasing flight safety and airspace utilization by reducing ATC loop errors in air-ground communications and allowing more accurate aircraft position-reporting information to be transferred to ground facilities. In oceanic and large continental areas with limited air-ground communications and surveillance capability, the ADS function is envisaged to be an important means of improving air traffic services and airspace management. Exchange of information and messages by digital data link is likely to become the most common means of air-ground communications. An automatic digital data link for ADS position reports and associated messages also presents the opportunity to alleviate the overloading of ATC radio frequencies, which interferes with message exchange during peak traffic in many busy continental areas.

Chapter 2
ADS SYSTEM CONCEPT

2.1 AUTOMATIC DEPENDENT SURVEILLANCE (ADS)

2.1.1 "**Automatic dependent surveillance** is a function for use by air traffic services (ATS) in which aircraft automatically transmit, via a data link, data derived from on-board navigation systems. As a minimum, the data include aircraft identification and three-dimensional position. Additional data may be provided as appropriate." [FANS/4 Report (Doc 9524), 3.3.1.2]

2.1.2 **An ADS-based ATC system** must also include the capability to exchange messages between the pilot and the controller via data link and by voice for emergency and non-routine communications.

2.2 PRINCIPLES OF OPERATION

2.2.1 The ADS concept (see Figure 2-1) is based on the use of digital data link communications and encompasses the transfer of the aircraft-derived position information to the controller in near real time. This is done automatically without the need for direct pilot or controller involvement. The information transferred comprises:

a) position information derived from the system being used to navigate the aircraft, at a rate which can be controlled by the ground ATC system;

b) information on the route stored in the system being used to navigate the aircraft, enabling ATC to verify the "next position" and the "following significant point" for conformance checking against the current flight plan (air traffic control clearance); and

c) meteorological data for ATC and appropriate Meteorological Offices.

Although ADS itself does not specifically encompass ATC communications, automation or procedures, clearly all of these elements must be tailored to support the ADS function and to make meaningful use of the data. For this reason it is useful to consider the ATC automation and communications systems as the foundation upon which the ADS-based ATC system is built.

2.2.2 ADS will significantly change the way air traffic control is performed in oceanic and other areas which are beyond the coverage of land-based radar, line-of-sight communications systems or combinations thereof. The accurate and timely indication of an aircraft's position and good communications are keys to the operation of a safe, responsive and effective ATC system. Given these capabilities, the air traffic controller can monitor flight progress, ensure safe separation of aircraft and respond in a timely manner to user requests. A gradual transition from procedurally oriented air traffic control towards a more tactical control environment will also be possible with the introduction of ADS.

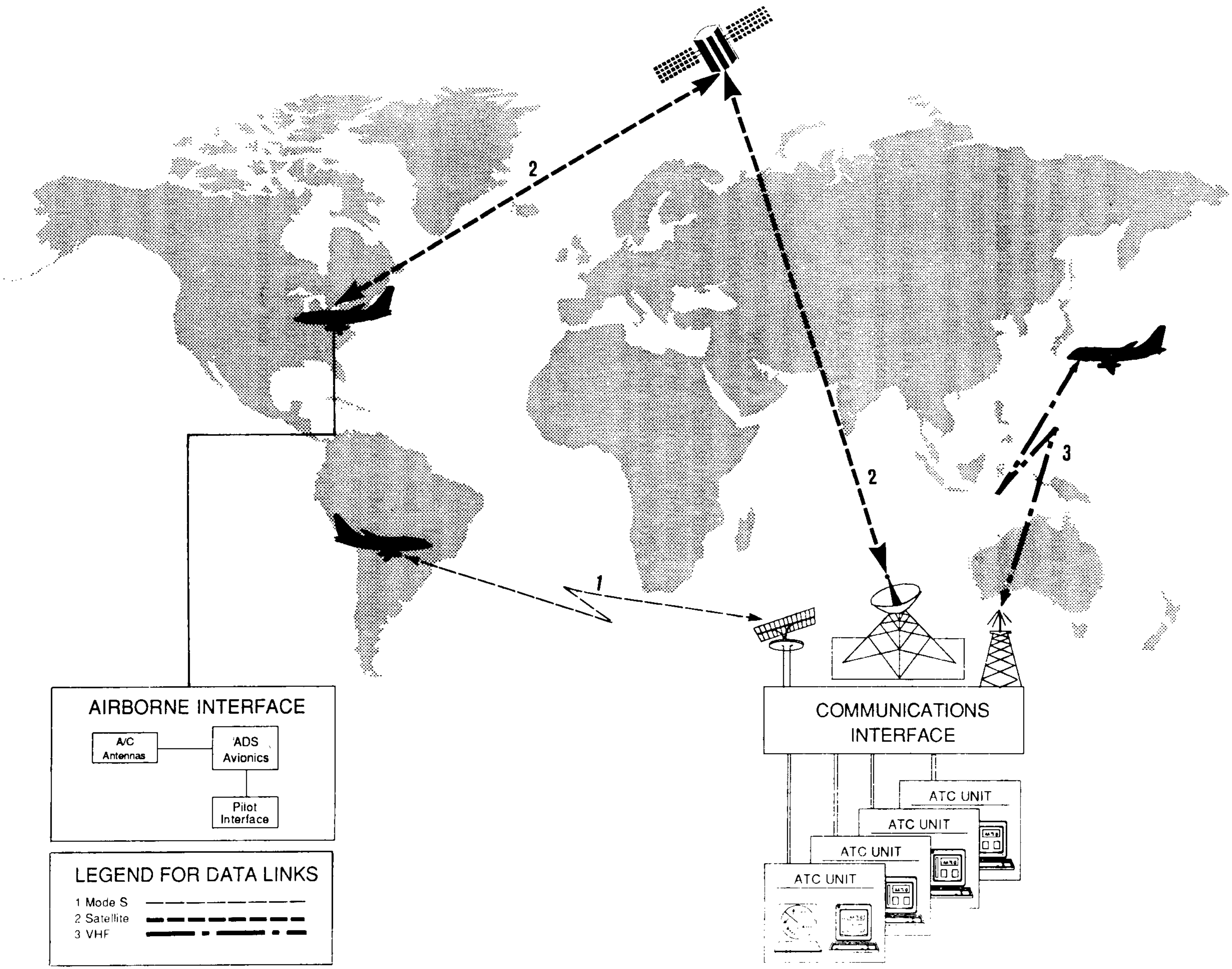

Figure 2-1. ADS system concept

2.2.3 The ADS system design must permit introduction of ADS without interruption of existing operational ATC services. The system should also be sufficiently flexible and expandable so that the following objectives can be achieved:

a) capability to incorporate the Standards and Recommended Practices (SARPs) in ICAO Annexes as they are developed;

b) capability to adapt to local regulations and special ATS requirements and flexibility to accommodate future changes in functional needs and technological advances;

c) ability to revert safely to other forms of operational ATC services in case of degradation or failure of the system;

d) provision of a minimum service capability to all appropriately equipped aircraft; and

e) provision of an ATS infrastructure capable of taking full advantage of ADS.

