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FOREWORD

General

1. The purpose of the Aircraft Accident Digest is to disseminate accident report information to Contracting States. Publication of the Digest began in 1951. Over the years States have reiterated their interest in the Digest not only as a valuable source of information for accident prevention, but also as a training aid for investigators and educational material for technical schools.

Selection of accidents

2. The Digest contains accident reports selected by the Secretariat from those sent by States. Reports were selected on the basis of:

a) their contribution to accident prevention; or

b) the successful employment of useful or effective investigative techniques; and

c) compliance with Annex 13 provisions including the format of the Final Report.

The Digest should not be seen as being statistically representative of the world distribution of accidents.

Editorial practices

3. The Final Reports are usually published as received. Accordingly, some deviations from standard ICAO editorial practices may occur. Lengthy reports may be abbreviated by omitting redundant information, appendices, attachments or diagrams. Minor changes in presentation and terminology may be introduced to ensure compliance with Annex 13 provisions.

States' co-operation

4. States are encouraged to send to ICAO those Final Reports which meet the criteria of 6.14 in Annex 13. The reports must be submitted in one of the working languages of ICAO, and in the format presented in the Appendix to Annex 13.

Digest publication

5. The Digest is produced once each year and includes accidents and incidents which occurred during a one-year period.

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No. 1

Boeing 727-100, HZ-TFA, incident near Riyadh, Saudi Arabia, on 22 January 1986. Report AIR 1-86 released by the Presidency of Civil Aviation, Saudi Arabia

SYNOPSIS

HZ-TFA, Boeing 727-100 operated under Flight Number (SV 7994) departed King Khalid International Airport Riyadh, at 1855 local time (1555 UTC) on 22 January 1986. The intended destination was Jeddah.

Some seventeen minutes after take-off, smoke was detected coming from the master lavatory. Further investigation revealed a fire. A return to KKIA was initiated and an emergency was declared.

The fire was extinguished prior to the landing.

The aircraft landed on runway 33L at KKIA, at 1951 local time and was evacuated at mid point on the runway, using the normal aircraft aft stairs. There were no injuries.

The Presidency of Civil Aviation, Aviation Standards and Safety Department determined that the probable cause of the fire was a defect in the electronic timer switch allowing continuous operation of the flush motor; the flush motor overheated and the temperature rise was sufficient to ignite combustible electrical components.

1. FACTUAL INFORMATION

1.1. History of the Flight

A privately owned Boeing 727-100, registration HZ-TFA, departed King Khalid International Airport, Riyadh, at 1855 local time (1555 UTC) on the 22 January 1986 (12 Jamad Awal 1406) as Saudia 7994. On board were six crew and fifteen passengers with Jeddah as an intended destination.

Departure and climbout was normal until the aircraft was 148 nautical miles outbound, at Flight Level 350, some 17 minutes after take-off. About that time, the Captain remarked that he could smell burning plastic. The Flight Engineer suggested that it was the humidifier and immediately turned it off. The Captain then called a flight attendant on the interphone and asked her to investigate. Shortly thereafter, the flight attendant entered the cockpit and reported that although the passenger area was clear she could smell plastic burning and saw smoke in the passageway. She went back and opened the door to the master lavatory. Seeing thick, dark smoke, she closed the door, rushed back to the cockpit and informed the crew.

The Flight Engineer left the cockpit and, on inspection, determined that the source of the smoke was near the toilet bowl, behind the trim (toilet shroud). He returned to the cockpit to collect the smoke mask and carbon-dioxide fire extinguisher. The circuit breakers for the toilets were pulled.

Wearing the smoke mask, the Flight Engineer started to remove the decorative trim (toilet shroud) but had to leave the area because smoke was entering his smoke mask. He returned to the cockpit to breathe clean air and, while there, informed the Captain that the problem was serious and recommended a return to Riyadh. The Flight Engineer then returned to the toilet, completed removal of the trim and directed the fire extinguisher on the now exposed fire. Because of more smoke inhalation, he had to again leave the area, take in clean air in the cockpit, and then return to the toilet to confirm that the fire had been completely extinguished.

In the meantime, the Captain had ordered a return to Riyadh and the First Officer declared an emergency. The cockpit crew donned their oxygen masks and details of the persons and fuel on board were passed to KKIA Air Traffic Control.

An additional crew member had already suggested to the flight attendant that she obtain a water fire extinguisher but this was not used (because of the nature of the fire) and the flight attendant went aft to reassure the passengers. During the return to Riyadh, smoke dispersed from the immediate area and was noticeable in the passenger cabin. The Flight Attendant moved the passengers to the very rear of the aircraft and drew the cabin dividing curtains to reduce the flow of contaminated air.

KKIA Crash/Fire/Rescue services were alerted by ATC and deployed to the standby position.

The aircraft landed safely on runway 33 Left at 1951 and was brought to a halt on the runway. The aft passenger stairs were lowered to allow the passengers to deplane without injuries. The forward door was used to allow the CFR personnel to enter the aircraft.

The aircraft was moved to the General Aviation Ramp after the CFR Chief had declared it safe.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others	Total
Fatal	0	0	0	0
Serious	0	0	0	0
*Minor	2	0	0	2
None	4	15	0	19

*The Flight Engineer and forward cabin attendant were treated for minor smoke inhalation.

1.3 Damage to Aircraft

There was fire damage to the flush motor, the timer switch, associated wiring, toilet bowl and trim.

1.4 Other Damage

None.

1.5 Personnel Information

The flight crew and cabin crew were properly certificated and qualified for the flight in accordance with current regulations.

Pilot name and age: age 56.

Mr. holds a Saudi Arabian, Presidency of Civil Aviation Airline Transport pilot certificate No. TA-1731 issued on 17/04/85 limited to the privileges of Federal Aviation Administration (FAA) certificate No. 133662. He has airplane multiengine land with Boeing 727 type rating.

Total time 21,000 hours
Boeing 727 total time 6,500 hours.

Mr. holds a first class medical certificate dated 31 July 1985 with restriction requiring glasses.

Co-pilot name and age: age 23.

Mr. holds a Saudi Araian, Presidency of Civil Aviation Commercial Pilot Certificate No. CA 863, issued on April 27, 1985, limited to the privileges of Federal Aviation Administration (FAA) certificate No. 2349770. He has airplane multiengine land instrument rating.

Mr. holds a first class medical certificate dated 20 February 1985 without limitation.

Flight Engineer's name and age: age 62.

Mr. holds a Saudi Arabian Presidency of Civil Aviation Flight Engineer certificate No. FE-822 issued on July 30, 1985, limited to the privileges of United Kingdom Civil Aviation Authority (CAA) No. FE-1743. He has B-727 turbojet rating.

Mr. holds a CAA first class medical certificate dated 14 May, 1985.

Flight Attendant name and age: 49.

Mrs. holds a Saudi Arabian, Presidency of Civil Aviation flight attendant certificate.

1.6 Aircraft Information

The aircraft HZ-TFA, Boeing 727-100, serial number 19006, manufactured in 1965, owned and operated by H.H. Prince Faisal Bandar Atturki.

The aircraft was certificated, equipped, in accordance with current Federal Aviation Regulations (FARs) and is maintained in accordance with (FARs) part 91.169 (F)(5).

The certificates of airworthiness and registration were dated 25 November 1985 and are valid until 01 December 1986.

The aircraft is maintained under contract by Lufthansa Airline, Frankfurt, Germany, in accordance with a program specified by FAR 91.169 (F)(5). Last required inspection was performed by Lufthansa on 7 October 1985, at a total time of 32,821 hours.

The aircraft total time is 33,000 hours. Records revealed that this aircraft was owned by three different airlines prior to purchase by present owner.

The aircraft had a complete interior refurbish in "PAGE" company U.S.A. in 1981, and at that time the pump motor assembly for the master lavatory was installed and has remained in use until the time of failure.

1.7 Meteorological Information

Weather was not a factor.

1.8 Aids to Navigation

Were not a factor.

1.9 Communcations

There were no communications anomalies between the ground and the aircraft.

1.10 Aerodrome Information

King Khalid International Airport, Riyadh, is located at 24° 57' 45" North Latitude, 46° 42' 28" East Longtitude. Airport elevation is 620 meters above sea level. It has two parallel runways and the one used, 33L is 4200 meters long and 60 meters wide. The airport is certified and well equipped to handle any emergency.

1.11 Flight Recorders

Flight Recorders were not transcribed.

1.12 Wreckage and Impact Information

There was no crash.

1.13 Medical and Pathological Information

Two crew members received treatment at the airport clinic for slight smoke inhalation and were released immediately.

1.14 Fire

Inspection revealed that the fire damage was confined to the lavatory pump motor and holding tank area. A 30 inch section of plastic shielded wire bundle from the forward lavatory bulkhead aft along the top of the holding tank to the lavatory pump motor was burned and melted exposing bare wires. The lavatory pump motor switch was also fire damaged. The pump motor was blackened from the fire and the wires at the pump attach point were burned and melted together. The timer switch also shows signs of overheat although located away from the overheated motor compartment.

The lavatory cover paint was cracked and discolored as evidence of heat damage.

The fire was extinguished by removing the cover trim (shroud) over the lavatory holding tank and extinguishing the fire with a seven-pound CO/2 fire extinguisher which proved to be very effective.

1.15 Survival Aspects

This was a survival accident. The fire was extinguished using the cockpit 7-pound carbon-dioxide fire extinguisher. The Flight Engineer inhaled smoke despite wearing a smoke mask.

1.15.1 Smoke Dectectors

There is no requirement for this aircraft to be fitted with lavatory smoke detectors. None were fitted.

1.15.2 Emergency Evacuation

The evacuation of the passengers was conducted down the aft airstairs.

1.16 Tests and Research

The lavatory flush motor and the time switch were too badly damaged to be tested. It is possible that the time switch failed and allowed continuous operation of the flush motor which then overheated to the point where it caught fire. The time switch has been sent to Boeing for their possible analysis.

PCA, Aviation Standards and Safety has requested the Federal Aviation Administration (FAA) to review the paper work on the installation of the pump motor assembly which was made with PAGE company in U.S.A. in 1981.

1.17 Additional Information

This aircraft being owned & privately operated under FAR (Federal Aviation Regulation) 91 does not require the installation of all the items listed in our safety recommendations. However all the recommendations are of a safety nature and would definitely enhance the safety of any aircraft and give the crew early warning of a probable fire hazard and permit corrective actions to be taken before a fire gets uncontrolable.

FAR 121.308 "no person may operate a scheduled passenger-carrying transport category airplane unless each lavatory in the airplane is equipped with a smoke detector system or equivalent that provides a warning light in the cockpit or provides a warning light or audio warning in the passenger cabin which would be readily detected by a flight attendant, taking into consideration the positioning of flight attendants throughout the passenger compartment during various phases of flight."

Some transport category aircraft should be equipped with the same system even though it is not required by FAR 91. FAR 121 shows the urgency for additional fire safety warning devices.

1.18 New Investigation Techniques

None.

2. ANALYSIS

Industry records clearly show that there is little margin to separate a successful outcome and a disaster. A key feature of such incidents is crew awareness, crew performance and training.

In this incident, a human natural born optimism was clearly demonstrated due to crew lack of awareness of the seriousness of in-flight fire. The door to the lavatory was opened twice before a fire extinguisher was prepared; some doubt exists as to when the area was electrically isolated; the Flight Engineer did not correctly fit the smoke mask.

Sound procedures would suggest that no fire-suspected compartment should be opened unless a fire extinguisher is ready to be used. Additionally, one of the first steps to be taken is for electrical isolation of that area. The smoke mask is designed to provide complete protection for the wearer; the adjusting straps are deliberately left loose to enable quick donning to be acomplished. Once on the head, the adjusting straps should be tightened to provide a complete seal between the mask and the face.

There can be no doubt that a smoke detector in the toilet would have alerted the crew to the situation at an earlier stage. Even the domestic battery-powered model would have given an audio warning to the cabin crew.

The fire itself most probably originated at the flush motor due to continuous operation. The continuous operation was probably due to a defective electronic time switch.

The comment on less than complete information relayed to KKIA CFR personnel needs local resolution. Happily, lack of full details had no bearing on this incident.

3. CONCLUSIONS

3.1 Findings

1. The crew were properly certificated and qualified to conduct the flight.

2. The aircraft was properly certificated and maintained in accordance with approved schedules.

3. The fire originated in the toilet flush motor and was extinguished by the Flight Engineer using a carbon-dioxide fire extinguisher.

4. Engineering tools had to be used to expose the base of the fire.

5. Crew procedures were not totally professional in that they opened a suspect (confined) area before they were completely equipped to fight the fire.

6. The Flight Engineer was unfamiliar with the use of the smoke mask.

7. The KKIA CFR report indicates a lack of full information in the notification message.

3.2 Probable Cause

The probable cause of the fire was a defect in the electronic timer switch allowing continuous operation of the flush motor; the flush motor overheated and the temperature rise was sufficient to ignite combustible electrical components.

4. RECOMMENDATIONS

The Aviation Standards and Safety of PCA recommends the following:

6 - 86 It is recommended that an immediate inspection of all (Saudi Arabian Registered) aircraft be conducted to determine that the wire bundle, switch and flush motors are properly installed and function normally.

7 - 86 No later than the end of 1986 install in some FAR 91 aircraft a flush motor heat sensing unit to warn the crew of an overheat condition. These heat sensing units are FAA approved and available at the present time.

8 - 86 Installations of a smoke detector system in some FARs 91 operated aircraft's lavatories in conformity with FAR 121.308. Additionally in any other areas of executive aircraft that are not occupied for long periods of time during flight.

9 - 86 The toilet holding tank cover be attached with fast opening fasteners so a crew member may get quick access to the pump motor and wiring area in case of need to gain access in flight for fire control purposes.

10- 86 To prevent water or liquids from short circuiting the switch, all flush motor switches should be mounted on a vertical surface to prevent water or other liquids from entering the switch.

11- 86 All toilets circuit breakers and switches be checked for proper size and amp carrying capacity. However, all circuit breakers should be exercised at least once a year.

12- 86 The Boeing factory low utilization maintenance schedule be incorporated into the present maintenance program for HZ-TFA.

13- 86 Each large transport operating under FARs 91 shall submit at his certificate renewal a suitable flight crew safety training programe acceptable to PCA, Aviation Standards and Safety inspector.

ICAO Note.— Names of personnel were deleted. The Attachments were not reproduced.

ICAO Ref.: 116/86

No. 2

Saab Fairchild 340, HB-AHF, accident at Bâle-Mulhouse, France, on 7 April 1986. Report released by the Bureau Enquetes-Accidents, France.

SYNOPSIS

Since the Bâle-Mulhouse aerodrome is located on French territory, the investigation was carried out by the French authorities.

The following States also played a major part in the investigation:

- SWEDEN (State of Manufacture)
- SWITZERLAND (State of the Operator)
- UNITED STATES (State of Manufacture of the engines)
- UNITED KINGDOM (State of Manufacture of the propellers)

Acceleration-stop on take-off after the crew became aware of anomalies in the operation of the right engine. After this engine was throttled back, it went into overspeed and exploded. Several pieces of debris pierced the engine cowlings and damaged various parts of the fuselage. The aeroplane stopped on the runway with no further damage and the passengers were evacuated.

1. FACTUAL INFORMATION

1.1 History of the flight

On 7 April 1986 at around 1241, the Saab Fairchild 340, registration HB-AHF, operated by Crossair, started to taxi towards runway 16 of the Bâle-Mulhouse aerodrome to perform scheduled flight LX 834 from Bâle-Mulhouse to Brussels. On board were two pilots, one cabin attendant and four passengers.

On the same day the aeroplane had already performed four flights without incident with another crew who informed the two pilots assigned to this flight of this fact.

After checking the documents and inspecting the aeroplane, the crew deemed that it was in a satisfactory condition and proceeded to boarding, start-up and checking the two General Electric CT7-5A2 turboprops.

The estimated take-off mass was 22 000 pounds, with the authorized maximum being 27 275 pounds. The aircraft was carrying 2 400 pounds of fuel and some baggage in addition to the passengers.

Meteorological conditions were satisfactory for the flight and no precipitation was recorded at the aerodrome.

At the holding point the crew carried out the pre-take-off checks and at 1245 they were cleared to take up position and take off. On power-up the engine parameters were normal and torque was rising progressively.

The aeroplane accelerated up to around 40 kt at which point the pilot-in-command noticed on two occasions, one or two seconds apart, a sudden increase to around 120% in the value of the torque of the right engine (No. 2), followed almost immediately by a return to normal values (of the order of 105% at the most).

At the same time he noticed that the aircraft was tending to veer to the left and he countered this movement with the rudder.

He decided to abort the take-off and in accordance with the instructions in the Flight Manual, moved the throttles to the ground-idling position and braked. Four to five seconds later the needle of the right engine torque indicator rose rapidly and the crew heard the engine overspeeding very violently.

The pilot-in-command cut the fuel supply to both engines immediately and simultaneously the crew heard a loud explosion. The aeroplane stopped on the runway at approximately the same time after a run of about 250 metres. When the co-pilot looked at the right engine through the window, he saw smoke coming from it. The engine fire alarm was triggered and the crew actuated one extinguisher bottle, notified the fire to ATC and requested emergency assistance.

The passengers, cabin attendant and co-pilot left the aeroplane on the orders of the pilot-in-command who remained on board. Two minutes later a second bottle was actuated over the engine, the fire alarm of which had lit up again. A very short time later the emergency assistance arrived on the scene and extinguished the remains of the fire.

1.2 Injuries to persons

The accident caused no physical injuries.

1.3 Damage to aircraft

The right engine turbine exploded and subsequently pieces were thrown out of the engine on to the fuselage where they made several holes and broke a hydraulic line.

1.4 Other damage

The accident caused no damage to third parties.

1.5 Personnel information

1.5.1 Pilot-in-command

Male.
36 years old.
Nationality: Swiss
Profession: Airline pilot

Licences

Swiss PL licence No. 1262 of 2 March 1984.
Licence renewed on 24 January 1986. Valid until 8 February 1987.
Valid SF 340 type rating.

Last medical examination: January 1986.

Flight experience

Hours of flight

Total:	5 000
SF 340:	800
In previous 30 days:	80
In previous 24 hours:	5

1.5.2 Co-pilot

Male
24 years old
Nationality: Swiss
Profession: Pilot

Licences

Swiss PP licence No. 3157 of 5 July 1985.
Licence renewed on 18 November 1985. Valid until 26 November 1986.
Valid SF 340 co-pilot type rating.

Last medical examination: October 1985

Flight experience.

Hours of flight:

Total:	950
SF 340:	450
In previous 30 days:	80
In previous 24 hours:	3

1.5.3 Cabin attendant

Female.
24 years old
Nationality: Swiss
Swiss Cabin Attendant's licence No. 537. Valid.

1.6 <u>Aircraft information</u>

Owner and operator:

CROSSAIR AG: Postfach 630, CH 8058 Zurich

1.6.1 Aeroplane

Manufacturer:	Saab Fairchild
Type:	SF 340
Serial No.:	340 A 026
Registration Certificate No.:	7309/B/2 of 24 June 1985
Certificate of Airworthiness No.:	7309/A/1 of 24 June 1985
Category:	TPP1
Total hours of flight:	1 748

1.6.2 Engines

Manufacturer:	General Electric
Type:	CT7-5A2 (Turboprop)
Right:	Serial No. E 367131 B 2 170 hours - 2 219 cycles
Left:	Serial No. E 367127 B 1 363 hours - 1 442 cycles

At the time of the accident the power turbine of the right engine had totalled 1 735 hours of operation and 1 802 cycles.

1.6.3 Airborne equipment

The aircraft was carrying the necessary equipment for the flight undertaken.

Its radio operating certificate bore the number 180 141 269.01 of 24 July 1985.