2.2.4 Components of an ADS-based ATC system are as follows (see Figure 2-2):

— pilot interface;
— avionics;
— data links;
— communications interface;
— ATC automation; and
— controller interface.

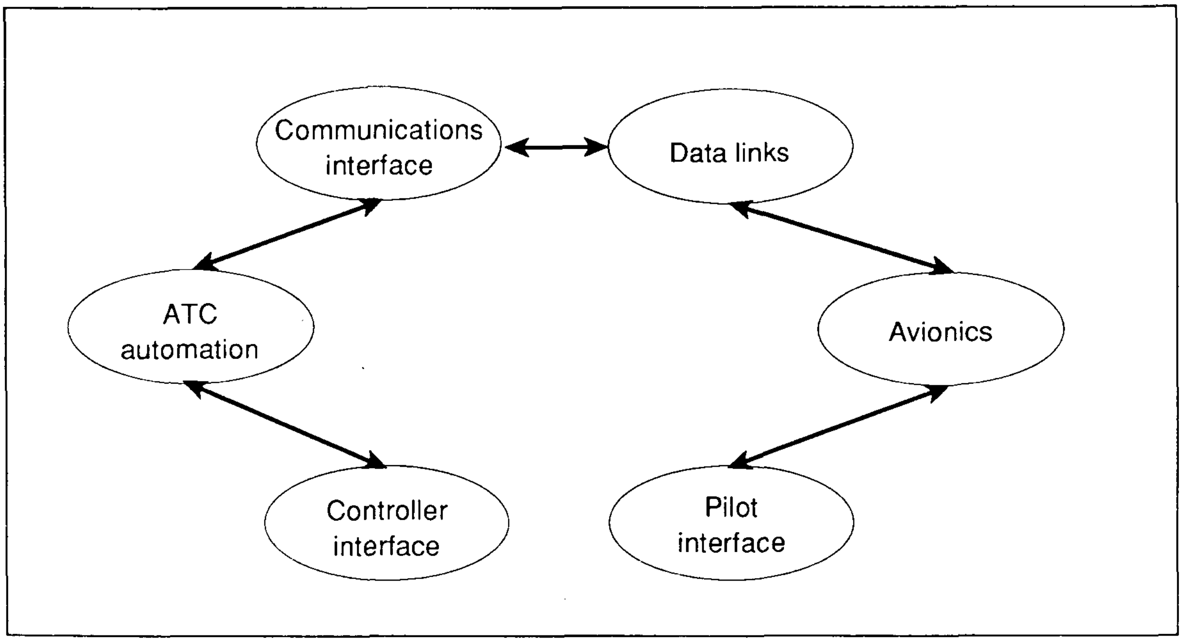

Figure 2-2. ADS system components

2.3 PILOT INTERFACE

2.3.1 The ADS data reports are transmitted automatically without pilot action. The frequency of reporting is determined by the ATC system; however, a capability will be provided to permit emergency messages to be initiated by the pilot by means of a simple operation using quick-action facilities. Additionally, pilot interface will provide a means to send and receive routine data messages. Direct pilot-controller voice capability must be available for emergency and non-routine messages.

2.3.2 The pilot interface should provide a means to monitor the operation of the system. Log-on and transfer of communications to another data link ground station should normally be automatic, but the pilot will have the capability to override at any time if necessary. Typically, a pilot wishing to establish a communications link should merely need to press a button in order to set in motion the log-on procedure, after which the avionics will handle link setup and handoffs.

2.3.3 To cater for emergency situations the system must also provide for a pilot-initiated communication which will indicate the state of emergency and include a basic ADS report and aircraft identification.

2.4 AVIONICS

2.4.1 The ADS function is supported by avionics equipment which is able to gather aircraft data from on-board systems, format them and direct them to the relevant air-ground link via the data link processor. The avionics will make maximum use of equipment already in place on most commercial air carriers.

2.4.2 On-board equipment will also have the capability to receive messages originated by the controlling ATS unit which will set the position report update rate of an aircraft and the data fields to be included in the report.

2.5 DATA LINKS

2.5.1 The complete end-to-end communications sub-system, operating between the ATS unit and the aircraft, is being designed to effectively support the ADS requirements. The architecture of this communications sub-system will permit a modular design and implementation and will accommodate an incremental system development approach. At the same time, functional uniformity in the services provided to airspace users can be maintained while allowing individual ATS providers considerable flexibility in the actual implementation.

2.5.2 Services capable of supporting satellite-based ADS systems are already available between latitudes 75° North and South. There is work ongoing to develop and upgrade the service with new-generation satellites. VHF and Mode S data links are being evaluated and may also be used to complement ADS systems in appropriate areas.

2.5.3 The establishment and termination of communications must be handled automatically by the system following initialization by the pilot.

2.5.4 The FANS Committee recognized that a satellite-related ADS service could be provided using any of the following four modes:

— contract mode, in which the aircraft automatically provides ADS reports at prearranged intervals or upon reaching preset navigational limits;

— on-demand immediate response;

— time-ordered polling; and

— random access.

Contract mode is expected to be the mode used for ATC purposes. It will permit the ATC system to instruct aircraft to report their positions periodically. Aircraft may also report at any time or be interrogated by the ATC system when so required by operational circumstances.

2.6 COMMUNICATIONS INTERFACE

2.6.1 The implementation of an ADS-based ATC system requires a ground communications interface connecting ATS units with the associated data link ground station(s). One of the functions of this interface will be to route the ADS messages to the appropriate end-users (ATS units). Direct routing to multiple end-users shall be accomplished by this interface and shall not require intermediate processing by an ATC. However, the logic for this routing shall be controlled by the appropriate ATS authorities. The communications interface should permit ADS-based ATC systems to accept data via any of the three data link media — satellite, VHF and Mode S (see Figure 2-1).

2.6.2 A specification of the communications interface and its characteristics is being developed by the appropriate ICAO bodies. This interface must be in place before full operational advantages of an ADS system can be obtained.