Its aircraft station licence was valid.

It was authorized for TPP1 use, that is IFR flight in icing conditions.

1.6.4 Mass and centre of gravity

The aeroplane was within the approved limits for mass and centre of gravity at the time of the accident.

1.6.5 Maintenance

The aircraft was maintained by Crossair in accordance with the maintenance programmes approved by FOCA (Swiss Federal Office for Civil Aviation).

1.7 Meteorological information

These played no role in the accident. At the time of the accident, conditions at Bâle-Mulhouse were:

Wind 320°/02kt - Visibility 5 km-3/8 Sc at 1 500 m, 6/8 Ac at 3 000 m - Temperature + 10°C - QFE 976 hPa.

1.8 Aids to navigation

Navaids were not involved in this accident.

1.9 Communications

Radio communications played no role in this accident.

1.10 Aerodrome information

The aeroplane accelerated and stopped over approximately 250 metres from the threshold of runway 16 which measures 3 900 m.

The aerodrome is equipped with a Category 8* fire fighting service.

1.11 Flight recorders

1.11.1 Cockpit Voice Recorder (CVR)

The aeroplane was equipped with a Fairchild CVR (Model A 100 A).

The CVR was analyzed and listened to at the Bureau Enquêtes-Accidents. It had worked perfectly. Recording had started before start-up of the engines for the accident flight.
Subsequently start-up, taxiing and the acceleration-stop were recorded. Recording continued for some minutes after the accident while the aircraft was immobilized on the runway.

The transcript of the conversations (in German) and their translation into English were made by the Swiss FOCA.

Spectral analysis of the tape was carried out on the portion of the flight starting from power-up for take-off until the engines stopped. The results are detailed in Section 1.16 "Tests and research".

The recording shows a normal situation until the moment of aeroplane acceleration for take-off. Procedures seem to have been well respected by the crew and so far no operational anomalies have emerged.

For take-off, the noise of engine power-up rises progressively, seems to stabilize for a few moments, then suddenly increases very strongly and disappears. After that event, the crew notifies the ATC that they have aborted the take-off, ask for fire fighting assistance and warn that they are unable to clear the runway. The order to evacuate the passengers is also audible, as is the sound of each of the engine extinguisher bottles being actuated and the arrival of the emergency assistance. At the end of the recording the pilots are making various comments on the accident. These last points are reproduced together with the statements of the crew in Section 1.17, "Statements by the crew".

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* According to ICAO Annex 14, aerodromes are equipped according to categories from 1 (smallest) to 9 (largest).

1.11.2 Digital Flight Data Recorder (DFDR)

The airborne DFDR was a Sundstrand UFDR. It was analyzed in France at the Bretigny Flight Test Centre. It had worked perfectly. The operational results are provided on the graphs below. A comparative study of the results of the spectral analysis and those of the DFDR appear in Section 1.16 "Tests and research", Part One.

It must be noted that the Np and torque parameters are sampled only every four seconds, whereas the other parameters are sampled once per second. In addition, the precise time of sampling within that second differs according to the parameters.

These two facts lead to limitations on the accuracy of the information and these must be taken into account when reading the graph.

The DFDR confirmed that the start of the flight ran normally until power-up. Taking that as the initial time reference, it can be seen that during the first two seconds, information on both engines is identical and represents the spin-up of the coupling.

The right Np speed then deviates from the left (a small increase) while the ITT temperature starts to rise more rapidly on the right engine than the left. The heading is stable and closely in line with that of the runway centre line (157°).

At 3 seconds, the right torque increases more quickly than the left.

Starting from 5 seconds, while all the parameters of the left engine show a normal progression, on the right the ITT increases rapidly, the torque continues to climb much more than on the left and the Np falls sharply (reaching a maximum of 1 060 rpm or 76.5%).

At the same time the aeroplane started to veer to the left and the crew countered this shift off centre with the rudder.

At 6 seconds the throttles were apparently moved to idling: the values of all parameters dropped on the left. On the right they continued to rise except for the Np which at around 900 rpm decreased further.

Between 6.5 and 7 seconds, the right Np reached a minimum at 700 rpm and then rose again sharply while the torque reached its maximum at almost 100% and the ITT continued to rise.

Starting from 7 seconds, the torque started to drop on the right. However, the Np continued to rise until around 8.5 seconds and then fell sharply and the ITT continued to increase to around 10 seconds where it reached a maximum of around 940°C.

Also at 7 seconds, the heading reached a minimum of 152° then rose again, the 43 kt speed fell and application of the rudder to the right was reduced.

This information confirms the statements by the crew who reported a sudden rise in the torque on the right causing the aeroplane to veer to the left, this being countered with the rudder. It also confirms the prompt decision to abort the flight. However, the noise of the acceleration of the right engine, audible on the CVR, does not seem consistent with the speed readings on the DFDR.

1.12 Wreckage and impact information

The aeroplane remained immobilized on the runway after the accident until it was towed away by a runway tractor. It was then taken to the Crossair workshops where preliminary examinations were carried out.

The right engine was subsequently sent to General Electric in the United States. The damage suffered by the engine is detailed in Section 1.16.3 "Examination of the right engine".

Several pieces of metal separated from the rotating parts of the turbine and were ejected at high radial speed, piercing and damaging the following parts:

- turbine body (pierced)
- engine tubing (cut, torn)
- lower part of the engine nacelle (pierced)
- engine fairing (1 hole with a diameter of around 8 to 10 cm and several other smaller holes)
- right wing leading edge de-icer boot (torn)
- external front right fuselage skin at the height of and in front of the leading edge of the wing and pressure bulkhead at the same level pierced in several places. (Some bits of metal were found in the cabin.)
- hydraulic circuit lines located below the fuselage (pierced and/or torn).

1.13 Medical and pathological information

Given the nature of the accident, no investigation was deemed useful in these areas.

1.14 Fire

The beginning of a fire occurred on the right engine after it exploded. In view of the large quantity of smoke released and the fire alarm warning light lighting up, the crew actuated the first extinguisher bottle. Shortly before the emergency assistance arrived, the warning light lit up again and the second bottle (left engine) was actuated. The emergency assistance noticed that there were still some flames upon their arrival and rapidly brought the remainder of the fire under control. However, no damage to the aircraft directly related to this fire was subsequently observed.

1.15 Survival aspects

Not applicable. All the occupants were unharmed.

1.16 Tests and research

1.16.1 Spectral analysis of the CVR tape and comparison with the data taken from the DFDR.

The noises produced by the engines in the acceleration-stop phase were analyzed at General Electric and at the NTSB. These signals come primarily from the propellers. Thus, they provide a direct indication of their real rotation speeds (Np).

The Np of the left propeller, which remained low, is barely visible but seems consistent with the DFDR recording.

However, the right speed differs significantly from the DFDR indication. The peak observed is 152% (2 100 rpm) as against a transient maximum prescribed by the Flight Manual of 105% (1 572 rpm).

1.16.2 Examination of the right engine propeller

Performed under the supervision of the Accident Investigation Branch (AIB) in the United Kingdom by the manufacturer Dowty Rotol, this examination confirmed that at the time of the accident the right engine propeller was operating perfectly and had played no role in the accident.

1.16.3 Examination of the right engine at General Electric

The right engine was sent to General Electric for inspection under the supervision of the NTSB.

The details of the inspections carried out and the damage identified will not be reproduced in this report.

It will be noted that the main damage is located on the shaft, the transmission tube and the turbines.

- The transmission shaft and the reference tube of the free turbine torque sensor are broken straight above the second stage of the power turbine.

- This turbine bears major signs of rubbing and battering particularly on the rotating parts. However, all the vanes are in place.

- Most of the rotor vanes of the free turbine are broken. Several holes, apparently caused by the ejection of bits of the vanes, can be seen in the turbine fairing.

Several mounting nuts have disappeared and the No. C sump shows several breaks.

The Np/torque sensor, a common sensor for both parameters, was destroyed. It had overheated.

1.16.4 Previous incidents involving this aircraft

On 1 December 1985, the No. 4 bearing of the right engine broke. It was replaced and the engine was put back into service on 11 March 1986.

On 13 March 1986, the right propeller was damaged during a run-up by gravel from the runway and a new propeller was fitted on 19 March.

The nature of these events means that they could not have played any role in this accident.

1.16.5 Similar events

Several events similar to the HB-AHF accident have occurred on aircraft of the same type or identically equipped.

Airline/ type	Date	Summary	Cause
BEA SF 340	27/05/85	Uncontrollable increase in propeller speed on take-off leading to a broken turbine	Not determined
	7/06/85	Acceleration-stop following erratic values of Np and torque	
CASA CN 235	9/09/85	Erratic indications of propeller speed and of torque	Failure of the Np/torque sensor due to misuse of APU
COMAIR SF 340	17/09/85	Drop in the indication of propeller speed on acceleration to 60% of indicated torque	Play in the connector of Np/torque sensor
SWEDAIR SF 340	26/11/85	Indication of high torque during climb after take-off.	Not determined.
KENDELL SF 340	6/02/86	Reduction in indicated propeller speed on take-off to around 75%. Reacting to this the control system made the engine accelerate to maximum speed.	Sensor examined at GE Same cause as for HB-AHF
	7/02/86	Hot parts broke during an acceleration-stop. Speed throttle on high-lock before throttling back.	
IPTN CN 235	15/04/86	Rapid variations in Np signal between 0 and 100% while cruising, then return to normal.	Same cause assumed for HB-AHF

Subsequently, it was shown that the cause of the HB-AHF accident was identical to that of certain of these events. For some others the lack of information has made it impossible to establish any relationship.

1.16.6 Comments on the SF 340 engine control and regulation system

The SF 340, like any aeroplane equipped with so-called "conventional" turboprops, is fitted with two throttles per engine, one for the propeller speed (speed throttle) automatically regulating the pitch and the other for the power supplied through the fuel flow (power throttle).

The fuel regulation system in particular consists of an electrical control unit (ECU) which receives information from the various engine parameter sensors which are useful for the flight (including generator speed Ng, propeller speed Np, torque and turbine temperature). It should be noted that one single sensor provides indications of both Np and torque. The ECU processes these signals and correlates them with the rest of the control system (hydromechanical regulators, limiters, flow regulators, ...) and the pilot's commands to ensure desired flight speed while respecting the authorized flight envelope.

The readings are supplied directly by the sensors to the ECU and are also repeated to the various control instruments in the cockpit.

1.17 Statements by the crew

The following points emerged from the hearing given to the crew:

The aircraft was fit for flight and no indication of faulty operation appeared until acceleration on runway 16. At the start of acceleration with the throttles in take-off position (the power throttle was set so as to achieve a torque of 80%) the crew noted two jumps of the needle of the right engine torque indicator and felt the aircraft veer to the left.

The pilot-in-command countered the movement, set the power throttles to ground-idling and started to brake. After four or five seconds, with no further action on the part of the crew, the right engine started to overspeed. They then heard a "terrible" noise of acceleration followed by a muffled explosion at around the moment that they set the throttles to "fuel off". Seeing the smoke coming from the right engine, they actuated the first extinguisher bottle. The pilot ordered an evacuation. A little later the second extinguisher was actuated.

2. ANALYSIS

On 7 April 1986 at around 1245, the SF 340 (Registration HB-AHF), took up position on runway 16 of the Bâle-Mulhouse aerodrome after taxiing without incident. The aircraft was in perfect condition and all conditions for the flight were met.

Initial acceleration was normal and the control parameters were consistent.

At around 40 kt the needle of the right engine torque indicator jumped apparently to 120% on two occasions and the pilot-in-command noticed that the aeroplane was veering to the left.

The DFDR did not confirm these fluctuations which were probably too rapid to be recorded. It did, on the contrary, record a greater increase in the right torque compared to the left. It also recorded a slight decrease in the heading resulting from this asymmetry which was rapidly countered by the pilots.

The pilot-in-command decided immediately to abort the flight. He set the power throttle to ground-idling and braked.

A few seconds later, the speed of the right propeller increased to a maximum calculated as 152% from the readings provided by spectral analysis of the CVR tape.

However, instead of recording the increase in speed of the right propeller, the DFDR in fact provided a contradictory reading. The speed fell to around 50% (about half the normal value) and never again rose above 76.5% (1 060 rpm) throughout the duration of the event.

This lack of consistency between the real Np speed as established by spectral analysis of the CVR and the speed indicated by the DFDR shows that the DFDR was at fault. This observation, plus the fact that, with no action on the part of the crew, the engine underwent considerable increases in torque, seems to indicate that the problem arose from one element linked to the Np and torque measurement channel.

The propeller speed information was supplied to the DFDR by the ECU which, in turn, received it by cable from a common torque and Np sensor. Investigations were thus focused on these elements.

On bench testing, the ECU showed no operational anomalies.

Note: One function of the ECU, inter alia, is to regulate propeller rotation (Np) as a function of the position of the speed throttle (so that any momentary drop in Np is automatically compensated by an order to the control system to increase speed).

Research on the other elements of the information transmission channel revealed that the faulty element was the connector between the Np/torque sensor and the transmission line.

The connector installed on the aircraft was not tested since it had been damaged in the accident. Various tests on the same type of connector have shown a fault in seal-tightness; when several pressure variations occur due to the flights, this fault can allow the connector to suck in moisture and impurities mixed in with the air.

New flight cycle simulation tests with the same connectors have shown that the rate of contamination could become such as to alter the sensor output information. This, effectively, resulted in a drop in the indicated Np.

The accident can thus be explained as follows:

The erroneous reading of the drop in Np was retransmitted to the ECU then to the speed governor which, in fulfilling its function, issued a command to increase the fuel flow until it reached maximum.

This increase in power was felt physically by the crew who countered the resulting deviation from course using the rudder. It was also perceived on the torque indicator.

When the crew decided to abort the take-off and set the power throttles to ground-idling, the propeller governor automatically reduced the pitch in response.

This manoeuvre rapidly reduced the torque applied to the propeller. This instantaneously increased the speed until overspeed was reached. The overspeed limiter, the purpose of which is to avoid limits being exceeded in such a way, did not trip since it was constantly receiving an erroneous value from the sensor which was lower than its trip threshold.

The overspeeding led to the damage observed since the engine was well outside its certificated range.

3. CONCLUSIONS

3.1 Findings of the investigation

- The crew held the licences and ratings required for the flight undertaken;
- the aircraft was certificated, equipped, maintained and operated in accordance with the regulations; its loading and centre of gravity were within the authorized limits;

- the meteorological conditions were satisfactory; in particular, there was little wind;
- during acceleration for take-off, at around 40 kt, the crew, on noticing abnormal variations in the right engine torque, decided to abort the flight;
- in line with the procedure to be followed in such a case they set the power throttles to ground-idling and braked;
- shortly afterwards the speed of the right engine rose sharply and as a result, the engine exploded;
- the DFDR indicated an erroneous propeller speed. This fault came from the connector between the Np/torque sensor and the transmission cable;
- after tests, it emerged that this connector had a fault in its seal-tightness which allowed for the ingress of impurities;
- contamination tests on connectors have led to variations in indicated propeller speed similar to those encountered on the day of the accident;
- the overspeed limiter did not fulfil its function because of the erroneous information transmitted to it.

3.2 Probable causes

The accident resulted directly from an overspeed by the right engine. This was caused by erroneous information due to a failure of the connector between the right propeller speed and torque sensor and its transmission cable.

An erroneous reading was thus supplied to the engine control systems. This led to an abnormal variation in the torque, leading the crew to abort the take-off. The action on the throttles, reducing the torque applied to the propeller, led to the coupling overspeeding since the trip of the overspeed limiter was inhibited by erroneous information.

ICAO Note.— Minor editorial changes were made. Figures 11 *bis*, 14 *bis*, 15 *bis* and the Appendices were not reproduced.

ICAO Ref.: 407/86

No. 3

DHC-6 Twin Otter, G-BGPC, accident on the Isle of Islay, Scotland, on 12 June 1986. Report No. 4/87 released by the Accidents Investigation Branch, United Kingdom.

Synopsis

The accident was notified to the Accidents Investigation Branch at 1620 hrs on 12 June 1986 and the investigation began the same evening. The aircraft was engaged on a scheduled public transport flight from Glasgow Airport to the Isle of Islay. There were two pilots on board, the handling pilot and a supervisory pilot who was the designated aircraft commander, together with fourteen passengers. Before departure from Glasgow the pilots had obtained a meteorological forecast that indicated generally cloudy conditions over the route and the probability of poor weather conditions at the destination aerodrome.

The departure from Glasgow and the cruise were uneventful, and shortly after starting a descent towards Islay the pilots received the latest Islay/Port Ellen aerodrome weather observation. This reported extensive low cloud, drizzle, and a visibility of 2000 metres. In spite of this information, the aircraft was positioned for a visual approach to the aerodrome from the south of the island. In conditions of low cloud and poor visibility the pilots mis-identified Laphroaig as being Port Ellen and very shortly after turning inland the aircraft struck rising ground approximately 1 nautical mile from the coast at a height of 360 feet above mean sea level.

The report concludes that the cause of the accident was the commander's decision to allow the handling pilot to carry out a visual approach in unsuitable meteorological conditions. An error in visual navigation was a contributory factor.

1. Factual Information

1.1 History of the flight

Loganair Flight LC 423 was a scheduled domestic public transport passenger flight from Glasgow Airport to Islay/Port Ellen aerodrome due to depart from Glasgow at 1440 hrs on 12 June 1986. There were two pilots and fourteen passengers on board. The handling pilot, who occupied the first pilot's position, had recently converted to flying the DHC–6 Twin Otter aircraft, and was completing a series of supervised route flights required by the airline before the award of full command status. A company supervisory captain, the designated commander for this flight, occupied the co-pilot's position. The Twin Otter is certificated for single pilot operation.

The two pilots reported for duty at 1410 hrs. They obtained the latest available weather information from the Glasgow Airport Information Service (AIS). The forecast was for a moist southwesterly airstream affecting the whole area with the sky obscured by stratus cloud. Cloud bases were forecast to be generally 1500 feet above mean sea level (amsl) with tops at 6000 feet. Scattered stratus was also forecast, base 500-800 feet with local patches at 300 feet and associated hill fog. A Terminal Aerodrome Forecast (TAF) is not issued for Islay/Port Ellen aerodrome, however the latest routine Meteorological Aerodrome Report (METAR) was given to the flight crew. This report, timed at 1150 hrs, recorded a surface wind at Islay of 150° at 13 knots, visibility in excess of 10 kilometres, recent rain, and cloud conditions of 3 oktas stratus at 700 feet, 4 oktas at 1200 feet, and 8 oktas at 1700 feet. These weather conditions were above company minima for commencing an approach for landing. The aerodrome approach plates and approved minima are included at Appendix 1.

The aircraft's engines were started at 1438 hrs, and, at 1444 hrs, Glasgow Airport Air Traffic Control (ATC) approved taxy clearance to the holding point of runway 28. The aircraft was operating on a stored Instrument Flight Rules (IFR) flight plan. The requested routeing was a Standard Instrument Departure (SID), to join Airway Blue 2 for the Skipness Very High Frequency Omni-Range (VOR) beacon, and thereafter direct to the Islay/Port Ellen Non-Directional Beacon (NDB). The direct track from the Skipness VOR to the Islay/Port Ellen NDB is the 272° Magnetic (M) radial from Skipness. The planned cruising level was Flight Level (FL) 60 and the estimated flight time was 35 minutes.