2.7 ATC AUTOMATION

An ADS-based ATC data processing system should be capable of automating the following functions:

a) Flight data validation, whereby the aircraft's route (way-points) entered into the aircraft's navigation system are compared to the cleared flight profile and any discrepancies found are reported.

b) Conformance monitoring, whereby the aircraft's reported actual and intended positions are compared to the cleared flight profile and out-of-tolerance conditions reported to the controller.

c) Automated tracking, in which ADS-reporting aircraft are tracked by the ATC system between position reports.

d) Detection of potential conflict in which positions of all aircraft are projected into the future and a search is performed to detect possible future violations of separation minima.

e) Conflict resolution, whereby a system solution to a potential conflict is offered to the controller which can either be used or modified.

f) Presentation of relevant processed data to the controller.

The functions listed above do not necessarily represent a complete set. It should also be noted that some of these functions may need to be performed by a controller depending on the level of automation of the ATC system.

2.8 CONTROLLER INTERFACE

The human-machine interface will be left to the individual service provider. However, all such interfaces should be designed and integrated into existing ATC systems, with the objective of reducing controller workload. The interfaces should have the following capabilities:

a) to display the traffic situation so as to enable a controller to monitor the traffic in the sector with minimum effort;

b) to alert the controller to potential conflicts (or loss of separation);

c) to enable the controller, using both predetermined and free format, to compose and transmit ATS messages via data link;

d) to display the arrival and content of data messages from the pilot;

e) to provide rapid access to a voice channel for emergency and non-routine communications with a pilot or a group of aircraft; and

f) to provide a method of responding rapidly to a request from a pilot via voice communications.

Chapter 3
FUNCTIONAL ELEMENTS OF ADS

3.1 GENERAL

An ADS-based ATC system must be defined in the context of all necessary components from aircraft avionics to controller interface. Functionally, however, ADS comprises two elements: surveillance and communication of related ADS messages.

3.2 POSITIONAL INFORMATION

3.2.1 The basic ADS report contains aircraft identification, latitude, longitude, altitude, time, figure of merit and field activation/reporting capability flags. The figure of merit is related to the accuracy of the position data contained in the report, while the last item describes any additional reporting capabilities the aircraft might possess, such as way-points or wind speeds. All ADS messages also contain the aircraft technical address, which is a globally unique identifier.

3.2.2 The basic ADS report is transmitted by the aircraft avionics on a periodic basis. The ground ATC system can vary the reporting interval as needed, based on the type of airspace, application and traffic density. A reporting frequency of once every 10 seconds is considered to be the most frequent update rate required for most oceanic and continental en-route applications.

3.2.3 The surveillance data obtained from the on-board navigation system is based on a specific geodetic reference datum when computing the aircraft position. To provide the greatest ATC benefit, a common global geodetic reference system must be used by all ADS-equipped aircraft, thereby ensuring that positions are computed using the same coordinate frame.

3.3 ADS MESSAGES

In addition to the basic ADS report, two other ADS messages are presently defined. Each message consists of mandatory data fields forming the basic surveillance report and various optional fields as requested from the ground. The extended ADS report provides information on the pilot's intent by supplying way-point, heading and speed data. The associated ADS report provides wind velocity and temperature data. Table 3-1 summarizes the defined ADS message fields.

Table 3-1. ADS messages

Basic ADS report

Data elements	To be transmitted: Every report	On request	Resolution	Bits
Latitude/longitude	X		0.0125′	42
Altitude	X		2.4 m (8 ft)	16
Time	X		0.125 s	15
Figure of merit	X			7
Field activation/ADS capability		X		16
Flight identification		X	8 x 6 bits	48

Extended ADS Report

Data elements	To be transmitted: Every report	On request	Resolution	Bits
Next way-point		X	0.0125′	42
Estimated altitude at next way-point		X	2.4 m (8 ft)	16
Next + 1 way-point		X	0.0125′	42
Estimated altitude at (next + 1) way-point		X	2.4 m (8 ft)	16
Track/heading		X	0.1°	12 + 1
IAS/Mach		X	0.5 kt/0.001	13 + 1
Vertical rate		X	0.08 m/s	12

Associated ADS report

Data elements	To be transmitted: Every report	On request	Resolution	Bits
Wind speed		X	2 km/h (1 kt)	9
Wind direction		X	0.7°	9
Temperature		X	0.25°C	12

Explanatory Notes for Table 3-1

1. **To be transmitted**

— every report: Self-explanatory.

— on request: The data elements indicated in this column have to be reported only after a specific request transmitted by the ATC system.

2. **Resolution**

The resolution given is derived in part from the avionics characteristics. The resolution of the fields identified above is specified for the purpose of allocation of bits necessary to accommodate the projected accuracy capability of future systems. It does not represent an accuracy requirement to be imposed on avionics. For some data, e.g. altitude, track/heading, IAS/Mach and vertical rate, the ATC system may not require such resolution.

3. **Bits**

The number of bits indicated does not include a status bit.

4. **Data elements**

The items which constitute an ADS message. Note that every ADS message has to contain the 24-bit technical address (identical to Mode S).

Latitude/longitude: aircraft present position in latitude and longitude.

Altitude: aircraft pressure-altitude expressed in feet.

Time: (UTC) time as reflected in the time stamping of a position report expressed in minutes and seconds and fraction of a second in accordance with the indicated resolution.

Figure of merit: indicates the quality of the ADS position report and availability of navigation equipment redundancy.

Field activation/ADS capability: indicates which of the "on request" fields are present in an ADS report and also serves as an ADS capability indicator in response to an appropriate request message to the aircraft. The first 11 bits are set to logical "1"s or "0"s to denote which of the "on request" fields are contained in the ADS message (i.e. a "1" in the lowest order bit indicates that the flight identification field will be present in the message). The remaining five bits are reserved for future expansion.

Flight identification: field 7 of ICAO flight plan. If no flight plan is available the aircraft registration will be used.

Next way-point: the way-point towards which the aircraft is proceeding at the moment of the ADS report, the so-called active way-point.

Altitude at next way-point: altitude at next way-point as estimated by the avionics.

Next + 1 way-point: the way-point which will become the next active way-point.

Altitude at (next + 1) way-point: altitude at next way-point +1 as estimated by the avionics.

Track/heading: actual true track or heading.

IAS/Mach: actual indicated airspeed or Mach number.

Vertical rate: actual vertical speed.

Wind speed/direction: wind direction and speed as derived by the avionics.

Temperature: outside air temperature as available in the avionics.