At 1446 hrs Glasgow ATC advised LC 423 of their flight clearance. The requirement to fly the SID was cancelled and the aircraft was cleared direct to Skipness, cruising level FL 55, and the secondary surveillance radar code of 5052 was allocated. The clearance was correctly read back by the flight crew, and the aircraft took off from runway 28 at 1448 hrs. Recordings of both the radio telephony frequency (RTF) and of the secondary radar returns show that the flight apparently proceeded normally, and according to flight plan, until the aircraft reported a position overhead the Skipness VOR at 1508 hrs. At this point the controlling authority (Scottish Airways) informed LC 423 that they should clear controlled airspace, contact Port Ellen, and that there was no known traffic to affect their descent. The radar recording shows that after passing overhead the Skipness VOR the aircraft did not depart that position on the 272° radial, but instead turned 15° left, and descended on the 257° radial towards the south of the island of Islay.

At 1510 hrs, having already started to descend, LC 423 contacted Islay/Port Ellen aerodrome, reported an arrival time of 1523 hrs, and requested details of the latest weather. The Islay/Port Ellen radio operator replied that the weather details were a surface wind of 220°/05 knots, visibility 2000 metres in drizzle, cloud 3 oktas at 400 feet, 5 oktas at 700 feet, and 8 oktas at 1400 feet. The sea level barometric pressure was 1018 millibars. LC 423 acknowledged the information and was asked to advise when overhead the aerodrome at 3600 feet, or when in visual contact. The radar recording shows that the aircraft then continued to descend, on a track of about 260° M towards the south of the island, until it disappeared from radar cover at a height of 1400 feet and at a position 12 nautical miles (nm) from Islay/ Port Ellen aerodrome on the 106° M radial.

From the position that the aircraft descended below radar cover it is estimated that a direct track was flown towards the southern coast of the Isle of Islay. The commander, who suffered concussion and other injuries during the accident, was unable to recall any details of the flight. Evidence from passengers at this time included reports of flying in and out of cloud, and then of first sighting the Eilean a'Chuirn off the south coast of Islay. From there the flight continued at very low level parallel to the south coast. At 1521 hrs the Islay/Port Ellen radio operator transmitted further weather information which recorded that cloud conditions were similar to the previous report but that there was then heavy drizzle. Changes in barometric pressure settings were also reported. LC 423 acknowledged this information and reported "over Port Ellen". From passenger and ground eye-witness evidence it has been established that the aircraft was not, at that time, over Port Ellen, but was in fact turning inland at very low level over Laphroaig. Eye-witnesses estimated the height as between 50 and 100 feet above ground level, and the weather conditions as 'misty'. From overhead Laphroaig the aircraft settled on to a northwesterly heading and very shortly afterwards crashed into rising ground, that was obscured in hill fog, approximately 1 nm from the coast at a height of 360 feet amsl. Shortly before the impact there was a sudden increase in engine noise and the sound of an audio warning from the cockpit. It was later established that this was the sound of the stall warning system. The estimated and intended tracks of the aircraft are shown at Appendix 2.

At 1523 hrs the Islay/Port Ellen radio operator transmitted a call to LC 423, but received no response. After a further call on the stand-by radio also obtained no response, the operator contacted Scottish Airways Centre and advised loss of contact. At 1526 hrs Scottish Centre confirmed that Emergency Procedures and Rescue Action had been initiated. A Royal Air Force Nimrod aircraft and three Search and Rescue helicopters were alerted. The Nimrod aircraft was on task and flying to the accident area at 1538 hrs.

During the impact the handling pilot was killed instantaneously, and the supervising pilot/aircraft commander sustained serious injuries. Some passengers managed to release themselves from the wreckage and went to summon help. Local residents were quick to arrive at the scene, and the surviving pilot and injured passengers were released from the wreckage and transferred to a local hospital. The more seriously injured were flown in Search and Rescue helicopters to hospitals on the mainland.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	-	-
Serious	1	11	-
Minor/none	-	3	-

1.3 Damage to aircraft

Aircraft destroyed.

1.4 Other damage

A small area of open ground, normally used for grazing sheep, was contaminated due to fuel spillage.

1.5 Personnel information

1.5.1	Commander:	Male, aged 54 years	
	Licence:	Commercial Pilot's Licence (Aeroplanes) valid until 20 October 1990	
	Type rating:	DHC–6, renewed 13 March 1986	
	Instrument rating:	Renewed 13 March 1986	
	Medical certificate:	Class 1 with the limitation that the holder wear spectacles which correct for near vision. Valid until 24 August 1986	
	Flying experience:	Total all types:	12,421 hours
		Total DHC–6:	867 hours
		Total flying last 28 days:	32 hours
		Total flying last 24 hours:	2 hours and 30 mins
	Duty time:	Off duty 0210 hrs 12 June until 1410 hrs 12 June 1986 (12 hours) On duty 1410 hrs 12 June 1986 (1 hour and 12 minutes up to accident time)	

The commander completed his initial flying training in the Royal Air Force in 1958, and subsequently qualified as a flying instructor. He left the Royal Air Force in 1970, taking up an appointment as a civil aviation flying instructor. Between 1966 and 1984 he carried out 5700 hours of instructional flying. He joined Loganair as a DHC–6 aircraft commander in October 1985, and was made a supervisory captain in March 1986. Since joining the company he has made 35 approaches and landings at Islay/Port Ellen aerodrome, the most recent being on 23 May 1986.

1.5.2	Handling pilot:	Male, aged 30 years	
	Licence:	Commercial Pilot's Licence (Aeroplanes) valid until 28 July 1992	
	Type rating:	DHC–6, issued 27 May 1986	
	Instrument rating:	Renewed 26 May 1986	
	Medical certificate:	Class 1 with no restrictions. Valid until 11 February 1987	
	Flying experience:	Total all types:	2110 hours
		Total DHC–6:	27 hours
		Total flying last 28 days:	30 hours
		Total flying last 24 hours:	nil
	Duty time:	Off duty 1030 hrs 11 June 1986 until 1410 hrs 12 June 1986 (27 hours and 40 minutes)	
		On duty 1410 hrs 12 June 1986 (1 hour and 12 minutes up to accident time)	

The handling pilot's initial flying training was on an approved course of instruction for a Private Pilot's Licence. He subsequently became a qualified flying instructor and obtained a Commercial Pilot's Licence in July 1982. He joined Loganair in October 1984 as a co-pilot flying the Shorts 360 aircraft. His Company reports were satisfactory throughout and he was selected for command of the DHC–6, Twin Otter. He had completed the initial conversion and, by 12 June 1986, had flown 29 route flights under supervision. He had carried out only one previous approach and landing at Islay/Port Ellen, which was on 29 May 1986. The weather on that occasion was generally fine with no significant cloud below 3000 feet. His most recent line supervision progress report, dated 10/11 June 1986 included the comment: 'I was certainly quite impressed with his performance. A good professional operator'.

1.6 Aircraft information

1.6.1 General information

G–BGPC was a DHC–6 Twin Otter, a twin turbo-prop high-winged all metal monoplane powered by Pratt and Witney of Canada PT6A engines driving three-bladed Hartzell variable pitch propellers. Provision was made for seating two pilots, side by side, and dual controls and full dual flight instrumentation was fitted. Passenger seats were arranged in 5 rows of 3, with single seats to the left and double seats to the right of a central walkway, plus two further doubles at the rear right side of the cabin opposite the main entry/exit door.

1.6.2 Leading particulars

Manufacturer:	De Havilland Aircraft of Canada Ltd
Aircraft type:	DHC6-310 Twin Otter
Date of manufacture:	July 1979
Constructor's Number:	635
Certificate of Registration:	The registered owners were Nordic Oil Services Ltd, certificate issued on 4 July 1983
Certificate of Airworthiness:	Certificate No 8876-2 renewed on 6 July 1985 and valid to 5 July 1986
Total airframe hours:	9206 hours 11 minutes
Last scheduled maintenance:	3 June 1986 at 9186 total airframe hours. The aircraft had been maintained in accordance with an approved maintenance schedule
Engines (2):	Pratt and Witney of Canada PT6A-27
Total Engine Hours:	Right – 9181 (5990 since overhaul)
	Left – 7545 (5770 since overhaul)
Maximum weight authorised for take-off:	5700 kg
Actual take-off weight:	5257 kg
Maximum weight authorised for landing:	5579 kg
Estimated accident weight:	**5117 kg**
Estimated fuel remaining at time of accident:	**408 kg**

Type of fuel:	Jet A–1 (AVTUR)
Centre of Gravity (CG):	The CG limits both at the actual take-off weight and at the estimated weight at the time of the accident were between 20% and 36% mean aerodynamic chord (MAC). The CG remained within the aircraft's safe weight and balance envelope throughout the flight.

1.6.3 Stall warning

G–BGPC was fitted with a stall warning system comprising two lift detecting vanes and switches (which were connected in parallel) in the left wing leading edge, and in circuit with a warning light and buzzer in the cockpit. The two vanes are set at slightly different levels in the wing leading edge to ensure the complete effectiveness of the stall warning system at all flap settings and aircraft attitudes. The lower vane is operative over the full flap range of 0° to 37½°, but the upper vane is effective only with flaps extended. In operation, as a stall condition is approached, the stagnation point moves from ahead of the affected vane to behind it and causes it to deflect sufficiently to actuate its switch and complete the warning circuit. The warning light illuminates and the buzzer sounds at 4-9 knots above the stall speed.

At an aircraft weight of 5117 kg, with 10° of flap deployed, the wings level stall speed is 63 knots.

1.7 Meteorological information

1.7.1 Forecast conditions

Prior to departure from Glasgow the weather forecast information available to the flight crew consisted of the fixed time chart, valid for flights between 1200 hrs and 1900 hrs on 12 June 1986, the United Kingdom Terminal Aerodrome Forecasts (UK TAFS) and the latest routine METAR for Islay/ Port Ellen aerodrome. There is evidence that all the available weather forecast information was collected and signed for by the flight crew.

1.7.1.1 Fixed time chart (time of origin 1215 hrs)

Synoptic situation:	A cold front was close to the western coast of Islay, moving east at about 10 knots
Cloud:	Broken stratus between 400 and 1500 feet amsl, 8 oktas stratus 2000 feet amsl
Visibility:	Locally 2000 metres
Weather:	Rain/hill fog

1.7.1.2 UK TAFS

The TAFS for Glasgow Airport and the nearest major diversion aerodrome, Prestwick Airport, were as follows:

Glasgow:	Surface wind 200/12 knots, visibility 8000 metres, cloud 3 oktas stratus at 300 feet and 6 oktas strato-cumulus at 1500 feet. Temporarily visibility 2000 metres, light rain, 6 oktas stratus at 500 feet.
Prestwick:	Surface wind 200/12 knots, visibility 8000 metres, cloud 3 oktas stratus at 800 feet and 6 oktas strato-cumulus at 1500 feet. Temporarily visibility 4000 metres, light rain, 6 oktas stratus at 500 feet.

1.7.1.3 METAR

The latest METAR for Islay/Port Ellen that was available to the pilots before departing Glasgow, was timed at 1150 hrs and reported:

> Surface wind 150°/13 knots, visibility in excess of 10 kilometres, recent rain, cloud 3 oktas stratus at 700 feet, 4 oktas stratus at 1200 feet and 8 oktas strato-cumulus at 1700 feet. Air temperature plus 10° Celsius, sea level barometric pressure 1018 millibars (mb).

1.7.2 Actual conditions

An aftercast of the actual weather conditions in the area around Islay at 1522 hrs on 12 June 1986 was prepared by the Meteorological Office, Bracknell. The observations were:

> Synoptic situation:
>
> Pressure was high to the south-east and low to the north-west of the British Isles. A cold front, moving eastwards, was close to the western coast of Islay, with the island and aerodrome lying in a moist south-westerly airstream.
>
> Winds and Temperatures:
>
> Surface – South to south-west 05-10 knots plus 11°C
>
> 2,000 feet – 230° (True) at 20 knots
>
> Cloud:
>
> 5 to 7 oktas stratus base 500-800 feet, locally 300 feet in patches, covering high ground, with tops at 1200 feet. 8 oktas strato-cumulus base 1500 feet, tops 6000 feet. Further layers above 9000 feet.
>
> Surface visibility:
>
> 5 kilometres, falling to 2000 metres in thicker drizzle patches, and to 200 metres or less in hill fog.

Weather:

Rain and/or drizzle with much hill fog.

1450 hrs METAR

Passed by RTF to the aircraft:

Surface wind 220°/5 kt
2000 metres in drizzle
3 oktas at 400 feet
5 oktas at 700 feet
8 oktas at 1400 feet

1.8 Aids to navigation

There are two radio aids to navigation available for use by pilots intending to overfly or land at Islay/Port Ellen aerodrome. They are the Skipness VOR, transmitting on 113.00 Megahertz (MHz), and the Islay NDB transmitting on 395 Kilohertz (KHz). Both these radio beacons were on and transmitting throughout the accident flight and no faults were reported at that time.

On 18 June 1986 both radio beacons were flight checked by a specially equipped aircraft from the Civil Aviation Authority Flying Unit. Relevant sections of the flight check report are:

> Skipness VOR (SKP)
>
> A part orbit was flown at a range of 20nm from SKP at a height of 2500 feet in the sector 225° – 315°. Bearings and ranges were within the flight inspection tolerances allowed.
>
> Islay NDB (LAY)
>
> A part orbit was flown at a range of 10nm from LAY at a height of 2500 feet in the sector 100° – 200°. The NDB provided adequate signal coverage with correct coding. These aspects were also satisfactory during the full promulgated procedure to runway 13. In addition a low level flight at 400 to 500 feet was made along the coastline to the south-east of Islay. The NDB indications were normal even at this low level.

1.9 Communications

Very high frequency (VHF) communication was satisfactory and RTF recording was available on all frequencies used during the departure and cruise stages of the flight. During the descent towards Islay/Port Ellen aerodrome two-way VHF communication was satisfactory until the accident time, however, this channel was not recorded nor required to be so.

1.10 Aerodrome information

1.10.1 General description

Islay/Port Ellen aerodrome is situated on a southern coast of the Isle of Islay at a height of 58 feet amsl. It is operated by Highlands and Islands Airports Limited. A diagram of the principal features and facilities is included at Appendix 1. Information to pilots is provided by the Aerodrome Flight Information Service (AFIS), and is confined to advising details of aerodrome traffic to assist pilots in preventing collisions, informing aircraft of essential aerodrome information (ie, the state of the aerodrome, its weather and its facilities), and alerting safety services and initiating overdue action. The radio operators providing this service are qualified meteorological observers.

The main runway is orientated 130°/310° M and measures 1405 metres by 46 metres with a tarmacadam surface. The landing threshold is displaced at either end, giving a Landing Distance Available (LDA) of 1245 metres in both directions. Both runways are equipped with Abbreviated Precision Approach Path Indicators (APAPI's), sited on the left side, and both runways are equipped with threshold and side lighting. At the time of the accident there was no approach lighting to the instrument runway (13), however, this has since been installed. All available lighting was serviceable and selected 'On' at the time of the accident.

1.10.2 Instrument approach procedure

There is an approved and published instrument approach procedure to the aerodrome, based on the Islay/Port Ellen NDB (Appendix 1 refers). Aircraft using this procedure may descend to a Minimum Descent Altitude (MDA) of 472 feet amsl. Aircraft that elect to complete the instrument approach and subsequently circle for landing on a runway that is not suitably located for a straight-in approach are restricted to an MDA of 1108 feet amsl, except that an MDA of 758 feet amsl may be used in the sector 150° clockwise to 050°. On the Jeppesen approach plate, use of which is mandatory for Loganair pilots, these altitudes are rounded up to 760 feet and 1110 feet respectively. The minimum in-flight visibility required to commence the procedure is 1500 metres. The procedure also includes a Missed Approach Point (MAP) which, due to terrain clearance considerations is 1.7 nm (3150 metres) back from the runway threshold.

1.10.3 Visual manoeuvring (circling) obstacle clearance

Visual manoeuvring (circling) area is the area in which obstacle clearance has been considered for aircraft manoeuvring visually before landing, but only after completing the relevant instrument approach procedure. The external limits of the total area applicable to each category of aircraft are defined by a combination of several arcs centred upon the threshold of each useable runway. Aircraft are categorised according to their maximum manoeuvring speeds, and the radii of the arcs determining the extent of the manoeuvring area increases with direct relation to the manoeuvring speeds. The minimum circling heights published for Islay/Port Ellen aerodrome refer to category A and B aircraft only, (the Twin Otter is a category A aircraft,) and the radius of the arcs defining the external limits of the manoeuvring area is 2.66 nm. Category A and B aircraft manoeuvring within the area and maintaining the MDA's appropriate to the sector (1110 and 760 feet respectively) will have a minimum obstacle clearance of 300 feet.

1.11 Flight recorders

None were required and none were fitted.

1.12 Wreckage and impact information

1.12.1 Impact sequence

The aircraft had crashed into the upper slopes of the southeast face of a hill 2.2 kilometres (km) northwest of Laphroaig on the south coast of the Isle of Islay. From examination of ground marks and the wreckage it was established that the aircraft had initially contacted a gently rising slope with the main landing gear before striking a steep rocky outcrop with the nose. Its attitude at the time was between 34° and 36° nose up, approximately 10° right bank, and 18° left yaw relative to its ground track of 330° (M); 5° of this yaw may be accounted for by drift.

After initially contacting the soft grass-covered slope, at a height of 360 feet amsl, the aircraft had pitched down, within its own length, to allow the nose landing gear to strike the ground firmly and, very shortly afterwards, to break off. It then continued in an almost level attitude, for a short distance, on the stub of the nose landing gear with the main wheels clear of the sloping ground. The nose then struck the steep rocky outcrop, whereupon the aircraft rapidly pitched nose up. In so doing the left wing rear spar-to-fuselage attachment failed, allowing the wing to pivot forward until failure of the front spar and wing strut attachments occurred. As a consequence of this sequence the left propeller blade tips, with the engine still under power, were able to enter the left rear side of the cockpit and subsequently strike the handling pilot.

The right wing had also contacted the ground, with its outermost section, but had remained attached to the fuselage. The right engine propeller blades had struck the rocky outcrop leaving three distinct slash marks. Calculations based on the measurement between these marks showed that if, at the moment of impact, the propeller had been rotating at its maximum speed of 2112 revolutions per minute, the aircraft would have had a ground speed of 88 knots. The aircraft had finally come to rest close to the top of the outcrop with the fuselage having slid back about 2 metres, and pitched up to 38°. In sliding back, the tail skid had dug into the ground, and worsened a bending/compression failure of the rear fuselage.

1.12.2 On-site wreckage examination

The aircraft had come to rest in three main sections, the cabin complete with the right wing, the left wing and the empennage. The main structure had survived the impact with remarkably little distortion, with the exception of the nose area housing the two pilots. The whole of the under side fuselage structure in this area had been removed or flattened, permitting the relatively undamaged instrument panel and residual upper nose structure to fall forward and hang inverted from the cockpit floor. The floor itself was grossly distorted back to the first row of cabin seats, but both pilots' seats with their restraining harness had remained in position. The front cell of the under fuselage forward fuel tank group had been ruptured but, because of the fuselage attitude, its content was the only fuel to be spilt. Prior to wreckage recovery approximately 298 kg of fuel was drained from the intact tanks.

The following relevant selections and readings were observed in the cockpit:-

(i)	Altimeters barometric pressure settings:	Left – 1017 mb Right – 1017 mb Centre – 1020 mb
(ii)	Airspeed indicators:	Severely damaged – readings not possible
(iii)	Radio Magnetic Indicators:	Left – Aircraft heading 315° (with yellow needle set to VOR, green needle to ADF) Right – Aircraft heading 315°
(iv)	Horizontal Situation Indicator (Left):	Aircraft heading 315° VOR radial selected – 272°
(v)	VOR/ILS indicator (Right):	Radial selected 268°
(vi)	VHF Radio Comm 1:	123.15 MHz (Islay/Port Ellen aerodrome)
	VHF Radio Comm 2:	130.65 MHz (Loganair company frequency)
(vii)	VHF Radio/Nav 1:	113.30 MHz (Skipness VOR)
	VHF Radio/Nav 2:	113.30 MHz (Skipness)
(viii)	Distance Measuring Equipment:	Set to 'knots' and Nav 1
(ix)	Automatic Direction Finding:	Both set to 395 KHz and ADF (Islay/Port Ellen NDB)
(x)	Transponder:	Code 5052, selected ON
(xi)	Flap lever:	Selected to 12°
(xii)	Flap position indicator:	Showing approximately 11°
(xiii)	Power levers:	Both towards full power position

(xiv)	Propeller levers:	Both towards maximum
(xv)	Fuel quantity indicators:	Aft – 425 lbs Forward – 375 lbs
(xvi)	Fuel selector:	Normal
(xvii)	Standby booster pumps:	Both set to OFF
(xviii)	Emergency fuel shut off switches:	Normal
(xix)	Fire handles:	Both IN (not fired)

1.12.3 *Detailed examination of wreckage*

Following wreckage recovery to the AIB at RAE Farnborough, a detailed examination was carried out. This examination did not reveal any pre-existing faults in the aircraft's structure or flying control systems. All flying control surfaces were correctly attached to their respective drive systems and their part of the airframe, and it was established from the flap actuation system that the flaps had been at the 11° position at impact. The rudder and elevator trim tab positions agreed with their mechanical indicators in the cockpit, showing that a small amount of right rudder trim (½ needle width) and nose down trim (1 needle width) existed at impact. The electrical aileron trim indicator in the cockpit had returned to zero but the tab on the left aileron was positioned to give a small degree of right roll trim. All three trim actuators are irreversible screw jacks, electrically driven on the aileron and the others are mechanically driven via cables from the cockpit. None of these cables had failed or been stretched and thus the tab positions were considered to reliably indicate the trim state of the aircraft at impact. The flap/elevator inter-connect trim tab on the right elevator had been pulled beyond its normal up position. This was as a result of disruption to its drive system in the fuselage roof as the left wing detached during the impact.

Of the primary flight instruments, only the left and right altimeters were in a condition to be calibrated. This revealed the left altimeter to be accurate within 30 feet, the right within 60 feet when tested on sub-scale settings of 1013 mb and 1017 mb over the height range of 0 to 7000 feet.

Both airspeed indicators had suffered case failures and could not be checked for accuracy. However, their working parts were intact, exhibited no signs of distress and could be functioned over their normal full range. Likewise, the pitot/static system could not be checked for leaks but all damage observed was consistent with being caused by the impact. The aircraft's stall warning system was tested and, whilst it could not be calibrated its component parts operated satisfactorily.

Both engines and propeller assemblies were strip examined at a UK overhaul agency. This revealed that each engine had been rotating at a high speed at impact. Visual assessment of the damage to each propeller blade, distortion of the engine cases, damage to the fuselage and ground marks all confirmed that both engines were delivering power, although the exact power output of either engine could not be determined with any accuracy. When initially examined, the power levers and propeller control levers were all towards the forward end of their travels, ie, high power and high RPM. However, the left wing had broken free from the fuselage, the right engine from its mountings and in doing so they had either broken or pulled on the control cables. It was not possible, therefore, to directly equate these lever positions with the power at impact, although they would be consistent with witness reports of a marked power increase just before impact.

A strip examination of each propeller unit was conducted which revealed no pre-impact abnormalities in either unit. An attempt was made to assess propeller blade angles, and hence power levels, at impact but with little success. The left propeller blades only struck the fuselage and ground after the wing had detached from the fuselage and consequently yielded no useful information. One blade from the right engine had struck the ground with sufficient force to break off, this alone indicating a high engine power output.

The propeller governor, overspeed units and engine fuel control units (FCU's) were all either rig tested or strip examined and, with one exception, found to be fully serviceable. The left engine fuel control unit was found on test to be governing the gas generator (Ng) speed at 98% instead of a possible maximum of 101.5%. A strip examination revealed some internal contamination of various bleed orifices, although none were blocked, and wear was present on the throttle cam, eccentric lever and governor spring. These defects are not unusual in used FCU's, according to the overhaul agency, and may cause the unit to alter its governing characteristics as described above.

Use of the maximum continuous/take-off power of the PT6A-27 engine of 680 SHP is restricted in the Twin Otter installation to 620 SHP. Also, the maximum propeller speed is limited to 2112 RPM (96% Np) and maximum indicated torque value of 50 psi.

In normal operation, particularly at the ambient temperatures experienced in the Loganair operation, a torque value of 50 psi will produce a gas generator speed (Ng) of 94% to 96% with the propeller speed (Np) governed at 96%. It is possible in the Twin Otter to exceed this rated power by advancing the power levers fully forward to their stops where maximum engine power may be expected to be developed in less than 1 second. It is therefore probable that this defect would only produce an effect when normal maximum power is exceeded on both engines and this could well have contributed to the large left yaw angle of the aircraft. It could not be determined if any sudden rudder deflection had been applied prior to the impact.

The avionic systems computers had survived the impact in good condition and were subsequently tested at their manufacturers' service facility in the UK. This revealed both VOR computers to be accurate within ½° of a selected radial and both automatic direction finding (ADF) computers to be within 3° of the correct relative bearing. The ADF units incorporate a visual indicator, for test purposes, which freezes when power is removed and which indicate the relative bearing of the selected NDB. ADF No 1 was showing 7° right of aircraft nose, No 2 showed 5° right. (The aircraft heading at impact was determined as 10° to the left of the NDB.) The distance measuring equipment (DME) computer was found to be accurate, but outside the manufacturers specification, in that its transmitter power and sensitivity were low. This would have the effect of reducing the useable range of the DME system, but at no time on test did the computer produce erroneous readings. According to the manufacturer such a defect is consistent with mechanical shock to the output valve in the unit.

The aircraft's master warning panel light bulbs were examined for evidence of illumination at the time of impact. A high proportion showed characteristics of filament failure whilst cold, and none showed evidence of hot failure.

1.13 Medical and pathological information

There was no evidence that any pre-existing medical condition of either pilot contributed to the accident. During the impact the handling pilot died from severe multiple injuries, and the supervisory captain sustained serious injuries. As a result of these injuries the surviving pilot cannot remember anything concerning the flight.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 The impact

At the moment of the major impact with the rocky outcrop the aircraft appears to have been in a level slightly right wing down attitude, and travelling at a ground speed of between 85 and 90 knots. Both pilots and all the passengers were strapped in and, largely because of this, injuries were kept to a minimum. When examined on site the forward right escape window had been operated and was lying outside the fuselage and the normal passenger exit door, at the rear on the left side, was open. It is believed that all the passengers escaped via this rear door. The other two emergency exits were later operated satisfactorily.

Despite the severe damage to the nose section there was no significant distortion to the fuselage structure over the length of the passenger cabin. All seats had remained securely attached to the cabin floor, and no seat belts had failed due to deceleration forces. The single fatality, to the pilot in the left crew seat, was a direct result of the initial impact forces and the subsequent detachment of the wing which allowed the left engine propeller to penetrate the cockpit.

1.15.2 The injuries

At the time of the impact all the aircraft's occupants were seated with their restraint harnesses fastened. The two pilots were restrained by a full harness, the passengers by lap straps only. All seats were forward facing. The supervisory pilot sustained serious injuries to his head and legs as the front of the aircraft forward of the pilots' seats disintegrated.

In view of the severity of the impact and subsequent deceleration of the aircraft, the injuries sustained by the passengers were remarkably slight. Apart from suffering shock, three passengers escaped without injury. Concerning the passengers who suffered serious injuries, expert medical advice is of the opinion that most of these resulted from high deceleration forces which caused people to rotate forwards around their lap straps and strike the seat in front with their heads and legs. It is probable that these injuries would have been minimal had the seats been rearward facing.

For the purposes of this report the definition of serious injury is that contained in the International Civil Aviation Organisation Standards and Recommended Practices, Annex 13. This defines serious injury as an injury sustained by a person in an accident which "requires hospitalisation for more than 48 hours, commencing within seven days from the date the injury was received, ...".

1.15.3 Search and rescue

The final radio message from the aircraft was at 1521 hrs when the incorrect position 'over Port Ellen' was reported. When, after two radio calls to the aircraft which failed to obtain a reply, the aerodrome radio operator became worried she immediately contacted Scottish Airways and advised the controller of the situation. Overdue action was commenced at 1526 hrs, and at 1533 hrs a Royal Air Force Nimrod aircraft was en-route to Islay to act as On Scene Commander and co-ordinate the area search and rescue units. Two Royal Air Force search and rescue helicopters and one Royal Navy helicopter were also alerted. In the event the position of the crash site was notified by a passenger who was first from the wreckage and help was directed to the scene. Seven of the seriously injured survivors were transferred to mainland hospitals by helicopters. The remainder were treated in a local hospital.

The total flying hours completed by search and rescue aircraft during the operation were as follows:-

RAF Nimrod	1 hr 43 mins Day
RAF Wessex	2 hr 40 mins Day
RAF Sea King	6 hr 12 mins Day 1 hr 30 mins Night
RN Sea King	3 hr 10 mins Day

1.16 Tests and research

Because it appeared that a significant factor in the accident may have been the decision of the pilots to fly a visual approach in unsuitable weather conditions, during which they mis-identified Laphroaig as being Port Ellen, it was considered necessary to the investigation to mount a trial flight. The purpose of the flight was to assess the difficulty of visual navigation along the south coast of the island, and to compare the differences between a visual approach and the published instrument approach procedure. To this end a fleet aircraft flown by a Company training captain was used to fly a similar flight profile to the accident flight. Both video and still photography were used to record the flight, which was carried out on the morning of 25 June 1986.

The weather on that morning was generally similar to that on 12 June 1986 in that a moist westerly airstream was producing extensive layers of stratus cloud; however, there was no precipitation and no significant cloud below 1000 feet. The aircraft was flown, at 6000 feet to overhead the Skipness VOR when a descent was commenced towards the south of the Isle of Islay. At the top of descent it was noticeable that the centre of the island and the high ground was obscured by cloud, but it was possible to see sufficient landmarks along the south coast through gaps in the cloud cover to enable a visual descent to be carried out. As the aircraft descended, conditions appeared to worsen as it became apparent that the tops of even the smaller hills inland were obscured by stratus.

At the bottom of the descent the aircraft was flown along the south coast at 500 feet above sea level. The flight was continued past Laphroaig until overhead Port Ellen. It was observed that although the two bays are very similar in shape, there is a considerable difference in size and background when viewed from the air. In conditions of good visibility, as were prevelant on the trial flight, it would be difficult to mistake one bay for the other, especially when both are in view. However, in the poor conditions that were prevailing on the accident flight, with an in-flight visibility of 2000 metres or less, identification would probably not be so simple. In these conditions Port Ellen would not have been visible from an aircraft overhead Laphroaig at 500 feet; from less than 100 feet it was considered that very little of the coastline would have been visible at all. Photographs of both bays were taken from the aircraft at a height of 500 feet above sea level and are included at Appendix 5. The prints have been modified to reflect conditions of poor visibility.

As a final part of the trial flight the full NDB instrument approach was flown. The procedure was found to be satisfactory and presented no problems. However, it was observed that, in a flight visibility of 2000 metres, neither the runway threshold nor even the coastline ahead would have been visible from the Missed Approach Point.

1.17 Additional information

1.17.1 The relevant regulations

The general regulations concerning the operation of public transport aircraft registered in the United Kingdom are laid down in Part V of the Air Navigation Order 1985 (ANO). The regulations are expanded in the United Kingdom Air Pilot (AIP), Rules of the Air and Air Traffic Services (RAC). Included in these regulations is the requirement that every operator shall produce an operations manual which must be available to each member of his operating staff. In the company operations manual the operator is required to establish and include operating minima appropriate to every aerodrome of intended departure or landing and every alternate aerodrome. It is also specifically laid down in the ANO Part V, Article 30, paragraph 5(b) that: "an aircraft shall not continue an approach to landing at any aerodrome by flying below the specified Decision Height unless from that height the specified visual reference for landing is established and is maintained."

1.17.2 The company operations manual

The Loganair company operations manual contained the required instructions on operating procedures and aerodrome operating minima. Relevant extracts from the manual are provided in Appendix 4 to this report. Although the conduct of the accident flight touches upon many other regulations and guidelines, only those pertinent to the discussion have been included. A fully amended and up-to-date edition of the company operations manual was on board the aircraft.

1.17.3 "De Havilland, Canada Service Bulletin 6/469"

This service bulletin, revision "A" of which is dated 14 June 1985, provides details of an optional modification, No 6/1752, entitled "Wings – Wing restraint Tension Rod Installation."

In previous impact survivable crashes with the Twin Otter, failure of the wing rear spar to fuselage fitting has allowed, as in the case of G–BGPC, the wing(s) to pivot forward and propeller blades to enter the rear of the cockpit. To enhance the crashworthiness of the aircraft an increased energy absorbtion capability at the rear spar attachment is achieved by the installation of a tension rod attached, at its outboard end, to a special fitting along the rear spar, and at its inboard end to the wing attachment bolt. A pivoted link is also provided at this end such that the rod will not react any tensile load until after the root fitting has failed. To date, no Twin Otter is recorded as having crashed with the modification fitted.

Since the accident, the operators of G–BGPC, have expressed their intention to fit this modification to their fleet of Twin Otters. A recommendation to the CAA to upgrade this modification is made in part 4 of this report.

2. Analysis

2.1 General

Only one defect was found during the engineering examination of the aircraft and its systems. The left engine fuel control unit, when tested, governed the gas generator speed at too low a value when the power levers were selected fully forward, ie, beyond the normal maximum torque position. This defect would not be apparent on a normal take-off when the power levers are progresssively moved to the required maximum torque. However, it readily explains the yaw angle at impact, when the power levers were probably slammed open, and the right engine produced significantly more than the maximum allowable torque whilst the left engine produced only slightly more.

The passengers recall the rapid increase in engine noise followed shortly afterwards by the sound of the stall warning system. This evidence suggests that the pilots probably glimpsed the ridge line in the mists ahead of them in the last few seconds and simultaneously put on the power and pulled up hard, so triggering the stall warning system. It is probable that the stall warning operated because of the rate of nose-up pitch and the "g" loading of the wings rather than a reduction in speed in straight and level flight. The aircraft therefore suffered an accelerated stall and the attitude in which it hit the ground suggests that it "mushed" into the ridge rather than flying directly into it. The lower available power on the left engine is not thought to be a factor in the accident.

It must be concluded that, whilst the pilots were attempting to fly a visual approach for landing at Islay/Port Ellen aerodrome in totally unsuitable weather conditions, the aircraft struck rising ground that was obscured in mist or hill fog. Thus, the main emphasis of the investigation has not been to attempt to establish what happened, for this was self-apparent, but rather to try to determine why the events took place. In this respect the total lack of recall of the aircraft commander and the absence of a cockpit voice recorder have proved to be significant handicaps.

Both pilots were well experienced, properly qualified, and, according to their previous company reports, had performed their flying duties to a satisfactory standard. The handling pilot was close to completing a series of supervised route flights which, if he had completed them successfully, would have resulted in the award of full command status. It was very much in his interests to demonstrate his good airmanship and ability to operate the aircraft safely and in accordance with the regulations. Equally, the supervisory captain was a very experienced pilot and flying instructor who must have been well used to commanding an aircraft in a supervisory capacity. Again it might be expected that, in these circumstances, he would have demanded a high standard of airmanship, and that he would not have permitted an ill-considered and unsafe approach to have been carried out. Yet all the evidence shows that this is precisely what happened. The various factors that may have contributed to this situation are discussed in more detail below.

2.2 The conduct of the flight

The pre-departure and take-off phases of the flight appear to have been normal. The aircraft was declared to be serviceable, it was properly loaded, and there was sufficient fuel on board for the flight to Islay/Port Ellen, an instrument approach followed by a go-around, and then a subsequent diversion either back to Glasgow or to any other nominated aerodrome. Prior to departure the pilots had obtained the latest available weather information. Although the forecast was not good, the conditions generally were not below the minima for commencing an NDB instrument approach at the destination aerodrome. The latest Islay/Port Ellen aerodrome METAR, timed at 1150 hrs, was such that, had these conditions prevailed, then a visual approach to the aerodrome from south of the island would not have been an unreasonable manoeuvre. This type of approach may well have been preferred by pilots to the instrument procedure as it would save time and fuel, and also, by avoiding any turbulence that may have been generated by the high ground in the centre of the island, might be expected to result in a smoother flight. Equally, it must be stressed that there was no evidence of any company pressure on pilots to adopt this procedure, and indeed the company operation manual makes it clear that in all cases the responsibility for the whole conduct of a flight rests exclusively with the aircraft commander. In this case, presumably before departing Glasgow, the pilots had discussed the forecast en-route and terminal weather conditions and agreed that the flight should proceed. In view of the forecast conditions and the availability of an instrument approach aid at the destination aerodrome their departure decision was perfectly reasonable.

2.3 The descent

The RTF and Radar recordings show that the flight proceeded according to flight plan until, at 1508 hrs, the aircraft passed overhead the Skipness VOR and was released from the control of Scottish Airways. From this point, instead of continuing on the flight planned track directly to overhead the aerodrome, the aircraft is shown to have turned about 15° left and commenced an immediate descent towards the south of the island. Some two minutes later, at 1510 hrs, the pilots received the Islay/Port Ellen latest weather and, from the evidence on the in-use flight log, which was recovered from the aircraft wreckage, there is no doubt that they noted it down correctly. In spite of the fact that the pilots were by then aware of the poor weather conditions at the aerodrome, the descent towards the south was continued and the reasons for this apparently extraordinary decision can only be conjectural.

Evidence from the passengers, who variously described the flight as being in and out of cloud, suggest that the stratus layers were probably broken, and it is possible therefore that, at the start of the descent, the pilots may have considered that there were sufficient gaps in the cloud to enable a visual descent to be carried out. What is certain is that they had decided upon a VFR descent towards the south of the island before receiving the actual weather conditions, and that thereafter, in spite of the weather actual, they did not change their minds. From the evidence of the passengers and ground witnesses it is also apparent that the closer the aircraft flew towards the south coast of the island, the worse the weather conditions became. It is highly probable that, in order to achieve even an intermittent visual contact with the sea or coastline, the aircraft was descended significantly below the 550 feet minimum stated in the company flight manual.

At this stage the only safe option to the pilots would have been to have turned the aircraft onto a southerly heading, climbed over the sea to the Minimum Sector Altitude (MSA) of 3600 feet, and navigated back to overhead the Islay/Port Ellen aerodrome NDB to carry out an instrument approach. This manoeuvre would have added perhaps 15 to 20 minutes to the flight time, and was possibly discarded for that reason. However, despite the weather conditions, the flight was continued along the coast of Islay until it turned inland over Laphroaig. There is reliable evidence from ground witnesses that, at that time, the aircraft's altitude was below 100 feet above ground level, and that visibility was extremely poor in the prevailing mist. The pilots, believing that they had turned inland over Port Ellen, would then have probably been looking for the A846 road which runs directly from the town to the aerodrome. Certainly the heading on which the aircraft left Laphroaig was parallel to and about 1 mile to the east of the road. From the position that the aircraft turned inland over Laphroaig, until the collision with the rising ground, it would have taken less than 45 seconds.

There is evidence from the aircraft's attitude and engine power at impact, that the pilots had seen the ground and attempted to climb the aircraft in the last seconds. However, it must be concluded that from the time that the pilots had misidentified Laphroaig as being Port Ellen, and turned inland at extremely low level, a collision with the ground was a distinct possibility.

2.4 The instrument procedure

As a further part of the investigation the Islay/Port Ellen aerodrome NDB approach procedure was studied in order to determine whether a safe approach and landing would have been possible in the weather conditions reported on the day of the accident. The conclusion must be that an approach and landing in accordance with the current regulations would probably not have been successful.