Chapter 4
POTENTIAL BENEFITS AND OPERATIONAL IMPLICATIONS

4.1 GENERAL

The ADS-based ATC systems will provide early benefits in non-radar environments through improved surveillance, communications, enhanced data processing and new procedures. These benefits will accrue from the combined improvements in future four-dimensional (4-D) navigational capabilities along with the increased reporting rate of aircraft position, which will permit more effective monitoring of flight progress and hence better and more efficient utilization of airspace.

4.2 SYSTEM SAFETY

4.2.1 In order to maintain or improve the target level of safety in the face of increasing traffic densities, improvements in surveillance and communications are required. An ADS-based ATC system will provide improvements in both these areas.

4.2.2 **Surveillance.** An ADS-based ATC system will process frequent position reports received via data links from suitably equipped aircraft. Associated ATC data processing will have the capacity to identify potential deviations from the cleared flight profile caused by way-point insertion errors (Figure 4-1) and continuously monitor a flight's progress to ensure conformance with the cleared flight plan within a pre-defined tolerance (Figure 4-2). Since the ADS system will rely essentially upon on-board navigation sensors, it will not necessarily enable ATC detection of track divergences attributable to the performance of an individual aircraft's navigational equipment. Nevertheless, the availability of frequently updated dependent surveillance data, including aircraft identification, position and altitude, will permit early detection of potential or actual deviations from the cleared flight profile attributable to human error. This will enable timely intervention to prevent these errors growing to such proportions so as to constitute a threat to safety.

4.2.3 **Pilot-controller communications.** The use of satellite communications in lieu of current HF communications will result in a dramatic shortening of the pilot-controller communications lag time and in improved integrity of these communications. It will provide the means for controllers to issue ATC clearances, out-of-conformance warnings and weather advisories in a timely manner. It will also provide a mechanism for controllers to respond quickly to in-flight emergency situations.

4.2.4 It is anticipated that in an ADS-based ATC system, early benefits of protection against way-point insertion errors and certain other types of navigational errors will accrue to each aircraft that is ADS-equipped. An ADS-based ATC system will also have enhanced search and rescue (SAR) alerting and locating facilities where ADS-equipped aircraft are involved. These improved capabilities are derived mainly from frequent aircraft position reporting and ADS surveillance, even when the aircraft's position is not in conformance with the cleared flight plan.

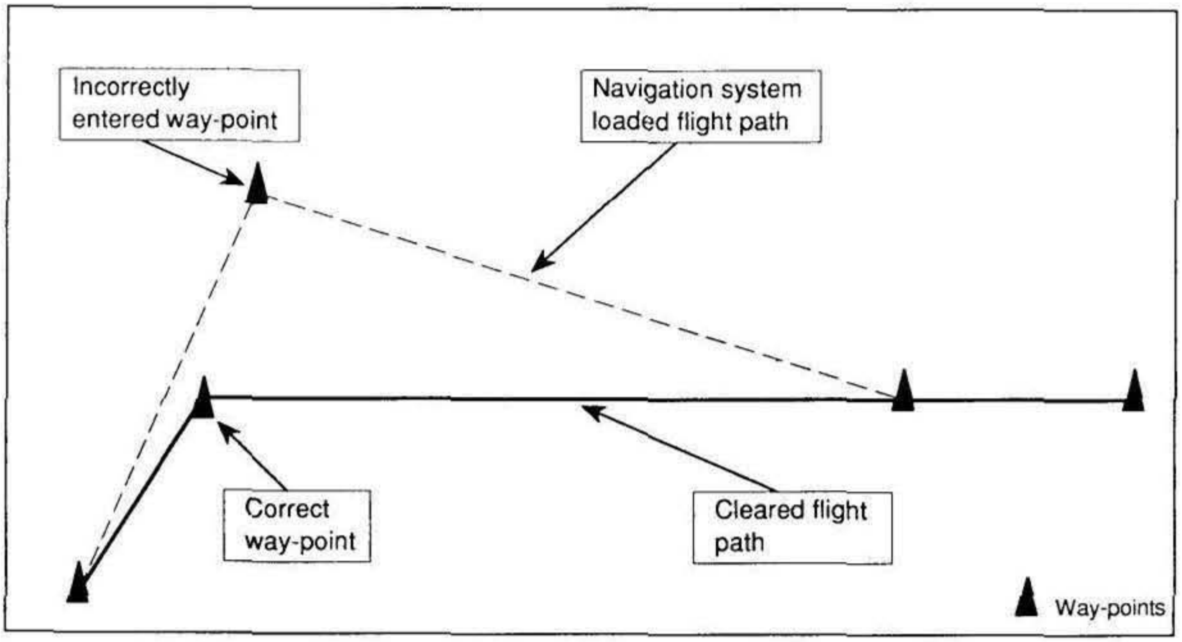

Figure 4-1. Way-point insertion errors

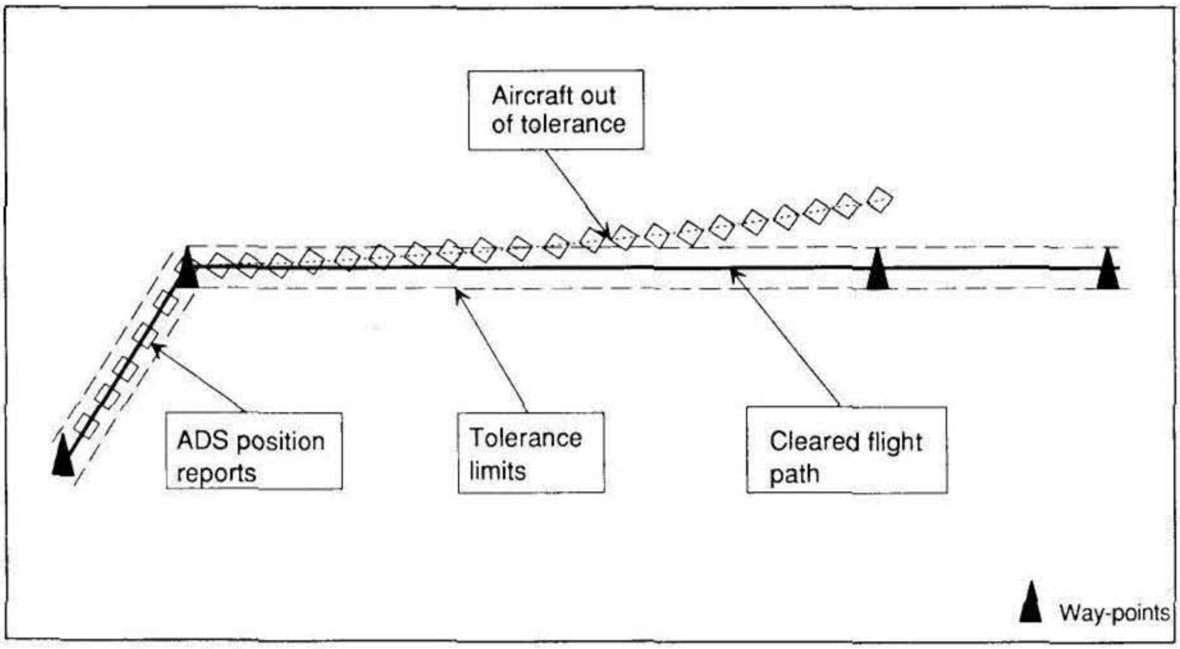

Figure 4-2. Flight plan conformance monitoring

4.3 INCREASED RESPONSIVENESS TO USER REQUIREMENTS

4.3.1 An ADS-based ATC system will initially provide controllers with the tools needed to be more responsive to users in two important ways:

a) increased ability to provide more efficient flight paths; and

b) more timely responses to pilot requests (tactical control).

In addition, an ADS-based ATC system offers the potential for reduced separation between aircraft on the basis of other air traffic management (ATM) improvements.

4.3.2 One tool in particular, automated conflict prediction and resolution, will increase the controller's ability to analyse and resolve complicated traffic situations. This function can also be used to assess the effects of user-requested changes to a cleared flight path before issuing an ATC clearance.

4.3.3 The ADS-based ATC system will contribute to increased user responsiveness through its improved surveillance and communications capabilities. Accurate knowledge of an aircraft's position and the means to quickly communicate with it will provide more tactical control capabilities.

4.4 TRANSITION TO SMALLER SEPARATION MINIMA

4.4.1 ADS will play an important role in improved productivity in the use of a specific volume of airspace through reduction of separation minima in those areas where the traffic demand is high but where there is no surveillance system and procedural separation minima are used.

4.4.2 With the combination of improved ATC automation, reliable communications and accurate surveillance data due to be realized in the next several years, it should be possible at some future time to reduce oceanic separation minima, thereby further increasing airspace capacity. This increased capacity can then be used to satisfy user requests for optimal routings.

4.4.3 Information on ADS developments should be shared with other relevant ICAO bodies so that those tasked with examining separation minima can develop ADS separation minima in a timely manner.

Chapter 5
DEVELOPMENT AND PLANNING

5.1 INTERNATIONAL CO-OPERATION

5.1.1 ICAO has been the forum for international development and standardization efforts for ADS, and satellite-based communication, navigation and surveillance (CNS) in general. Studies were initially performed in 1978 in conjunction with the United States Federal Aviation Administration (FAA) by the Committee to Review the Applications of Satellite and Other Techniques to Civil Aviation, commonly referred to as the Aviation Review Committee. The result of this study was the Oceanic Area System Improvement Study (OASIS) report. The report, completed in 1981, presented a survey of alternative approaches to improving air traffic services in oceanic areas, including the use of satellites in the application of ADS, and provided the basis for subsequent ADS work. Since then, ICAO has continued to develop the concept of a global CNS systems approach to ATS through the work of its various committees, panels and groups, as discussed below.

5.1.2 Special Committee on Future Air Navigation Systems (FANS)

5.1.2.1 The FANS Committee was established by the ICAO Council at the end of 1983 to study, identify and assess new concepts and new technology in the field of air navigation, including satellite technology, and to make recommendations for the development of air navigation for international civil aviation over a period of the order of twenty-five years. The final FANS Committee Report (Doc 9524, FANS/4), published in 1988, was a consolidation of all of the FANS meetings.

5.1.2.2 Upon completion of the FANS work programme and its blueprint for future air navigation systems, the Aeronautical Mobile-satellite Service (AMSS) Panel, the ADS Study Group and subsequently the ADS Panel were established within ICAO to continue the FANS work and develop the necessary detailed specifications and procedures. In addition, a new ICAO Committee (FANS II) was established with the objective of advising on the over-all monitoring and co-ordination of development in transition planning to ensure that implementation of the future CNS system takes place on a global basis in a cost-effective manner.

5.1.3 Aeronautical Mobile-satellite Service Panel (AMSSP)

5.1.3.1 The AMSS Panel was established in 1987 to undertake specific studies as approved by the Air Navigation Commission with a view to developing on an urgent basis, using the Open System Interconnection (OSI) model, Standards, Recommended Practices, procedures and, where appropriate, suitable guidance material related to air-ground digital data and voice communications of aeronautical mobile-satellite services compatible with other air-ground data links and ground air traffic services communications network giving due consideration to automatic dependent surveillance requirements.

5.1.3.2 The AMSS Panel is concerned with standardizing the satellite communications sub-system. Its scope is broader than just ADS, but the SARPs generated by this panel must accommodate the ADS function and help to ensure that communications for ADS are compatible with other air-ground data link systems.

5.1.4 Secondary Surveillance Radar Improvements and Collision Avoidance Systems Panel (SICASP)

5.1.4.1 The SICAS Panel was established in 1981 to develop SARPs and suitable guidance material concerning secondary surveillance radar (SSR) enhancements and related data links and collision avoidance systems. In 1987, as a result of FANS/3, Recommendation 7/3, the panel was given the task of developing protocols to permit commonality and interoperability between Mode S and other ATS data links, including satellite data links. In the specific area of ADS, the SICAS Panel is working on the development of the upper layer OSI protocols to support the periodic reporting requirement of ADS such that the AMSS Panel can define the satellite sub-network (lower OSI reference model) layers. In particular, this will include the interface between ADS and the aeronautical telecommunication network (ATN). The ATN connects heterogeneous avionic, air-ground and ground communications interface together so that they appear as a continuous communications system to the users.

5.1.4.2 SICASP working groups have been progressing the work on matters related to the development of SARPs and guidance material for SSR Mode S systems based on the aeronautical telecommunications network and material relating to SSR Mode S data link and interoperability considerations between Mode S and other ATS data link systems.

5.1.5 North Atlantic Systems Planning Group (NAT SPG)

5.1.5.1 The NAT SPG is composed of Member States directly involved with airspace within the North Atlantic. This group is charged with continuously studying, monitoring and evaluating the system in the light of changing traffic characteristics, technological advances and up-dated traffic forecasts, to the end that the North Atlantic Regional Plan may be adjusted on a timely, evolutionary basis.