The minimum visibility for commencing an NDB instrument procedure at Islay/Port Ellen is 1500 metres, and in any conditions of visibility below that limit an approach ban is mandatory. The visibility passed to the pilots on the accident flight was 2000 metres, and so, in accordance with the current regulations, an instrument approach was permissable. However, on the instrument approach procedure the missed approach point is positioned 3150 metres (1.7 nm) back from the runway threshold. At this point if the actual visibility was indeed 2000 metres then the pilots could not possibly have achieved the recommended suitable reference for landing and a go-around would have been mandatory. Although the missed approach point is correctly plotted on all the instrument approach plates examined, the fact that it is a significantly greater distance from the runway threshold than the minimum visibility for commencing an approach, is not highlighted. It is felt that, under conditions of stress or high work load, this factor could well be missed and induce an unwary pilot to commence an approach in flight conditions in which he could not land. A safety recommendation is made accordingly.

2.5 The regulations

The regulations concerning the conduct of public transport flights were examined in detail, in order to determine whether any amendments or additions to the current disciplines might contribute towards preventing similar type accidents in the future. The production of an Operations Manual is the statutory responsibility of an Operating Company and is necessary to the granting, by the CAA, of an Air Operator's Certificate. It is the responsibility of the Operating Company to ensure that the Manual provides clear and explicit regulation of the manner in which the Company's flying operation is to be conducted. The Loganair Company Operations Manual meets all statutory requirements, and is considered to be clear and unambiguous in its description of Company operational procedures. Relative extracts considered pertinent to the accident flight are included at Appendix 4. There is strong evidence that some, if not all of these Company regulations were contravened during the accident flight. It is also apparent that Rule 5 of the Rules of the Air contained in the Air Navigation Order 1985 was contravened. Certainly at the time and position of the impact the aircraft could not be described as "landing in accordance with normal aviation practice", as from that position the pilots could not have possibly been in visual contact with the aerodrome.

Subsequent to the accident the Company has ruled that their aircraft commanders are banned from conducting a visual approach to an airfield which is served by a serviceable approach aid when the reported cloud cover includes more than 4 oktas cloud below circling height, or the reported visibility is less than 2 nm. It is not considered that further changes to current regulations would be appropriate.

3. Conclusions

(a) *Findings*

(i) The commander held a valid Commercial Pilot's Licence with a current medical certificate.

(ii) The handling pilot held a valid Commercial Pilot's Licence with a current medical certificate.

(iii) The aircraft had a valid Certificate of Airworthiness in the Transport Category (Passengers) and had been maintained in accordance with an approved schedule.

(iv) The handling pilot died of injuries sustained during the impact.

(v) The aircraft commander and 11 passengers suffered serious injuries during the impact.

(vi) There was no evidence that any mechanical failure or malfunction had occurred that was relevant to the accident.

(vii) The engines were developing high but asymmetric power at impact.

(viii) Communications throughout the flight were normal.

(ix) The weather forecast was suitable for the flight to be undertaken, but the actual weather on arrival was totally unsuitable for a visual approach.

(x) The final stages of the flight were conducted below the minimum height and minimum visibility conditions stipulated in the Company Operations Manual, and apparently in direct contravention of Rule 5 of the Rules of the Air, Air Navigation Order 1985.

(xi) The published minimum visibility for commencing an NDB instrument approach to Islay/Port Ellen is incompatible with the published Missed Approach Point.

(xii) The Islay/Port Ellen AFIS radio operator initiated overdue action promptly and with initiative.

(xiii) Search and Rescue Services were alerted promptly and responded without delay.

(b) *Cause*

The report concludes that the cause of the accident was the commander's decision to allow the handling pilot to carry out a visual approach in totally unsuitable meteorological conditions. An error in visual navigation was a contributory factor.

4. Safety Recommendations

It is recommended that:

4.1 The CAA should consider upgrading the modification (De Havilland Canada Service Bulletin 6/469) to improve crashworthiness of the Twin Otter by the introduction of a wing restraint tension rod.

4.2 The CAA should require that on those airfield approach plates where the distance from the missed approach point to the minimum visual reference is significantly greater than the published minimum visibility requirement, the difference should be highlighted.

ICAO Note.— The Appendices were not reproduced.

ICAO Ref.: 171/86

No. 4

DHC-6-300, N76GC, and Bell 206B, N6TC, mid-air collision over Grand Canyon National Park, United States, on 18 June 1986. Report NTSB/AAR-87/03 released by the National Transportation Safety Board, United States.

SYNOPSIS

On June 18, 1986, at 0855 mountain standard time a Grand Canyon Airlines DHC-6, N76GC (Twin Otter), call sign Canyon 6, took off from runway 21 of the Grand Canyon Airport. The flight, a scheduled air tour over Grand Canyon National Park, was to be about 50 minutes in duration. Shortly thereafter, at 0913, a Helitech Bell 206B (Jet Ranger), N6TC, call sign Tech 2, began its approximate 30-minute, on-demand air tour of the Grand Canyon. It took off from its base at a heliport adjacent to State route 64 in Tusayan, Arizona, located about 5 miles south of the main entrance to the south rim of the park. Visual meteorological conditions prevailed. The two aircraft collided at an altitude of 6,500 feet msl in the area of the Tonto Plateau. There were 18 passengers and 2 flightcrew members on the DHC-6 and 4 passengers and 1 flightcrew member on the Bell 206B. All 25 passengers and crewmembers on both aircraft were killed as a result of the collision.

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the flightcrews of both aircraft to "see and avoid" each other for undetermined reasons. Contributing to the accident was the failure of the Federal Aviation Administration to exercise its oversight responsibility over flight operations in the Grand Canyon airspace and the actions of the National Park Service to influence the selection of routes by Grand Canyon scenic air tour operators. Also contributing to the accident was the modification and configuration of the routes of the rotary-wing operators resulting in their intersecting with the routes of Grand Canyon Airlines near Crystal Rapids.

1. FACTUAL INFORMATION

1.1 History of the Flight

On June 18, 1986, at 0855 mountain standard time, 1/ a Grand Canyon Airlines DHC-6 (Twin Otter), N76GC, call sign Canyon 6, took off from runway 21 of the Grand Canyon Airport (GCN). The flight was a scheduled 50-minute air tour over Grand Canyon National Park. At 0913, a Helitech Bell 206B (Jet Ranger), N6TC, call sign Tech 2, began its approximate 30-minute, on-demand air tour of the Grand Canyon. It took off from a heliport adjacent to its base near State route 64 in Tusayan, Arizona, located about 3 miles south of the boundary of the park and 1 mile northeast of the approach end of runway 21 at GCN. There were 18 passengers and 2 flightcrew members aboard the DHC-6; there were 4 passengers and 1 flightcrew member aboard the Bell 206B.

The flights, scenic air tours over the Grand Canyon, were conducted in uncontrolled airspace under visual flight rules. The only air traffic control facility in the area, the control tower at GCN, controlled only departures and arrivals into the airport. At the time of the accident, most sightseeing flights were conducted under the requirements of 14 Code of Federal Regulations (CFR) Part 91, in accordance with the provisions of 14 CFR 135.1(b)(2). 2/

Both flights proceeded normally, making the customary voluntary position reports over frequency 122.75 MHz. (See Section 1.9. Communications for additional information.) A pilot who was flying south of Mencius Temple, a prominent landmark in the Grand Canyon, stated that about 0930, he saw the Bell 206B and heard "Tech 2" report "west of Mencius at 6400 feet, southbound." This pilot had previously heard "Canyon 6" report passing another landmark, Havasupai Point.

About the same time, a pilot who had just passed Havasupai Point eastbound at 7,100 feet believed that he saw a flash of light. From his position about halfway between Havasupai Point and the Scorpion, he saw a "mushroom-topped" column of smoke about 1,000 feet high rising from the Tonto Plateau. By the time he passed south of Scorpion he could identify another column of smoke and a smaller area of vaporous cloud between the two columns.

1/ All times herein are mountain standard time based on the 24-hour clock, unless otherwise indicated.

2/ 14 CFR 135.1(b)(2) allows nonstop sightseeing flights that begin and end at the same airport, and are conducted within a 25-statute-mile radius of that airport to be conducted under 14 CFR Part 91.

A group of whitewater rafters had just passed the Boucher Rapids on the Colorado River inside the Grand Canyon about 3 miles from the accident site. Although none of the rafters saw either aircraft before they collided, several stated that they looked up in time to see both aircraft as they emerged from a small cloud of smoke or a vaporous cloud. They reported seeing the helicopter fall to the west and the DHC-6 fall to the east of the collision point. After the debris disappeared from view behind a plateau, they heard the sound of ground impact and saw black smoke rising from the impact sites.

About 0930, a Bell 206B, operated for the National Park Service (NPS), departed the South Rim Heliport on a medical evacuation flight to Phantom Ranch. The pilot subsequently overheard a radio report describing the accident which reported that survivors were walking about the wreckage site. He flew to the heliport to acquire needed medical equipment and returned immediately to the site. On arrival, he circled over the wreckage of the helicopter and then proceeded to the wreckage of the DHC-6. He was unable to locate survivors.

The accident was estimated to have occurred about 0933 during daylight hours at 36°10' N latitude and 112°15' W longitude.

1.2 Injuries to Persons

Injuries	*Cockpit crew*	*Passengers*	*Other*	*Total*
Fatal	3	22	0	25
Serious	0	0	0	0
Minor	0	0	0	0
None	0	0	0	0
Total	3	22	0	25

1.3 Damage to Aircraft

Both aircraft were destroyed by impact and the postimpact fire. The value of the Bell 206B was estimated at $300,000 while the value of the DHC-6 was placed at $750,000.

1.4 Other Damage

The vegetation in the immediate area of the DHC-6 was consumed by the postimpact fire.

1.5 Personnel Information

1.5.1 The DHC-6

The flightcrew of the DHC-6 was qualified in accordance with existing Federal aviation regulations. Both crewmembers were qualified to act as pilot-in-command of the DHC-6 in accordance with the requirements of 14 CFR Part 135.

The captain, 27, was employed by Grand Canyon Airlines in July 1982 and assigned to the position of pilot-in-command of the Cessna 207, a seven-passenger, single-engine airplane. He completed ground school and flight training in the airplane in

August 1982. In September 1983, he completed the transition training required to act as first officer of the DHC-6. In October of that year he also qualified as an instructor pilot in the Cessna 207. In March 1986 he upgraded to captain on the DHC-6. At the time of the accident, he had accrued 5,970 hours of flight time, about 5,000 of which were as pilot-in-command. He had accrued 1,556 hours in the DHC-6 airplane.

The captain had been scheduled to be off-duty on June 15 and 16. On June 15, however, he provided flight instruction to a friend, and on June 16, he flew two scenic air tour flights for Grand Canyon Airlines. Therefore, he was considered to have been on-duty for 2 hours on June 16. On June 17 he reported for duty at 0630 and went off-duty at 1930. He had dinner with a friend and retired at 2300. On the day of the accident he arose at 0600 and reported for work at 0630.

The first officer, 27, was employed by Grand Canyon Airlines in July 1980 and completed all ground and flight training for the Cessna 207 in that month. He flew as pilot-in-command of the Cessna 207 until 1984. In July 1984 he successfully transitioned to the first officer position on the DHC-6. He upgraded to captain on that airplane in April 1986. At the time of the accident, he had accrued 4,450 hours of flight time, 3,500 of which were as pilot-in-command. His total flight time in the DHC-6 was 1,076 hours. Both pilots of the DHC-6 flew 9 hours on the day preceding the accident. In addition, the pilot-in-command flew 111 hours in the 30 days before the accident while the second-in-command had flown 160 hours during the same period.

The first officer was off-duty on June 16. On June 17 he reported for duty at 0630 and went off-duty at 1930. He retired at 2200 and on the day of the accident awoke around 0600. He reported for duty at 0630. Both the captain and first officer flew one Grand Canyon Airlines scenic air tour before the accident flight. The duty day for pilots at Grand Canyon Airlines was from 0630 to 1830. On a typical day pilots would accrue 8 to 9 hours of flight time.

Grand Canyon Airlines ground training incorporated instruction in the following general topics: general operating and flight rules, rules applicable to air taxi and commercial operators (operations conducted under 14 CFR Part 135), company operations, navigation and air traffic control procedures, company routes, meteorology, and emergency procedures. Flight instruction included training in takeoffs and landings, normal and emergency maneuvers, flight under simulated instrument conditions, climbs and climbing turns, engine failure, flight at minimum controllable airspeeds, and stalls. All training and certification met the requirements of 14 CFR Part 135.

1.5.2 The Bell 206B

The pilot-in-command of the Bell 206B was 39 years old at the time of the accident. He was employed by Helitech on June 13, 1986. Since Helitech began operations on June 1, 1986, the pilot-in-command had previously received his training in the Bell 206B and in Grand Canyon flight operations when he was employed by other companies which operated in the Grand Canyon. He received his initial helicopter training and flight experience while he was in the U.S. Army. He was employed by Grand Canyon Helicopters in May 1978 where he flew the Bell 206 in flight tours over the Grand Canyon and in contract flights for the NPS. In August 1979, he was employed by a company performing mineral exploration activities in Utah. He returned to the Grand Canyon area in July 1981 and was employed by Madison Aviation to conduct air tours over the Grand Canyon in the Bell 206B and to perform the duties of chief pilot under the provisions of 14 CFR Part 135. At the time of the accident, he had accrued 6,953.6 flight hours, all of which were in rotary-wing aircraft.

The pilot had been off-duty from June 14 through June 17. He returned to the Grand Canyon on June 17 following a trip to the east on a commercial air carrier to attend personal business. On June 17 he retired about 2000 to 2030 and awoke at 0630 the following morning. He reported for work about 0800. The duty day at Helitech began about 0800 and continued until 1800.

1.6 Aircraft Information

1.6.1 The DHC-6

The DHC-6-300, Twin Otter, United States Registry N76GC, was operated by Grand Canyon Airlines and was configured for a flightcrew of 2 and 19 passengers.
The airplane was modified in March 1982 with larger than standard windows in the passenger compartment under Federal Aviation Administration (FAA) approved Supplemental Type Certificate (STC) No. SA1814NM. The airplane was equipped with two Pratt and Whitney of Canada PT6A-27 powerplants, each with a three-blade, Hartzell, constant-speed propeller. The airplane was painted with an overall beige paint scheme with horizontal dark brown, gold, and blue stripes. The stripes were about the same width for the length of the fuselage. The brown was 24 inches wide, the gold was 6 inches wide, and the blue was 3 inches wide. The stripes tapered gradually along the rear fuselage and swept upward along the rudder and then forward near the top of the vertical stabilizer.

The cruise airspeed of the airplane with 10° of flaps extended, the configuration used by Grand Canyon Airlines, was 100 miles per hour. The maximum certificated takeoff weight of the airplane was 12,500 pounds. The takeoff gross weight of the DHC-6 before the accident was 11,934 pounds and its center of gravity (CG), expressed in percent of mean aerodynamic chord was 25.1 percent. Both the weight and CG were within allowable limits for the accident flight. The maintenance records of the airplane revealed that the only deferred minimum equipment list item at the time of the accident was a discrepancy in the first officer's attitude gyro. All maintenance had been performed according to an FAA-approved program. No discrepancy trends or repeated maintenance actions on major items were found.

1.6.2 The Bell 206B

The Bell 206B III, Jet Ranger, United States Registry N6TC, was a single-engine, utility-type helicopter. It was configured for a pilot and one passenger in the front seats and three passengers in a rear bench-type seat. It was equipped with an Allison 250-C20B powerplant, a two-blade main rotor and a two-blade tail rotor.
The aircraft was painted white and yellow with yellow the predominant color of the passenger cabin. The main rotor color was gray and the tail rotor was mostly red.

The maximum takeoff weight of the aircraft was 3,200 pounds. Its weight and CG were within acceptable limits at the time of the accident. There were no discrepancy trends or repeated maintenance actions relating to the aircraft. Its maintenance and inspection activities were performed in accordance with applicable regulations.

1.7 Meteorological Information

At the time of the accident, visual meteorological conditions prevailed. The 0845 local observation taken at GCN was as follows:

> Sky—clear; visibility—50 miles; temperature—74° F; dew point—39° F; wind—200° F at 7 knots; and the altimeter—30.27 inches of mercury.
>
> The 0958 local observation taken at GCN was:
>
> Sky—clear; visibility—50 miles; temperature—77° F; dew point—36° F; wind—200° F at 8 knots; and the altimeter—30.27 inches of mercury.

The clear conditions with a high degree of visibility were considered typical of meteorological conditions at the Grand Canyon at that time of year and that time of day. In addition, there was often low-level turbulence associated with the Grand Canyon in the late afternoon.

1.8 Aids to Navigation

There were no reported problems with aids to navigation.

1.9 Communications

There were no reported problems with communications between the DHC-6 and the GCN air traffic control tower or the Bell 206B and the GCN air traffic control tower. Air tour operators in the Grand Canyon had developed an informal, voluntary reporting system in which pilots gave position reports, altitudes, and flight directions over the common frequency, 122.75 MHz, when they passed prominent landmarks in the Grand Canyon. This system had been in use for several years.

Following the accident, several pilots of air tour aircraft told Safety Board investigators that in recent years there had been increasing congestion on the common frequency. One helicopter pilot stated that the congestion had been getting worse and that there had been excessive, nonpertinent "chatter" particularly when air tour traffic was light. The director of operations of Grand Canyon Airlines testified that although the frequency was congested at times, in his opinion it had "never been congested to the point where it became unsafe." In addition he noted that when air tour traffic was heavy, simultaneous transmissions from two flights might interfere with or block each other. He added that pilots of transient aircraft, both general aviation and military, would not be familiar with the position reporting system and, therefore, would not use it. When a transient aircraft was observed by an air tour pilot, the air tour pilot would typically broadcast position information on the nonreporting aircraft.

The former president of Helitech testified that the aircraft reporting system was an effective one. Moreover, when two or more transmissions interfered with each other, pilots would generally inform each other that the transmissions had been "stepped on" or interfered with.

On the day of the accident, there were no reported difficulties with the ability of either the DHC-6 or the Bell 206B to make position reports over the common frequency.

1.10 Aerodrome Information

The departure airport of the DHC-6 was located 7 miles south of the park headquarters and 3 miles south of the park boundary. The airport elevation was 6,606 feet above mean seal level (msl). The single runway, 03/21, was 8,999 feet long and 150 feet wide. The air traffic control tower operated from 0800 to 1800.

The heliport from which the Bell 206B departed was used by Helitech aircraft only. Clearance to traverse the GCN airport traffic area from the heliport was obtained from the GCN air traffic control tower.

1.11 Flight Recorders

Neither of the two aircraft was equipped with a cockpit voice recorder or a flight data recorder nor were such recorders required for the type of operations being conducted at the time of the accident.

1.12 Wreckage and Impact Information

1.12.1 The DHC-6

The wreckage of the two aircraft came to rest about 2,450 feet apart on the Tonto Plateau between Mencius Temple and Tuna Creek. The sites are about 1 1/2 statute miles north of the Crystal Rapids of the Colorado River.

Most of the wreckage of the DHC-6 was located on the western side of the base of Mencius Temple oriented to a magnetic heading of 150°. The rear fuselage and the empennage were positioned on a magnetic heading of 057° and were separated from the remainder of the airplane by 953 feet.

The left main landing gear leg with the wheel, tire, and brake missing, and a 4-inch portion of a blade tip of the left propeller were located between the rear fuselage and the main wreckage. The nose gear strut was found north of the wreckage site. Various pieces of both aircraft, including the baggage door and fuselage skin sections of the DHC-6 and sections of the main rotor mast including the boot, as well as engine cowl sections with particle separator components, were randomly scattered over a distance of 300 feet west of the tail section of the DHC-6. A 6-foot section of the main rotor blade spar of the Bell 206B was located 810 feet southwest of the DHC-6 tail section. The left main wheel of the DHC-6 was located 177 feet from the airplane's tail section. The main rotor mast of the Bell 206B was found about 150 feet farther to the east. The main rotor hub was located about 875 feet south of the main rotor mast.

Most of the DHC-6 fuselage from just aft of the wings forward came to rest in an inverted position. It was destroyed by impact and postimpact fire. The aft section of the fuselage below the floor line was relatively free of fire damage. There was a diagonal slash on the left side of this section from just aft of the baggage door forward angled aft about 24°. This section above the floor line was fragmented in a large area to the west of the location of the airplane's tail section. The ailerons and flaps, which were in the 10° position, were attached to the wing trailing edges. There was no evidence of the in-flight collision on the wings.

Nearly 18 inches of the red main rotor blade spar cap of the Bell 206B was found embedded in the left side of the rear fuselage of the DHC-6. There was a 5-inch chordwise penetration of the bottom surface of the left horizontal stabilizer and several other skin penetrations in this area, including one that severed the underlying stringers. There was aftward crushing of the leading edge of the right horizontal stabilizer, angled aft about 16°, as well as gray paint transfer on the deicer boot.

The nose gear was separated from the airplane at a distance of about 400 feet northwest of the main wreckage. The right side of the tire had been cut near the crown. There was a 21-inch by 28-inch portion of the fuselage structure attached to the strut. The left main landing gear, which also was separated from the fuselage, was 175 feet north-northeast of the tail section. There was a large dent in the leg tube about 11 inches above the brake flange near the 10:30 position when viewed from outboard. The axle was fractured 3 inches outboard of the bottom of the leg with the remaining portion displaced forward.

The wheel and tire assembly was separated from the gear leg, southeast of the tail section. The axle, bearings, and brake disc were missing. The inboard half of the wheel was broken on a line several inches wide through the hub and rim. The right main landing gear remained with the debris of the fuselage. There was no evidence of the collision on its components.

The right engine was severely damaged by impact and postimpact fire. Disassembly of the engine revealed no evidence of preexisting damage. The propeller blades were bent slightly opposite to the direction of normal rotation and were twisted toward low pitch.

The left engine was severely damaged by ground impact and the postimpact fire. Disassembly of the engine revealed no evidence of preexisting damage. The propeller blades were bent opposite to their direction of normal rotation and were twisted toward a low pitch position. All blades exhibited gouging along the leading edges.

1.12.2 The Bell 206B

Most of the wreckage of the helicopter was located near the edge of Tuna Creek, 2,450 feet from the main wreckage of the DHC-6. It was inverted and on a heading of 204°. Most of the forward part of the fuselage had been consumed by the postimpact fire. The tailboom was displaced to the left about 60° and was twisted clockwise. The top 40 inches of the vertical fin was located about 1,200 feet northeast of the main helicopter wreckage. There was a lateral indentation at the base of the leading edge of the vertical fin and red paint transfer on the left side of the fin.

Most of the engine and transmission cowlings were fragmented. The forward right transmission cowling was crushed inward and aft with evidence of rubber transfer on the surface. The forward edge of the right access door of the engine was crushed at an angle of 35° aft from the vertical. There was a light rubber transfer mark closely resembling the main gear tire tread of the DHC-6 on the aft cowl of the engine at an approximate 20° angle forward of vertical.

The main rotor hub and mast were separated and located apart from the aircraft. The entire mast, which had separated from the transmission, was located near the tail section of the DHC-6. It was bent forward about 45° near the top of the swashplate support. There were heavy contact marks on the vertical portion of the swashplate support about 20° to 25° right of forward. The mast was fractured just below the static stop area. The main rotor hub was located about 1,300 feet northeast of the main wreckage of the Bell 206B. About 5 feet of each rotor blade remained with the hub. There was a 23-inch black rubber transfer mark across the top surface of one blade progressing outward from the root to a fracture of the trailing edge. Pieces of deicer boot material were found between the blade skin and honeycomb filler. In addition, there was a 10-inch-long patterned indentation, matching the splines of the brake discs of the DHC-6, on the bottom surface of the mating section. There was no rubber transfer on the top surface of the mating section.

The remainder of the rotor blade was found at a later date about 4,700 feet north of the main wreckage of the Bell 206B. It was comprised of two sections which were close to each other--a 3-foot section from the blade tip inboard and an 8 1/2-foot section which mated with the blade root that remained with the hub.

The blade spar was deflected aftward from about midspan to the tip. The total deflection at the tip was about 1 inch. The top of the blade spar was broken out from the tip to about 4 1/2-inches inboard, and the tip block was broken out. There were approximate 1/4-inch deep gouges just outboard of the surface of the tip section that mated with the intermediate blade section. In addition, there were approximately 5-inch-long scratches in the spar which extended from the gouges inboard at a 350° angle.

There was a fracture that was deflected upward at an approximate 40° angle at the tip section of the main spar. There appeared to be compression-type bulking at the inboard fracture of the blade spar.

Across the lower surface of the blade were gold and brown paint transfer marks extending from the gouges as well as numerous parallel indentations in the intermediate section. There were several chordwise skin buckles in the intermediate section of the afterbody of the blade.

Two sections of the red blade spar were found in the wreckage area of the Bell 206B. The blade spar was fractured about 62 inches from the root. The outboard section was separated from the remainder of the blade. It was bent up at the inboard end and down at the outboard end. A section of sheet metal from the bulkhead/skin joint of the aft fuselage below the horizontal stabilizer of the DHC-6 was lodged in the inside radius of the blade spar. In addition, there were scoring marks in the counterweight and a red and white paint transfer on the bottom surface near the counterweight location.

The tail rotor and 90° gearbox had separated from the tailboom. There was a leading edge strike evident near the white stripe of one blade.

The engine of the Bell 206B was extensively damaged from impact and postimpact fire. There was no evidence of preexisting damage in the remaining portion of the engine and transmission.

1.13 Medical and Pathological Information

The three flightcrew members and the passengers onboard the two aircraft sustained fatal injuries as a result of the accident. Following the post mortem examination, the cause of death of the crewmembers and passengers was listed as "multiple severe crushing and thermal injuries, consistent with an airplane or helicopter crash." Toxicological analysis of the flightcrew members of both aircraft revealed no ethyl alcohol or illicit drugs.

1.14 Fire

There was no evidence of an in-flight fire on either of the two aircraft before the collision. Following the collision, the wreckage of both aircraft burned continuously for several hours. The fire consumed the cockpit, much of the fuselage, and most of the systems on the DHC-6. Similarly, the fire on the Bell 206B consumed most of the cabin, most of the systems of the aircraft, and all cockpit instruments except for one altimeter.

1.15 Survival Aspects

The accident was not survivable due to the severity of the ground impact and postcrash fire. Nevertheless, because of the remote location of the accident site, the Safety Board examined the potential ability of crash, fire, and rescue personnel to rescue survivors from the accident site had the accident been survivable.

The NPS informed the Safety Board that it operated a Bell 206B for its exclusive use. According to the NPS, this was used extensively in rescuing injured individuals from remote areas of the National Park. In addition, in an emergency, it could access both rotary-wing and fixed-wing aircraft from private and corporate operators in the area. These aircraft could have been used to reach and transport survivors to hospitals in Williams and Flagstaff, Arizona, if necessary. These hospitals, the closest to the Grand Canyon, are located about 50 and 70 miles, respectively, from the main entrance to the South Rim. The NPS maintains a clinic in the National Park to treat minor injuries.

1.16 Tests and Research

1.16.1 Photographic Reconstruction

Following the accident, the Safety Board performed a photographic reconstruction of the point of impact using a photograph of the postimpact vaporous cloud. The photograph had been taken by a passenger on board a raft near Boucher Rapids on the Colorado River. The photographer estimated that he took the photograph within seconds of the collision.

The technique employed in the reconstruction, known as photogrammetry, recreates a scene in three dimensions using terrain features in the photograph and in the topographic map of the area in the photograph as well as other data pertaining to the size of the negative, the camera lens, and the lens setting. To derive the altitude of the vaporous cloud, terrain features in the photograph and the topographic map were correlated with the location of the photographer, the impact site, and the elevation of the river at the point the photographer took the photograph. The resultant altitude was determined to have been 6,507 feet msl plus or minus 106 feet.

1.16.2 Flightpath

It was not possible to reconstruct the flightpath of either of the two aircraft before the collision due to the absence of flight recorders on either aircraft and the lack of radar data in the Grand Canyon airspace.

* 1.17 Additional Information

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*ICAO Note.— Section 1.17 was not reproduced.

ANALYSIS

2.1 General

The flightcrew of the DHC-6 and the pilot of the Bell 206B were properly certificated and qualified in accordance with the applicable regulations for their respective, local sightseeing flights. There were no medical or behavioral factors identified which could have affected their ability to conduct the flights. Both aircraft were certificated and maintained in accordance with applicable regulations and established maintenance procedures. Examination of the wreckage of both aircraft revealed no evidence of precollision structural failure, malfunction, or other abnormality.

Visual meteorological conditions existed at the time of the accident and there were no adverse winds reported. No weather factors that could have limited the ability of each pilot to see the other aircraft or to control his aircraft and avoid the other were identified.

In view of these findings, the Safety Board examined the operational and human performance factors related to each flight to determine why the pilots of the two aircraft failed to "see and avoid" each other. The Safety Board also examined the surveillance that the FAA performed on Grand Canyon sightseeing flights and the actions of the NPS relative to such flights both independently and with the FAA to determine how these agencies influenced the conduct of sightseeing flight operations. The Safety Board also focused on the role of the Grand Canyon Flight Operators Association to determine their influence on sightseeing flight operations. Finally, the crash, fire, and rescue efforts in the Grand Canyon were examined for their effect on passenger survivability.

2.2 The Accident

The lack of data from cockpit voice recorders, flight data recorders, as well as the air traffic control radar recorders prevented the Safety Board from reconstructing the flightpaths of the two aircraft before the collision. Without these data the Safety Board was unable to definitively analyze the pilots' abilities to "see and avoid" each other. Based on an examination of the wreckage of the aircraft, the Safety Board believes that the following events occurred in the collision sequence:

- The left side of the DHC-6 and the right side of the Bell 206B sustained the initial impact.
- The main rotor blade of the Bell 206B struck and severed the nose gear of the DHC-6.
- The opposite blade of the Bell 206B struck the aft portion of the fuselage of the DHC-6.
- The fuel cell of the DHC-6 ruptured and created the vaporous cloud of fuel that the witnesses on the Colorado River most likely had observed.
- The rotor head of the Bell 206B separated, concurrent with disintegration of the rotor head and blades.

- Debris from the disintegrating rotor blade struck the left side and tail of the DHC-6.
- The tail of the DHC-6 separated creating a loss of control.
- The DHC-6 pitched over, rotated, and struck the ground in an inverted position.
- The Bell 206B free-fell to the ground following the rotor separation.

2.3 Human Performance

There were no obstructions to the vision of the pilots found inside either aircraft. Although it is not known whether the Bell 206B pilot wore a baseball-type cap at the time of the accident, had he been wearing such a hat, its bill would not necessarily have obscured his view of the airplane. This is because the airplane would have appeared to the helicopter pilot about level with the design eye reference point of the helicopter, a point in his vision unobstructed by the hat. At the same time, there is no evidence that the color of either aircraft limited the ability of the pilots to see the other. Thus, the pilots of both aircraft should have been able to "see and avoid" each other.

The evidence indicates that the pilots possessed considerable experience in the type of aircraft they were flying and in operating those aircraft on Grand Canyon sightseeing flights. Because of the level of their experience, the pilots should have anticipated and been prepared for the presence of other aircraft near Crystal Rapids even without a position report from another pilot over the voluntary reporting frequency since Crystal Rapids was a highlight of many of the Grand Canyon air tours.

Due to the lack of flightpath data, the Safety Board was unable to assess with certainty the visibility of each aircraft to the flightcrew of the other. Nevertheless, based on the sizes of the aircraft and their probable positions before the collision, the Safety Board believes that each aircraft should have been visible to the pilots of the other aircraft at least 60 seconds before the collision. At that point, the Bell 206B had reported west of Mencius Temple, while the DHC-6 would most likely have been in a northerly heading over the river. Also, at that point the aircraft were about 3 1/2 miles from each other and should have been large enough to have been visible to the crew of the other aircraft. This is particularly so since there were no obstructions to pilot visibility identified in the cockpit of either aircraft. Consequently, the Safety Board could not explain or determine why the pilots of both aircraft failed to see each other in time to avoid the accident.

Nevertheless, the Safety Board believes that certain aspects of the operation of both the DHC-6 and the Bell 206B were deficient. Specifically, the lack of limitations to the flight and duty times of the flightcrew members of the DHC-6, and the absence of an intercom or public address system on the Bell 206B detracted from the safety of both operations. Grand Canyon Airlines operated its scenic air tour flights under 14 CFR Part 91; therefore, it was not required to limit the flight and duty times of its pilots to that of others, operating point-to-point flights under 14 CFR 135.265. As a result, the second-in-command of the DHC-6 had accrued 160 hours of flight time in the 30 days before the accident. This exceeded the maximum number of flight time hours allowed in

14 CFR Part 121 and 14 CFR 135.265 by 40 hours. Although he was reported to be rested before the accident, without more information the Safety Board cannot determine the extent to which he may have been fatigued at the time of the accident.

Further, the Safety Board believes that the hours flown in scenic air tour flights can be especially tiring since the aircraft generally have no autopilots and they are flown predominantly at low altitudes, where there is often turbulence and the pilot must exercise vigilance at all times to "see and avoid" other aircraft. Simultaneously, they narrate highlights of the air tour. Conversely, in most Part 121 operations and in many of the Part 135 operations in which flight time maximums apply, autopilots generally control much of the aircraft functions. At the same time, many of these flight regimes occur at high altitudes with little or no turbulence, little conflicting traffic and lower pilot workload. Despite the fact that those flights, in general, are less fatiguing to pilots than Grand Canyon scenic air tour flights are, flight and duty time maximums apply to those operations and not to the air tour flights. Therefore, the Safety Board concludes that to reduce the potential fatigue, the FAA should apply to revenue air tour operations the same flight and duty time limitations that apply to operations conducted under 14 CFR 135.265.

The Safety Board also believes that the practice of Helitech pilots turning their heads toward passengers to narrate tours compromised their ability to "see and avoid" other air traffic. Although the former president of Helitech testified that the collision occurred at a point where there would have been no narration, the Safety Board could not determine, due to the absence of cockpit voice recorders, whether the Bell 206B pilot had been turning his head to talk to passengers at the time of the collision. Regardless, the Safety Board believes that any unnecessary activity that detracts from the ability of pilots to "see and avoid" other aircraft should be prohibited. Therefore, the Safety Board urges the FAA to require that pilots of revenue and tour flights use a public address system, intercom, or similar system while narrating air tour flights.

2.4 Grand Canyon Flight Operations

The Safety Board believes that the Grand Canyon airspace, in general, presented few hazards to flight operations. Visual meteorological conditions existed throughout much of the year and there were no obstructions above the rims to endanger aircraft. In fact, despite the considerable volume of uncontrolled traffic in the Grand Canyon airspace, there had not been a midair collision there in almost 3 decades before the accident.

However, before the accident, the Office of Aircraft Services of the Department of the Interior identified two hazards to flight safety in the Grand Canyon airspace: the narrow area, just above the Colorado River, known as the inner gorge, where flying was considered to be dangerous due to the limited airspace available for aircraft maneuvering; and, the possibility of a midair collision over the Grand Canyon.

In addition, the Safety Board believes that several factors, together with those mentioned, further reduced the safety of flight operations in the Grand Canyon airspace, particularly those of scenic air tour operators. Perhaps most important of these factors was the limited number of scenic points and the similarity of routes, within the Grand Canyon airspace along which many of these operators flew. As a result, the Safety Board believes that the risk of midair collision was higher along the scenic points where air tour aircraft operated than elsewhere in the Grand Canyon airspace.

While some scenic air tour operators attempted to assign separate altitudes along the air tour routes according to aircraft type, the system was an informal one that was not followed by all flight operators. Therefore, pilots could not expect other aircraft to consistently maintain standardized altitudes, particularly since violators of the informal altitude separation system received no official warnings, reprimands, or enforcement actions.

Moreover, fixed-wing and rotary-wing aircraft, aircraft with substantially different flight characteristics, shared the same airspace. The mix of aircraft types created little risk to air safety as long as the aircraft were separated by altitude. However, with neither altitude nor route separation, the variety and number of aircraft types within a narrow corridor of airspace increased the risk of a collision. In addition, because there was no external air traffic facility to either monitor or control aircraft separation, the risk of a collision further increased. Consequently, pilots could not reliably anticipate the flightpaths or characteristics of the aircraft they might inadvertently encounter along the air tour routes.

The Safety Board believes that the danger of a midair collision was greatest in the area of the routes used by the scenic air tour operators. When the rotary-wing operators modified their entry and exit points on April 1, their routes were brought closer to those of Grand Canyon Airlines. The new route of the helicopter operators intersected with that of Grand Canyon Airlines in the vicinity of Crystal Rapids, the area in which the collision occurred, at a point where the DHC-6 would have been in a right bank and the Bell 206B in straight and level flight. Although Grand Canyon Airlines requested that their pilots fly at 7,000 feet msl, and the helicopter operators generally flew 500 feet below that, the collision indicated that altitude separation according to aircraft type was not consistently followed. The Safety Board believes that the modification of the entry and exit points of the rotary-wing operators placed their routes closer to those of Grand Canyon Airlines at a point where the Grand Canyon Airlines airplanes would be in a right turn. Therefore, the Safety Board believes that modification of the helicopter routes, and the lack of oversight on aircraft separation within the routes contributed to the accident.

2.4.1 FAA Oversight

Since many of the scenic air tour flights were carried out under 14 CFR Part 91, under existing rules the FAA was not required to perform routine surveillance on those operations. As a result, they did not examine the separation among the routes and the altitudes used by the local air tour operators, require adherence to those routes and altitudes or oversee changes to them. Consequently, when helicopter operators modified their routes, the FAA did not examine the new routes for their potential effect on aircraft separation and clearance.

In 1984 the Safety Board recommended that the FAA examine the procedures, and, if necessary, develop and publish standards for route and altitude selection by Grand Canyon scenic air tour operators. This investigation revealed that this had not been done. The FAA inaction could have been due to the difficulty of requiring compliance of operators, flying under the provisions of 14 CFR Part 91, with published altitudes and routes. However, the Safety Board believes that if the FAA, through its rulemaking procedures, had modified the existing Federal aviation regulations to implement oversight of Grand Canyon scenic air tour flights, it likely would have recognized that the fixed-wing and rotary-wing scenic air tour routes intersected near Crystal Rapids and the risk of a midair collision could have been reduced had the operators been apprised of this.

Therefore, the Safety Board believes that the failure of the FAA to oversee and examine the routes and altitudes of Grand Canyon scenic air tour operators contributed to the accident.

However, Grand Canyon scenic air tour operators were based in a variety of locations including Phoenix, Los Angeles, and Salt Lake City. While the FAA's Las Vegas FSDO possessed the jurisdiction over Grand Canyon scenic air tour operators who were based at the Grand Canyon as well as those based in Las Vegas, the fact remains that had the FAA possessed the necessary jurisdiction, the surveillance of operators based elsewhere would have been carried out by the FSDOs that were closest to them. Those FSDO's could not have been as familiar with the special requirements of Grand Canyon scenic air tour operators as was the Las Vegas FSDO. Therefore, because of the geographic separation among the FSDO's and the unique requirements of each, surveillance of the scenic air tour operators would not have been as effective as it could have been had one FSDO overseen all operations traversing the Grand Canyon.