5.1.5.2 A task force has been established to develop a common future air traffic management (ATM) system concept for the North Atlantic, on the basis of which a regional implementation plan will be prepared. It is envisaged that several tasks will be finalized in time for their results to be reviewed by a NAT Regional Air Navigation Meeting scheduled to be held in late 1992.

5.1.5.3 In defining the common future ATM concept, the task force is assessing the problems related to the operational concepts that must be developed in order to accommodate the transition to the new technologies. Satellite voice requirements for the North Atlantic Region are also being developed, following review of the work carried out by the AMSS Panel and the ADS Study Group.

5.2 NEED FOR HARMONIZATION

5.2.1 The goal of ATS system harmonization is to provide an environment for the airspace users in which full benefits of ADS-based ATC systems can be achieved and the transition of aircraft from one FIR to another is facilitated through maximum compatibility between ATC centres. To accomplish this, the basic set of automation functions that support ATS must be harmonized. The implementation of ADS is the first world-wide opportunity to establish this level of harmonization using cost-effective justifications based on a single sensor-type system. It will not be possible to use ADS to its full potential if the individual ATS units cannot communicate data directly to each other. Such data communications will require that operational interface control procedures be established.

5.2.2 In oceanic environments, achieving this goal is complicated by the fact that automation systems are being developed simultaneously by many provider States. These systems must be harmonized and integrated to the point where they each present the same basic level of service to airspace users. They must also interface efficiently with non-automated FIRs. In order to achieve this goal, harmonization will be necessary. This harmonization must be applied to the communications data link, the messages that drive the system, ATC procedures and automation functionality. The ADS service itself must be designed to an ICAO Standard, and it must also be capable of serving several classes of users operating in a variety of environments.

5.2.3 The communications data link which forms the foundation of an ADS-capable system will need to be standardized in terms of communications protocols and interface techniques. It will also be necessary to define what data will be sent to which ground stations to ensure that ATS messages are made available to all ATS units concerned in support of certain air traffic automated functions.

5.2.4 Once the data link foundation for the system has been defined, the system can then be integrated using the existing ICAO ATS message set as a starting point. These messages will include flight plans and amendments, co-ordination messages, track assignments, wind information, weather forecasts and operational data.

5.2.5 In addition, the basic set of automation functions that support the ATC procedures must be harmonized to define the minimum operational requirements and functionality needed to use and process ADS data as well as the way these automated functions will interact with non-automated systems in adjacent FIRs.

5.2.6 A critical element in the efficient management of the airspace will be ATC procedures that can take full advantage of technological advances. Some of the issues that must be addressed include reduced separation in an airspace with mixed equipped aircraft, the handling of aircraft within the scenario of an ATC system failure and procedures for automated transfer of control between centres.

5.3 FUTURE DEVELOPMENT

5.3.1 The concept of ADS is not limited to the oceanic environment. ADS can be used in other areas such as deserts, jungles, mountainous regions — anywhere there is satellite or VHF data link communications coverage. This is economically advantageous, since satellite-based communications and surveillance do not require as large an initial capital investment as radar and VHF communications-based systems. Operations and maintenance costs are also expected to be lower.

5.3.2 Since ADS transmits position information derived by an aircraft's on-board navigation system, independent of the type of navigation system employed, highly accurate satellite navigation systems such as the United States Global Positioning System (GPS) and the USSR global navigation satellite system (GLONASS) can be integrated into an ADS-based ATC system. The use of the GPS or GLONASS world-wide navigation systems, in conjunction with ADS, will support a reduction in separation minima, since the effect of each individual aircraft's navigation system performance and deviations will be minimized.

5.3.3 Satellite data link is and will remain the principal communications mode. Direct communication between the ATC automation on the ground and the airborne flight data management system will be accomplished via data link. Digital voice communications utilizing satellite channels will, however, play an increasing role in the pilot-controller interface. Due to the generally high reliability and availability of satellite communications and their cost-effectiveness when implemented on a large scale, current air-ground voice systems such as HF will be employed in future primarily as a backup capability. Initially, HF may have to be maintained over polar regions until such time as satellite communication is available.

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Appendix A
STATUS OF DEVELOPMENT

Substantive information has been received as a result of ICAO's request to be kept abreast of States' experiences and results of trials and experiments concerning ADS application and pre-implementation programmes. Although the information received for some of the trials and experiments indicates an early stage of development, these experiences and results have been most valuable for the over-all review of ADS and the development of initial operational and communication requirements for the use of ADS in ATS. Some of this provided information has been included in this circular to reflect the status of experiments which took place before February 1990.

1. Canada

1.1 For the last two years Canada has been carrying out limited ADS-type tests using a VHF data link as the communication vehicle. From the experience gained, the decision has been taken to build a development system to investigate the impact ADS will have on ATC operations and procedures. A co-operative experiment is also being carried out by Transport Canada and Air Canada in which data are acquired from data link-equipped Air Canada 767s, using appropriate VHF ground sites of the Air Canada air-ground communication network.

1.2 Provision of a Teleglobe earth station in the province of Quebec, capable of accessing an INMARSAT satellite, should be available by 1990. This will allow satellite-delivered data to be processed as experimental way-point positional data for direct display to the controller. The position update data may also be processed to provide input to a modified Northern Airspace Control System (presently in a manual input mode) to experiment with appropriate situation displays in an oceanic environment.

1.3 By mid-1990, Canada should be testing ADS message types and experimenting with appropriate two-way links in its Northern airspace and coastal oceanic areas using existing VHF networks. There will be a transition to satellite trials as soon as earth station links are available and interested airlines, both national and foreign, are capable of participating.

2. Iceland

2.1 In 1989, the Icelandic Civil Aviation Administration (ICAA) awarded a contract for the development of a basic flight data processing system to support Reykjavik FIR operations. Delivery is expected in 1992. This system provides the basis for later development of ADS capabilities. Several possibilities for investigating aspects of using ADS in oceanic ATC are under consideration by ICAA. These involve the application of a simulation facility used to generate air traffic scenarios in support of FANS activities.

2.2 The installation of an Aircom/Aircraft communications and reporting system (ACARS) digital ground radio station in Iceland by Société internationale des télécommunications aéronautiques (SITA) provides a potential opportunity for obtaining automatic air-reports from suitably equipped aircraft within VHF range.

Work on a generic situation display for ADS-type application is at an advanced stage. This system has been developed using the X-windows environment running on a powerful workstation under the UNIX operating system. This prototype workstation displays either simulated or real data on a 19-inch high-resolution display. It is already being used for displaying ADS-type data for ATC purposes.

3. Japan

3.1 Several study programmes are currently under way in Japan. An ETS-V satellite was launched in August 1987 by the Japanese National Space and Development Agency for experiments in communications, navigation, positioning (ADS and CIS) and ATC. Flight experiments in domestic airspace using a Beechcraft B99 and in North Pacific airspace using a Japan Air Lines (JAL) Boeing 747 began in November 1987 and will continue through March 1990. ADS positions were reported by polling every three seconds from the ground and displayed on a cathode ray tube (CRT) together with maps, airways and data blocks, etc.

3.2 The data link research and development programme for ATC applications will begin in April 1990 and continue for the next five years. An experimental data processing system for ADS and data communications will be developed and set up at the Electronic Navigation Research Institute (ENRI). This system will be interfaced with an INMARSAT satellite and VHF data links. A Beechcraft B99 will be equipped with a satellite communication device complying with Aeronautical Radio Inc. (ARINC) 741 and navigation equipment as an ADS source for flight experiments.

3.3 JAL is also conducting satellite communications experiments in conjunction with INMARSAT. The first phase covering voice transmissions only was completed in March 1988. JAL is now preparing to conduct a so-called Phase 2 experiment over the Pacific from June to September 1990. This time both airborne and ground equipment, which are being developed to satisfy the requirements of INMARSAT System Definition Manual (SDM) and ARINC 741, will be tested. The purpose of the test is to verify the acceptability of the satellite communications system. At present, the services are limited to the Pacific Region; however, there is a plan to expand the service area to the Indian Ocean Region by 1991 for the data service and by 1992 for the voice service, by relocating equipment from Ibaragi to Yamaguchi ground earth station (GES), where both Pacific and Indian Ocean satellites can be accessed.

3.4 As part of these efforts, the Japanese Civil Aviation Bureau signed co-operative study agreements with the United States FAA in 1988 and intends to provide improved satellite-based communications and surveillance capabilities to oceanic sectors of ATC centres, taking into account the current limitations of both HF radio and radar.

4. Portugal

4.1 As a follow-up to FANS activities in Portugal, work is planned on the following projects: research programmes with Lisbon University regarding the application of artificial intelligence to the conflict resolution; optimization of a human-machine interface of the air traffic control working positions; development with MITRE Corporation of an evaluation model of the present specifications of the oceanic flight data and visualization system; and trials and experiments with SITA and participating airlines in air-ground data link communication capability.

4.2 In preparation for ADS, Portugal is in the initial stages of procuring the NAV 2 system that will perform oceanic flight data processing functions. Portugal is participating with EUROCONTROL, the

United Kingdom and Spain in the European Space Agency PROSAT/PRODAT satellite experiment and intends to continue its participation throughout the entire programme. Portugal and EUROCONTROL have decided to include in the studies, tests and trials programme, two real-time simulations (in 1990 and 1992) of the Santa Maria Oceanic FIR aimed at studying the Atlantic projects as well as performing studies on ADS and its data link.

5. **Spain**

5.1 The Spanish General Directorate of Civil Aviation (DGAC) undertook, within the PRODAT/PROSAT experimental system, flight tests in evaluation of a satellite data link ATS system.

5.2 On 24 October 1988, the DGAC succeeded for the first time in controlling an aircraft from Biggin Hill, United Kingdom, to Madrid-Barajas Airport by means of a data link using the INMARSAT MARECS B-2, the European Space Agency (ESA) ground earth station at Villafranca, Madrid and a ground data link, data processing and display at Madrid ACC.

5.3 All messages including en-route, descent and approach clearances, radar vectoring and weather information were given by Madrid ACC to the aircraft exclusively by means of the PRODAT/PROSAT satellite data link until the aircraft was at 4 000 ft on the localizer of runway 33 at Barajas Airport. Voice communications were not even used to confirm ATC clearances. Simultaneously, and through the same data link channel, ADS was performed and the aircraft position data presented on a radar screen.

5.4 Spain, continuing with the PRODAT programme with the United Kingdom and EUROCONTROL, is planning the installation of a GES in the vicinity of the Madrid ACC which, in combination with the other two GESs in the programme and about 20 aircraft earth stations (AES) on board IBE and BEA aircraft, will constitute an experimental set-up for ADS and ATS communications. The objective of this experiment is the evaluation of the technical performance of the digital data links to determine their efficiency as an ATC tool.

6. **Union of Soviet Socialist Republics**

6.1 The USSR ADS programme consists of the following steps:

6.1.1 First step (1988-1992). Theoretical research activities are being undertaken in simulation of the air traffic management system utilizing ADS for different control areas and zones. Display of simulated data to both controllers and pilots will be performed. Particular emphasis is being placed on the future use of GLONASS/GPS-derived position data.

6.1.2 Second step (1993-1995). The experimental implementation and testing of future air traffic management system elements using ADS will be performed.

6.1.3 Third step (1996-2000). One experimental ATC centre will be built to complete the work on flight control procedures using ADS.

7. **United Kingdom**

7.1 PRODAT: The PRODAT ATC air-ground satellite data link trials are continuing. Analysis of data collected during flight trials with experimental aircraft is under way and flight trials with commercial aircraft have commenced. The project is enabling data link performance to be measured and experience to be gained of several aeronautical data link applications. These applications cover ADS, including way-point and meteorological reporting, and ground database access from aircraft. It is also planned to demonstrate oceanic clearance delivery via satellite.

7.2 Mode S: Future plans will aim towards equipping more commercial and non-commercial aircraft with data link equipment so that greater opportunity exists for practical data link trials. From a communications viewpoint this will provide experience in operating and utilizing networks and internetwork communications, assessing the validity of proposed air-ground data link protocols and measuring data link performance. In carrying out trials, certain proposed data link applications will be supported, e.g. the uplink of weather information (Volmet) and the collection of air-derived parameters for ground-based applications such as short-term conflict alert (STCA).

7.3 VHF data link: A proof of concept trial is taking place at Atlantic House, Prestwick using VHF data link to issue oceanic clearances to suitably equipped westbound transAtlantic flights. Experience to date indicates that this method of delivery of oceanic clearances is likely to be acceptable in the future.

8. United States

8.1 The Oceanic Display and Planning System (ODAPS) will provide the automation baseline for an ADS-capable system. The ODAPS will be operational at both the Oakland and New York oceanic ATC centres in 1990.