The Safety Board was pleased to learn that the FAA intends to address the deficiencies in oversight and surveillance that have been identified as a result of this accident. By initiating the process through NPRM 86-21 to modify the rules under which Grand Canyon scenic air tours are conducted, the exemption to 14 CFR Part 135 for Grand Canyon air tour operations will be removed. The NPRM will require those operators to develop an operations manual with specified routes and altitudes. The manuals will be subject to FAA approval, thereby requiring compliance with its contents, including routes and altitudes. Furthermore, by placing the approval authority for the manual with the office with the most experience in Grand Canyon sightseeing operations, the Las Vegas FSDO--the FAA will be able to examine the routes of those operators performing sightseeing flights over the Grand Canyon. In addition, according to the SFAR proposed in the NPRM, by restricting the accessability of the Grand Canyon airspace to transient general aviation and military aircraft, only air tour operators familiar with the particular demands of flight in the airspace encompassing the Grand Canyon will be permitted to fly there. The Safety Board believes that implementation of these procedures should enhance Grand Canyon flight safety by providing the FAA with the needed authorization to ensure compliance with its directives concerning the conduct of flight operations there.

At the same time, the Safety Board believes that in order for the FAA to exercise the oversight authority outlined in the rules proposed in the NPRM, the FAA must reduce the workload of the staff of the Las Vegas FSDO. The Safety Board is concerned about the potential implications of the response of the POI to the former president of Helitech when the latter sought 14 CFR Part 135 certification for the company. The POI, according to the former president, informed him that due to workload demands, the FSDO could take no action on the application for 3 months. Although the chief of the FSDO testified that the POI did not believe that the request of Helitech was a serious one, FAA personnel admitted that the FSDO workload was high. The Safety Board believes that the POI in the interest of promoting flight safety should have encouraged operators to seek the operating certificate requiring the highest possible standards of operations and maintenance. Therefore, the Safety Board concludes that the workload of personnel at the FSDO at the time of the accident was high and for the proposed rules to be effective that workload must be reduced.

In addition, the Safety Board believes that the deficiencies in the current regulations, which permitted regularly scheduled and on-demand scenic air tour flights to carry revenue passengers under the provisions of 14 CFR Part 91, exist beyond the Grand Canyon airspace. For example, from 1983 to 1985, the Safety Board investigated 24 accidents involving scenic air tour flights operating under 14 CFR Part 91 in a variety of aircraft including fixed-wing and rotary-wing as well as lighter-than-air aircraft. In these accidents, 17 persons were killed, 10 received serious injuries, and 33 received minor injuries. The Safety Board believes that operators of revenue air tour of sightseeing flights should be required to adhere to the same regulations as operators of on-demand and scheduled flights. These regulations specify minimum levels of experience and minimum training and proficiency standards for hiring, training, and certificating flightcrew members, as well as standards for aircraft maintenance. Since the standards of 14 CFR Part 135 are considerably more stringent and necessarily involve a higher level of FAA surveillance than exists under 14 CFR Part 91, the Safety Board believes that the elimination of 14 CFR 135.1(b)(2) will enhance the level of safety of scenic air tour or sightseeing flights. Consequently, the Safety Board believes that the FAA should require all scenic air tour or sightseeing flights, regardless of the distance flown, to be subject to the regulatory provisions of 14 CFR Part 135 and not 14 CFR Part 91.

2.4.2 Grand Canyon Flight Operators Association

The Grand Canyon Flight Operators Association was an alliance of most of the scenic air tour operators who flew over the Grand Canyon. It attempted to provide some guidance on the conduct of the flight operations of its members. However, the ability of the association to affect the nature of flight operations over the Grand Canyon was limited. The association had no authority to require compliance with any advisory that it initiated, even among its own members. For example, it could take no action against the operator who flew just above the Colorado River. Although the association recognized the need for improvements to Grand Canyon sightseeing flight operations, according to the letter of agreement with the FAA that it had drafted, it had no enforcement capability and could not guarantee its members' compliance with the provisions of the letter of agreement. While the association could communicate with its members and could inform them of a need to modify operating procedures they had no such ability with nonmembers.

Nevertheless, the Safety Board believes that the attempts of the Grand Canyon Flight Operators Association to enhance the level of safety of the air tour operations were commendable in the light of the lack of authority available to the association to require compliance with its directives.

2.4.3 National Park Service

The Safety Board examined the actions of the NPS and its coordination with the FAA to determine what effects these actions may have had on the events that led to the accident. The Safety Board found that the NPS recognized and accepted the statutory authority of the FAA to regulate airspace over the Grand Canyon.

Nonetheless, the Safety Board concludes that the NPS, through its statutory authority to preserve the resources of the park created an atmosphere that led Grand Canyon scenic air tour operators to accede to their requests to reduce aircraft noise. Moreover, the Safety Board believes that the NPS made it clear to the operators, through its study process, that the conservation of resources at the Grand Canyon would affect scenic air tour operations there.

The NPS was scheduled to submit its report and conclusions to the Secretary of the Interior in the autumn of 1986. At the time of the accident, there were no restrictions to flight operations above the Grand Canyon. However, many operators believed and the NPS implied that it would recommend to the Department of the Interior that they seek the legislative authority to implement such restrictions. Consequently, suggestions by NPS personnel to Grand Canyon scenic air tour operators on the operation of their flights, irrespective of the informality of the requests, were taken seriously by scenic air tour operators in the hope that such cooperation would forestall the implementation of extensive restrictions. When such a request was made to rotary-wing operators to move their entry and exit points because of the proximity of those points to popular tourist sites, the operators willingly complied.

The Safety Board believes that the NPS did create the impression that they would seek restrictions on the operation of flights above the Grand Canyon. Their request for route modification was consistent with their mandate to preserve the resources of the Grand Canyon National Park; however, had the operators not complied, they would have been faced with the probability that the NPS would seek more restrictive legislation affecting flight operations in the Grand Canyon airspace than would otherwise have been sought.

Moreover, there was no evidence that the NPS worked with the FAA in making suggestions on route changes to the operators or considered the safety implications of those suggestions. Therefore, the Safety Board concludes that because the NPS indirectly influenced the modification of the routes of the rotary-wing operators, which resulted in their routes being closer to those of the fixed-wing aircraft, the NPS contributed to the accident.

2.5 Crash, Fire, and Rescue Efforts

Despite the fact that the accident was not survivable, the Safety Board was concerned that, because of the remote nature of the wreckage site, the rescue efforts may have been inadequate in the event that there had been survivors. However, due to the many helicopters in the area and the use of the common radio frequency, the Safety Board believes that a sufficient number of helicopters could have been alerted to the accident and would have been prepared to provide assistance quickly. The NPS routinely provided helicopter rescue services to those injured in remote sections of the park.

Although the small clinic that the NPS maintained in the Grand Canyon would, most likely, have been inadequate to provide care to as many as 25 survivors of an aircraft accident, hospitals in Flagstaff and Williams could have provided the needed services. These hospitals had been used in the past by Grand Canyon visitors in need of more extensive treatment. Consequently, the Safety Board believes that crash, fire, and rescue capabilities in the Grand Canyon would have been adequate to respond to a survivable aircraft accident in the park.

3. CONCLUSIONS

3.1 Findings

1. The flightcrews of the two aircraft were properly certificated and qualified for their respective flights.
2. The flightcrews of the two aircraft possessed considerable experience in operating their respective aircraft in Grand Canyon sightseeing operations.
3. The accident was not survivable due to the impact forces and postaccident fire that consumed much of the aircraft.
4. The two aircraft were properly certificated and maintained in accordance with applicable regulations and established maintenance procedures.
5. There was no evidence of structural failure, malfunction, or other abnormality in either of the two aircraft before the in-flight collision.
6. The flightpaths of the two aircraft before the accident could not be reconstructed due to the lack of flight recorders and recorded air traffic control radar data.
7. It could not be explained why the flightcrews of the two aircraft failed to "see and avoid" each other.
8. The lack of flight and duty time limitations of the DHC-6 pilots and the lack of intercom or public address system on the Bell 206B limited the safety of each operation.
9. The similarity of routes and limited number of scenic points overflown by scenic air tour operators increased the risk of a midair collision.
10. The FAA did not modify the regulations necessary to allow them to properly oversee Grand Canyon scenic air tour flight operations.
11. The Grand Canyon Flight Operators Association lacked authority to influence the conduct of Grand Canyon scenic air tour flight operations.
12. The rule changes that the FAA has proposed should correct many of the deficiencies in current FAA authority to perform surveillance over Grand Canyon scenic air tours. However, the workload of the personnel in the Las Vegas FSDO may preclude their effective implementation.
13. The National Park Service, through its authority to preserve the resources of the National Parks, created the impression that it would seek restrictions to the use of the Grand Canyon airspace. This influenced operators to modify their Grand Canyon scenic air tour routes.

14. The modification of the routes of the rotary-wing operators resulted in their routes intersecting with those of Grand Canyon Airlines in the area of Crystal Rapids and this contributed to the accident.

15. Crash, fire, and rescue capabilities would have been adequate to respond to a survivable aircraft accident in the Grand Canyon.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the flightcrews of both aircraft to "see and avoid" each other for undetermined reasons. Contributing to the accident was the failure of the FAA to exercise its oversight responsibility over flight operations in the Grand Canyon airspace and the actions of the National Park Service to influence the selection of routes by Grand Canyon scenic air tour operators. Also contributing to the accident was the modification and configuration of the routes of the rotary-wing operators resulting in their intersecting with the routes of Grand Canyon Airlines near Crystal Rapids.

4. RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board recommended that the Federal Aviation Administration:

> Apply to revenue air tour flights the same flight and duty time limitations that apply to operations conducted under 14 CFR 135.265. (Class II, Priority Action) (A-87-91)
>
> Require pilots of revenue air tour flights to use a public address system, intercom, or similar system while narrating air tour flights. (Class II, Priority Action) (A-87-92)
>
> Require all revenue air tour flights, regardless of the distance flown, to be subject to the regulatory provisions of 14 CFR Part 135, and not 14 CFR Part 91. (Class II, Priority Action) (A-87-93)

Member filed the following dissenting statement:

I respectfully disagree with my colleagues' adoption of the two recommendations (A-87-91 and -93) to the Federal Aviation Administration (FAA) which recommended that all revenue air tour flights be subject to and conducted under the provisions of 14 CFR Part 135. In my opinion the recommendations encompass every sightseeing flight and would therefore impose unrealistic and unnecessary restrictions on a substantial number of operations conducted safely under Part 91.

I believe there is reason to support these requirements for regularly scheduled revenue air tour flights of the type that are present at the Grand Canyon. Those air tour operations exhibit the characteristics typically associated with Part 135 commuter operations including advertised regular schedules and routes, formalized reservation and ticketing procedures, and terminal buildings with passenger waiting areas. Such operations often carry a high volume of passengers on multiple daily flights and would be appropriate candidates for the increased requirements of Part 135.

However, the accident and incident data does not support a blanket prohibition of all revenue sightseeing operations under 14 CFR Part 91. There is no indication of a widespread degradation of the safety of such operations.

The existing Federal Aviation Regulations offer an enhanced level of safety for revenue sightseeing operations under Part 91 by requiring the pilot to be commercially rated and hold a Class II medical certificate. The aircraft used for sightseeing under Part 91 are required to have an inspection for each 100 hours of operation. These requirements are considerably more stringent than those required for a nonrevenue operation and, as accident data have shown, have resulted in an adequate level of safety.

It is my belief that the vast majority of nonscheduled, revenue sightseeing operations do not involve excessive flight and duty time and their inclusion under the requirements of Part 135 is inappropriate. With regard to FAA oversight of such operations, if it is the lack of oversight by the FAA that the Board feels is wanting, then the recommendation should address that need instead of applying the blanket provisions of Part 135.

Therefore, I vote against adoption of these two recommendations as presented.

ICAO Note.— Section 1.17, Figures 1 to 3 and the Appendices were not reproduced.

ICAO Ref.: 178/86

No. 5

Boeing 737-200, C-GQBH, accident at Wabush, Newfoundland, Canada, on 20 July 1986. Report No. 86-A60024 released by the Canadian Aviation Safety Board.

SYNOPSIS

The aircraft was on a scheduled flight from Wabush, Newfoundland to Sept-Iles, Quebec. On take-off at a speed between 114 and 126 knots, a bird was ingested into the left engine. The engine lost power, and the crew rejected the take-off. The aircraft came to a stop in a bog 200 feet beyond the end of the runway.

The Canadian Aviation Safety Board (CASB) determined that, because the runway was wet, the distance required to stop the aircraft exceeded that which was available. Pre-flight take-off performance calculations did not take into account the effects of the wet runway, nor was such a calculation required by regulation.

1.0 FACTUAL INFORMATION

1.1 History of the Flight

On 20 July 1986, Quebecair Flight 461, a Boeing 737, C-GQBH, taxied to runway 19 at Wabush, Newfoundland for a scheduled flight to Montreal, Quebec via Sept-Iles, Quebec. The aircraft began its take-off with the first officer in the right seat flying the aircraft. During the take-off roll, the first officer sighted a bird on the runway. He called "bird" at 114 knots*, and, at 126 knots, the left engine began to lose power. The first officer called "reverse"; the captain selected reverse thrust, deployed the speed brakes, and both crew members applied maximum wheel braking. The aircraft left the right side of the runway about 175 feet before the runway's end. It proceeded another 375 feet before coming to rest in a bog 200 feet beyond the end of the runway. As the aircraft entered the bog, the captain shut down both engines by pulling the fire handles. Once the aircraft had stopped, the crew completed the emergency shutdown check-list, and the passengers and crew evacuated through the rear doors. One passenger suffered a broken ankle during the evacuation.

The accident occurred at lat 52°55'N, long 66°52'W** at 1448 Atlantic daylight time (ADT)*** during the hours of daylight.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	1	-	1
Minor/None	6	57	-	63
Total	6	58	-	64

1.3 Damage to Aircraft

The aircraft sustained substantial damage.

* Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

** See Glossary for all abbreviations and acronyms.

*** All times are ADT (Coordinated Universal Time (UTC) minus three hours) unless otherwise stated.

1.4 Other Damage

The aircraft broke a runway threshold light when it overran the runway.

1.5 Personnel Information

	Captain	First Officer
Age	47	37
Pilot Licence	Airline Transport	Airline Transport
Medical Expiry Date	01/10/86	01/09/86
Total Flying Time	14,000 hr	9,500 hr
Total on Type	3,500 hr	1,900 hr
Total Last 90 Days	160 hr	120 hr
Total on Type Last 90 Days	160 hr	110 hr
Hours on Duty Prior to Occurrence	7 hr	7 hr
Hours off Duty Prior to Work Period	14 hr	14.5 hr

Both pilots held valid Class 1 Group 1 instrument ratings, and both had completed pilot proficiency checks and simulator training on type within the past three months.

1.6 Aircraft Information

Manufacturer	Boeing Aircraft Corp.
Type	737-200
Year of Manufacture	1981
Serial Number	22516
Certificate of Airworthiness	Valid
Total Airframe Time	12,210 hr
Engine Type (2)	Pratt & Whitney JT8D-9A
Maximum Allowable Take-off Weight	119,500 lb
Recommended Fuel Types	Jet A, Jet B

The aircraft was maintained in accordance with approved Transport Canada procedures. All required maintenance checks and airworthiness directives had been carried out.

1.7 Meteorological Information

The captain received a company dispatch weather briefing before leaving Montreal on the outbound leg. The actual weather at Wabush was as forecast: 500 feet scattered, estimated ceiling 1,100 feet broken, 2,000 feet overcast, visibility eight miles in very light rain showers, and temperature 17 degrees Celsius. Light rain had been falling at Wabush for over five hours prior to the accident.

1.8 Aids to Navigation

- Not applicable -

1.9 Communications

The flight crew was in very high frequency (VHF) contact with Wabush Flight Service Station (FSS). All communications were normal.

1.10 Aerodrome Information

Transport Canada operates the Wabush Airport as a licensed public airport. The one runway, 01/19, is 6,000 feet by 150 feet with an asphalt surface and concrete buttons. Runway 19 has a 700-foot clearway and no stopway.

The runway was wet during the take-off. The captain reported there was no standing water on the runway. Investigators could not confirm the presence of standing water during the accident. In the days after the accident, five inspections of the runway were made after moderate rainfalls and at no time was standing water detected.

1.11 Flight Recorders

The aircraft was equipped with a Fairchild Model A100 cockpit voice recorder (CVR) and a Lockheed Model LAS 209E flight data recorder (FDR). Both recorders were recovered from the aircraft and analysed at the National Research Council, Flight Recorder Playback Centre. The sequence of events as determined from the CVR and FDR was as follows:

1447:24 - Aircraft in take-off position.
1447:39 - Engine pressure ratio (EPR) stabilized at 1.40.
1447:45 - EPR at 2.00 on both engines.
Knots indicated airspeed (KIAS)
KIAS 47 - KIAS starts to indicate.
1447:49 KIAS 55 - Thrust confirmed OK.
1447:56 KIAS 86 - Eighty-knot call.
1448:03 KIAS 114 - "Bird" called.

1448:06	KIAS 126	- EPR on left engine decreases rapidly.
1448:07		- Thump sound on CVR.
1448:08	KIAS 130	- "Reverse" called.
1448:09	KIAS 131	- EPR decreasing on right engine. - Speed starts to decrease rapidly. - Another thump sound heard.
1448:10	KIAS 128	- Aircraft starts slight right turn on runway. - EPR left engine 1.00 and remains there.
1448:11	KIAS 120	- EPR right engine drops to 1.20 then increases rapidly (reverse thrust).
1448:12		- Left rudder applied (up to 50 per cent).
1448:15	KIAS 93	- EPR right engine levels off at 2.10.
1448:23	KIAS 47	- EPR on right engine starts to decrease. - Heading about 220 degrees magnetic.
1448:24		- Call for engine shutdown.
1448:25		- Aircraft pitched down (nosewheel goes over edge of solid ground and falls into the bog).
1448:26		- EPR right engine 1.10, aircraft returning to level (main wheels enter bog).
1448:28		- EPR right engine 1.00, aircraft level, heading 236 degrees magnetic.
1448:29		- Aircraft stopped.
1448:30		- Power off FDR.

1.12 Wreckage and Impact Information

The aircraft left the right side of the runway 175 feet before the end. It proceeded another 375 feet before going over a small ridge and into a bog.

The brakes and anti-skid system were examined and found to be serviceable. Inspection of the tires showed no indications that hydroplaning had occurred during the rejected take-off procedure.

The remains of a herring gull weighing approximately two pounds were found on the fan intake of the left engine. Post-accident inspection revealed no damage to either engine as a result of the bird strike. The aircraft nosewheel light, lower radio antenna, nosewheel door, left engine thrust reverser, and tail cone were damaged after the aircraft left the runway.

1.13 Medical Information

There was no evidence that incapacitation, physiological, or psychological problems affected the crew's performance.

1.14 Fire

There was no evidence of fire either before or after the occurrence.

1.15 Survival Aspects

The accident was survivable; impact forces present during the deceleration were well within human tolerance. The airport firemen responded quickly to the accident; the elapsed time between the crash alarm and their arrival on site was 1 minute and 55 seconds.

Because the aircraft had departed the runway at a relatively slow speed and because there were no indications of fire or other hazards, the captain elected to deplane in the normal manner rather than by an emergency evacuation. The airstairs could not be used, however, because battery power is required to operate them from inside the aircraft, and the battery had been selected off during the shutdown check-list. The captain decided, therefore, to evacuate from the rear of the aircraft as the rear doors were already open. The cabin crew then deployed the chutes. Because of interference from some bushes near the aircraft and because the aircraft was so low to the ground, the cabin crew was unable to fully deploy the chutes until assisted by crash/rescue personnel from outside the aircraft.