8.2 The ADS function is being developed as an enhancement to the ODAPS and will use commercial communications satellites to provide two-way data link and voice communications between the aircraft and the ATC system. ADS Step 1 will provide fixed rate automatic position reporting. It will also provide several functional enhancements to the ODAPS baseline. These enhancements will provide flight plan conformance monitoring, missing report detection and unique display symbols for ADS-equipped aircraft. Step 2 of the ADS programme will add two-way data link capability and variable update rates for ADS position reports. Step 1 ADS will be operational in 1991 and Step 2 in 1993.

9. EUROCONTROL

9.1 As one of the ATC participants in the ESA's PRODAT experiment, EUROCONTROL undertook up to the end of 1989 technical assessments of the PRODAT communication system performance and an operational demonstration using real-time simulation of airspace controlled by Portugal where messages were actually transiting via the PRODAT satellite link. This trial, which used colour display of ADS positions, flight plan information and circles of uncertainty around ADS positions, was conducted from December 1987 to January 1988. In 1989 the technical assessments were pursued using airline aircraft.

9.2 In October 1989, as a further development of the above demonstration, an ATC real-time simulation was carried out with the participation of operational staff from France, Ireland, Portugal and the United Kingdom. Two sectors were simulated, representing Shannon West sector and a Shanwick sector. At the request of Portugal, a real-time simulation of the Santa Maria FIR is planned for 1991. Part of the simulation slot is reserved for investigating ADS aspects. Definition of the simulation specifications will start in 1990. A second simulation is tentatively planned for 1992-1993.

9.3 The description and results of the abovementioned trials are in EUROCONTROL Experimental Centre reports published in 1988, 1989 and 1990.

10. INMARSAT

10.1 INMARSAT presently operates eight satellites and has ordered four second-generation satellites. The current planning is based on the launch schedule from October 1990 to November 1991. The technical characteristics of the second-generation satellites include a design life greater than 10 years, L-band frequencies for satellite to mobile of 1 530-1 548 MHz and mobile to satellite of 1 626.5-1 649.5 MHz and a total effective isotropically radiated power (EIRP) of 39 dBW edge of coverage.

10.2 On 2 October 1989, INMARSAT issued a formal Request For Proposals (RFP) to the satellite manufacturing industry. Bids have been received and are currently being evaluated for its third-generation satellites. Delivery of the first satellite will be in June 1994, and successive spacecraft deliveries will be at four-month intervals. The total L-band EIRP of each satellite will be 48 dBW, providing nearly 10 times the effective capacity of each of the INMARSAT-2 satellites, or 30 times the capacity of the first-generation satellites currently in operation. Each satellite will carry five spot beams in addition to a global beam capability. The technical characteristics of the third-generation satellites include an orbital life of 13 years, a manoeuvre life of 10 years and L-band frequencies from satellite to mobile of 1 530-1 559 MHz and from mobile to satellite of 1 626.5-1 660.5 MHz.

Appendix B
GLOSSARY OF TERMS

Note.— The definitions given for the following terms relate specifically to their use in the context of ADS. These definitions may not be applicable in other contexts.

Aircraft Earth Station (AES). A mobile earth station in the aeronautical mobile-satellite service, other than a survival craft station, located on board an aircraft (see also Ground Earth Station (GES)).

Aircraft identification. A group of letters, figures or a combination thereof which is either identical to, or the coded equivalent of, the aircraft call sign to be used in air-ground communications, and which is used to identify the aircraft in ground-ground air traffic services communications.

Air-ground communication. Two-way communication between aircraft and stations or locations on the surface of the earth.

Air-ground control radio station. An aeronautical telecommunication station having primary responsibility for handling communications pertaining to the operation and control of aircraft in a given area.

Air-ground data link. A system for the two-way exchange of digital data between the ground and an aircraft.

Air-report. A report from an aircraft in flight prepared in conformity with requirements for position and operational and/or meteorological reporting.

Air traffic. All aircraft in flight or operating on the manoeuvring area of an aerodrome.

Air traffic control clearance. Authorization for an aircraft to proceed under conditions specified by an air traffic control unit.

Note 1.— For convenience, the term "air traffic control clearance" is frequently abbreviated to "clearance" when used in appropriate contexts.

Note 2.— The abbreviated term "clearance" may be prefixed by the words "taxi", "take-off", "departure", "en-route", "approach" or "landing" to indicate the particular portion of flight to which the air traffic control clearance relates.

Air traffic control (ATC) unit. A generic term meaning variously, area control centre, approach control office or aerodrome control tower.

Air traffic services (ATS) unit. A generic term meaning variously, air traffic control unit, flight information centre or air traffic services reporting office.

Collision avoidance system (Airborne collision avoidance system). An airborne system which provides the detection and tracking of aircraft in the vicinity of the equipped aircraft, signals the presence of aircraft presenting a collision threat and provides resolution manoeuvre advice to ensure the safe separation of the conflicting aircraft.

Control area. A controlled airspace extending upwards from a specified limit above the earth.

Current flight plan. The flight plan, including changes, if any, brought about by subsequent clearances.

Note.— When the word "message" is used as a suffix to this term, it denotes the content and format of the current flight plan data sent from one unit to another.

End-user. An ultimate source and/or consumer of information.

Global beam. A satellite antenna coverage pattern that encompasses the Earth's surface that is within line-of-sight view of the satellite.

Ground Earth Station (GES). An earth station in the fixed satellite service, or, in some cases, in the aeronautical mobile-satellite service, located at a specified fixed point on land to provide a feeder link for the aeronautical mobile-satellite service.

Note.— This definition is used in the ITU's Radio Regulations under the term "Aeronautical Earth Station". The definition herein as "GES" for use in the draft SARPs is to clearly distinguish it from an Aircraft Earth Station (AES), which is a mobile earth station in the aeronautical mobile-satellite service located on board an aircraft.

Message field. A group of one or more bits defined for a specific purpose within a Mode S message format. In this circular the term "message field" normally refers to an MA, MB, MC or MD field.

Mode S. An enhanced mode of secondary surveillance radar (SSR) that permits the selective interrogation of Mode S transponders, the two-way exchange of digital data between Mode S ground stations and transponders and also the interrogation of Mode A/C transponders.

Mode S data link. A means of performing an interchange of digital data through the use of Mode S ground stations and transponders in accordance with defined protocols.

Network. A communication system that consists of multiple nodes and necessarily contains means of managing the data transfer through the nodes.

OSI reference model. The Open Systems Interconnection communications system architecture defined by the International Organization for Standardization (ISO).

— END —

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

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.

Procedures for Air Navigation Services (PANS) are approved by the Council for world-wide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.

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