The flight attendants were unable to use the aircraft intercom or public address systems without aircraft electrical power. Raised voices were used in the cabin to communicate; the loud hailers were not used. The majority of passengers interviewed stated that the evacuation instructions were clear and that there was very little confusion.

A degree of urgency developed during the evacuation after the chutes had been correctly deployed. During the orderly evacuation, the firemen gave instructions to the flight attendants to hurry, and, as a result, the attendants, perceiving that something was wrong outside the aircraft, sped up the evacuation process.

There were seven minor injuries and one serious injury (broken ankle), all of which occurred during the evacuation.

1.16 Tests and Research

An airport site survey was conducted at Wabush to assess the bird hazard potential. The report indicated that Wabush Airport does not appear to offer any significant attraction other than the well-known appeal that flat-surfaced open areas have to seagulls. Potential food sources on the airfield are scarce. The only identifiable factor which could contribute to the presence of birds on the airfield is the weekend accumulation of garbage at the entrance to an incinerator/dump one kilometre away. The report recommended that the airport management discuss and attempt to resolve this issue with the dump operators.

1.17 Additional Information

1.17.1 Manuals

Quebecair utilizes three manuals in the calculation of aircraft take-off data: the Federal Aviation Administration (FAA) approved B737 Airplane Flight Manual, the B737 Operations Manual, and the Quebecair Operating Gross Weight Manual. The take-off data in the B737 Airplane Flight Manual complies with Federal Aviation Regulation (FAR) 25 (Airworthiness Standards) and FAR 121 (Certification and Operation). The other two manuals also conform with these FARs in that the manuals cannot be less restrictive. Aircraft which have been certified in the United States in accordance with these FARs are certified in Canada once Transport Canada determines that any additional Canadian requirements have been met.

1.17.2 Definitions

The following terms are used throughout this report:

1. Critical Engine Failure Recognition Speed (V_1) - the speed at which, if an engine failure occurs, the distance to continue the take-off to a height of 35 feet will not exceed the usable take-off distance; or the distance to bring the airplane to a full stop will not exceed the accelerate-stop distance available.

2. Accelerate-Stop Distance (ASD) - that distance required to accelerate the aircraft from a standing start to V_1, then continue accelerating for two seconds beyond V_1, and then bring the aircraft to a full stop. The accelerate-stop distance available (ASDA) includes the length of an available stopway.

3. Take-off Distance (TOD) - that distance required to accelerate the aircraft to the V_2 climb speed at a height of 35 feet. The take-off distance available (TODA) includes the length of an available clearway.

4. Take-off Safety Speed (V_2) - Assuming engine failure at V_1, the V_2 value is equal to the actual speed at 35 feet above the runway end as demonstrated in flight and must be equal to or greater than 120 per cent of stall speed in take-off configuration.

1.17.3 Existing FAA Regulations

Under FAR 25.105, all take-off calculations must take into consideration the aircraft weight, the aircraft configuration, the surface wind, the ambient temperature, the take-off altitude, and the runway gradient. Unless a cluttered runway exists, the pilot is not required to consider the runway condition, and all take-off data are based on a smooth, dry, hard-surfaced runway. Under FAR 121.189, the FAA restricts turbine-powered aircraft to take-off weights such that the ASD must not exceed the length of the runway plus the stopway, and the TOD must not exceed the length of the runway plus the usable length of any clearway. The requirements of FAR 121 are adhered to by Boeing in determining aircraft performance and, therefore, are incorporated into the Boeing and Quebecair manuals.

1.17.4 Quebecair Take-off Calculations

In the calculation of take-off data, Quebecair defines three types of take-offs: normal take-off, take-off with runway clutter (one-quarter inch or more of standing water, wet snow or slush), and take-off with anti-skid inoperative. As neither of the two latter conditions was present on departure from Wabush, calculations for the accident take-off were based on a normal take-off.

Dispatch personnel determine the operational requirements, fuel load, and passenger load and then calculate the take-off weights (actual and maximum) using the Quebecair Operating Gross Weight Manual and the forecast weather. The fuel load is based on both operational requirements and cost; fuel is 'tankered' if the fuel cost differential warrants it. (Tankering is the industry term used to describe the intentional carriage of fuel in excess of the amount dictated by operational requirements.) The captain is responsible for recalculating the take-off data using the actual weather conditions and notifies dispatch if a discrepancy exists between the two calculations. He then records his calculations on the take-off data bug card.

In this case, there were no discrepancies. The computed data for the take-off conditions at the time of the accident were as follows:

V_1 = 127 knots;
ASD = TOD = 5,600 feet (no wind);
ASDA = 6,000 feet; and
TODA = 6,600 feet (600 feet is the maximum clearway usable for a 6,000-foot runway in accordance with the B737 Airplane Flight Manual).

According to the Quebecair weight and balance and load sheet for the accident flight, the aircraft fuel load was 17,800 pounds. The sheet also indicated that the minimum acceptable fuel load for the trip was 12,800 pounds; that is, 5,000 pounds of fuel were being tankered.

1.17.5 Accelerate-Stop Distance

As previously stated, applicable FARs only require that runway condition be considered in calculating ASD when there is one-quarter inch or more of standing water, wet snow, or slush on the runway. The B737 Airplane Flight Manual, however, does recommend that, when taking off from a wet/slippery runway, the operator review the existing runway conditions and decide how much additional stopping distance is required. There are no published data to assist the operator in determining this extra distance required, nor is the manufacturer required to provide any. The operator can reduce the ASD by an amount equal to this additional stopping distance by reducing the aircraft take-off weight or, in some cases, by reducing V_1. As a reduction in V_1 will increase the TOD required, V_1 can only be reduced when there is excess runway and/or clearway available. In addition, and as detailed in both the B737 Operations Manual and the Quebecair Operating Gross Weight Manual, the ASD can be reduced by approximately 100 feet by turning the aircraft air-conditioning off for take-off.

It is not normal practice for Quebecair or other Canadian operators to make an additional allowance for the effects of wet or slippery runways when calculating ASD. The Canadian Forces in its transport aircraft operations routinely reduces take-off weights and V_1 when operating at runway limited weights from wet runways in order to ensure that the wet runway ASD is not greater than the available runway length.

1.17.6 Quebecair Take-off Procedures

1.17.6.1 Right Seat Take-off

Quebecair regulations permit a first officer take-off from the right seat. The first officer was qualified to conduct the take-off.

1.17.6.2 Bird Protection

Quebecair regulations require the use of landing lights for take-off. The inboard landing lights and the runway turn-off lights were selected on for take-off.

1.17.6.3 Air-Conditioning

In accordance with Quebecair procedures, the air-conditioning was selected on for take-off.

1.17.6.4 Rejected Take-off

On take-off, Quebecair procedures specify that either pilot may call an emergency before V_1. The captain then decides if the take-off is to be rejected and, if so, calls "reject" and carries out the rejected take-off procedure. In this case, the first officer called "bird" and "reverse" instead of specifying the emergency, and the captain did not call "reject." These non-standard calls had no effect on the execution of the reject procedure. Apart from these calls, the crew carried out all normal and emergency take-off actions in accordance with published procedures.

The rejected take-off procedure in the B737 Operations Manual requires that the captain "apply reverse thrust rapidly as required."

2.0 ANALYSIS

2.1 Introduction

Although the take-off was planned and carried out in accordance with existing regulations and procedures, the aircraft could not be stopped on the runway remaining. Post-accident inspection revealed that the left engine was not damaged by ingestion of the bird. However, the ingestion of the bird disrupted the airflow sufficiently to cause the engine to flame out. Because of the use of asymmetric reverse thrust on the wet runway, the aircraft departed the right side of the runway just before reaching the end. Pre-flight calculations to determine the ASD were based upon performance data for a dry runway. The runway was wet at the time.

The analysis of this accident will concentrate on the calculation of ASD for wet or slippery runways and the options available to the operator to reduce the ASD in these conditions.

2.2 Wet Runway ASD

Whenever a runway surface is wet, the coefficient of friction between the aircraft tires and the runway surface is reduced from that of a dry runway. This reduction in the coefficient of friction can be as much as 30 per cent, thus resulting in up to a 60 per cent increase in the distance required to stop the aircraft and, therefore, a significant increase in the ASD.

There are a large number of variables associated with the calculation of runway coefficients of friction: surface type, surface condition, aircraft type, tire type, and tire condition, to name but a few. Although it is possible to estimate a coefficient of friction for any given set of conditions, this coefficient is accurate only for that particular set of conditions. It may differ considerably for a different aircraft type or even within a short period of time for the same aircraft. Therefore, it is difficult to estimate a coefficient of friction for every take-off. The regulatory authorities do not require the publication of criteria for operators to use for take-off calculations on wet or slippery runways.

Although the B737 Airplane Flight Manual does recommend reducing ASD on wet runways, the operator must select an arbitrary distance to compensate for the reduced braking action. There are no charts or figures provided to aid the operator in these calculations.

This lack of published criteria has made it difficult to develop enforceable standards and regulations in this matter. As a result, the aircraft manufacturers and operators in the main do not provide quantitative data on the effects of wet or slippery runways on ASD when calculating take-off data.

2.3 Reduction of ASD

Although there are no published criteria which pertain to the reduction of ASD on wet runways, there are options open to the aircraft operators. ASD can be reduced by decreasing the take-off weight and, in certain circumstances, by reducing the V_1 speed or by a combination of both. At all times, the ASD can also be reduced by 100 feet by turning the air-conditioning off for take-off.

The weight for this take-off was well within legal limits. However, because of the Quebecair policy to tanker fuel from Wabush, the aircraft fuel at take-off was 5,000 pounds in excess of that required for the flight. According to the B737 Airplane Flight Manual, a fuel load reduction of 5,000 pounds would have reduced the TOD and ASD by 700 feet and the V_1 by 5 knots from 127 to 122 knots. With this reduced fuel load, the engine failure would have occurred four knots after reaching V_1, and the take-off would have been continued. If the failure had occurred at or below V_1, the reduction in ASD would have resulted in 700 feet of additional stopping distance available. The reduction of gross weight either by reducing fuel load or payload is the only way to reduce ASD when operating at field limited gross weight.

If the TODA exceeds the TOD and if the ASDA is at least equal to the ASD, then the operator also has the option to arbitrarily reduce V_1. For example, for the accident flight, a range of V_1 from 122 to 127 knots (no wind) was available to the operator. A V_1 of 122 knots at a take-off weight of 94,000 pounds gives a TOD of 6,400 feet and an ASD of 5,400 feet. Therefore, a V_1 reduction to 122 knots would have provided an additional 200 feet of stopping distance while still permitting the take-off to be performed in accordance with regulations, using both the runway and the clearway. If V_1 had been reduced in this manner for the accident flight, the engine failure would have occurred four knots above V_1, and the take-off would have been continued.

There is no reason to believe that the take-off would not have been successful as the wet runway, although a significant factor in aircraft deceleration, would have had a negligible effect on aircraft acceleration.

It is not possible to say precisely what effect a 5,000-pound reduction in take-off weight or a reduction in V_1 would have had on the outcome of this accident. These options, although open to both the operator and the pilot, were not exercised, nor was there a requirement to do so by regulation. However, reductions of gross weight and V_1 are acceptable and effective methods of decreasing the ASD.

2.4 Evacuation

With aircraft electrical power selected off, it was necessary to use the emergency chutes to evacuate the aircraft. Experience has shown that in any evacuation using the emergency chutes the potential for injury is high. In this occurrence, one passenger sustained a broken ankle. Although in this case no fire occurred, *given the high potential for fire in runway excursions*, the actions of the crew to complete an emergency shutdown and use the emergency slides are considered prudent.

3.0 FINDINGS

3.1 Cause-Related Findings

1. As the aircraft speed approached V_1, a seagull was ingested into the left engine, and, as a result, the engine lost power.
2. In accordance with established procedures, the captain elected to reject the take-off.
3. Pre-flight take-off performance calculations did not take into account the effects of a wet runway, and, as a result, the distance required to stop the aircraft exceeded the distance available.
4. Although it is known that wet runways increase stopping distances, existing airplane flight manuals do not provide data which take into account the effects of wet runways on accelerate-stop distances.

3.2 Other Findings

1. The flight crew was certified and qualified for the flight in accordance with existing regulations.
2. The aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.
3. The weight and centre of gravity were within the prescribed limits.

4.0 SAFETY ACTION

4.1 Action Required

4.1.1 Take-off Performance Requirements-Wet Runway Operations

Under current certification criteria for transport category aircraft, take-off speeds and performance calculations (including accelerate-stop distance requirements) are based upon a smooth, dry and bare runway. A wet runway reduces the braking efficiency of an aircraft during a rejected take-off, resulting in increased accelerate-stop distances. Manufacturers and regulatory authorities have established take-off distance requirements for transport category aircraft when standing water of one-quarter or one-half inch in depth is present. However, similar accelerate-stop distance calculations for wet runways, where there is no measurable amount of standing water, have not been made due to the variable effect on aircraft deceleration performance of such factors as tire design and condition, aircraft type, runway surface type and condition.

As a consequence, take-off performance calculations are based upon the following runway conditions: either the runway is smooth, bare and dry or it is "cluttered" (e.g., with measurable amounts of water or slush). Flight crews are faced with a difficult decision when a runway is wet (but not cluttered) and performance calculations (based upon a dry runway) indicate that the take-off distance required is equal to or near the length of runway available. Air carrier procedures state that flight crews can reduce the required length of runway by reducing the aircraft take-off weight. This reduction in take-off weight can only be achieved through a reduction in payload (passengers and freight) or fuel. Reducing payload would have a negative economic impact, and air carriers normally do not carry fuel in excess of operational requirements. Furthermore, air carriers are reluctant to reduce the aircraft take-off weight as the resultant performance benefit for a wet runway take-off cannot now be reliably measured. As a consequence, wet runway take-offs do not always provide a margin of safety comparable to that for dry runway take-offs.

Providing that the accelerate-stop distance required for a dry runway is less than the take-off run available (including the stopway), air carriers do have another alternative; i.e., reduce the critical engine failure recognition speed V_1 in accordance with performance data contained in airplane flight manuals.

Reduced V_1 speeds result in less runway being used during the acceleration to V_1 and less stopping distance being required because of the lower peak speed attained. The combined effect contributes to an increased safety margin during a rejected take-off. However, use of reduced V_1 speeds is not fully supported by air carriers. In addition, the calculations required to determine minimum-allowable reduced V_1 speeds require flight crew to perform relatively complex graph analysis.

After discussion with a number of air carrier flight operations personnel, the CASB believes that flight crews have minimal knowledge of how to increase the margin of safety when operating off wet runways. Additionally, the CASB is aware that flight crews have doubts about the adequacy of current criteria for operating on contaminated runways.

In view of the absence of certificated performance data and the apparent lack of knowledge on the part of flight crews regarding wet runway take-off performance, the CASB recommends that:

> The Department of Transport revise air carrier procedures involving wet runway take-off operations, in order to provide a margin of safety comparable to that for dry runway operations.
>
> CASB 87-45
>
> The Department of Transport require air carriers to improve flight crew knowledge of the effects of wet runways on take-off performance and the means available to flight crews to provide a margin of safety comparable to that for dry runways.
>
> CASB 87-46

ICAO Note.— The Appendices were not reproduced.

ICAO Ref.: 2047/86

No. 6

McDonnell Douglas DC-9-32, XA-JED, and Piper PA-28-181, N4891F, mid-air collision over Cerritos, California, United States, on 31 August 1986. Report NTSB/AAR-87/07 released by the National Transportation Safety Board, United States.

SYNOPSIS

On August 31, 1986, about 1152 Pacific daylight time, Aeronaves de Mexico, S.A., flight 498, a DC-9-32, Mexican Registration XA-JED, and a Piper PA-28-181, United States Registration N4891F, collided over Cerritos, California. Flight 498, a regularly scheduled passenger flight, was on an Instrument Flight Rules flight plan from Tijuana, Mexico, to Los Angeles International Airport, California, and was under radar control by the Los Angeles terminal radar control facility. The Piper airplane was proceeding from Torrance, California toward Big Bear, California, under Visual Flight Rules, and was not in radio contact with any air traffic control facility when the accident occurred.

The collision occurred inside the Los Angeles Terminal Control Area near 6,560 feet mean sea level. At the time of the collision, the sky was clear, and the reported visibility was 14 miles. The air traffic controller providing service to flight 498 did not observe the Piper airplane's radar return on his display and therefore did not provide any traffic advisory to flight 498 concerning the location of the Piper airplane before the collision. Both airplanes fell to the ground within the city limits of Cerritos. Five houses were destroyed and seven other houses were damaged by airplane wreckage and postimpact fire. Fifty-eight passengers and six crew members on the DC-9 were killed; the pilot and 2 passengers on the Piper were killed; 15 people on the ground were killed and 8 others received minor injuries.

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.

1. FACTUAL INFORMATION

1.1 History of the Flights

On August 31, 1986, about 1141 Pacific daylight time 1/, Piper PA-28-181, N4891F, departed Torrance, California, on a Visual Flight Rules (VFR) flight to Big Bear, California. The pilot of the Piper had filed a VFR flight plan with the Hawthorne, California, Flight Service Station (FSS). According to the flight plan, his proposed route of flight was direct to Long Beach, California, then direct to the Paradise, California, VORTAC 2/, and then direct Big Bear. The proposed enroute altitude was 9,500 feet 3/. However, the pilot did not, nor was he required to, activate his flight plan. At 1140:36, after being cleared for takeoff, the Piper pilot told Torrance tower that he was "rolling;" this was the last known radio transmission received from the Piper.

According to recorded air traffic control (ATC) radar data, after leaving Torrance, the Piper PA-28 pilot turned to an easterly heading toward the Paradise VORTAC. The on board transponder was active with a 1200 code. Postaccident investigation revealed that as the Piper proceeded on its eastbound course, it entered the Los Angeles Terminal Control Area (TCA) without receiving clearance from ATC as required by Federal Aviation Regulations (14 Code of Federal Regulations (CFR) Part 91.90 [a] [1].)

Aeronaves de Mexico, S.A. (Aeromexico), flight 498, a DC- 9-32, Mexican Registry XA-JED, was a regularly scheduled passenger flight between Mexico City, Mexico, and the Los Angeles International Airport (L.A. International), California, via Guadalajara, Loreto, and Tijuana, Mexico. At 1120:00, flight 498 departed Tijuana with 58 passengers and 6 crew members in accordance with its filed instrument flight rules (IFR) flight plans. As the flight proceeded toward L.A. International, at 10,000 feet, it was handed off to Coast Approach Control, which cleared the flight to the Seal Beach, California, VORTAC, and then to "cross one zero miles southeast of Seal Beach at and maintain seven thousand (feet)." At 1144:54, flight 498 reported that it was leaving 10,000 feet, and, at 1146:59, it was instructed to contact Los Angeles Approach Control.

1/ All times herein are Pacific daylight based on the 24-hour clock.

2/ A collocated very high frequency OMNI range station and ultra-high frequency tactical air navigation aid providing azimuth and distance information to the user.

3/ All altitudes are mean sea level unless otherwise specified.

At 1147:28, flight 498 contacted the Los Angeles Approach Control's Arrival Radar-1 (AR-1) controller and reported that it was "level" at 7,000 feet. The AR-1 controller cleared flight 498 to depart Seal Beach on a heading of 320° for the ILS (instrument landing system) runway "two five left final approach course..." Flight 498 acknowledged receipt of the clearance. At 1150:05, the AR-1 controller requested flight 498 to reduce its airspeed to 210 knots indicated airspeed (KIAS) and the flightcrew acknowledged receipt of the request.

Between 1149:36 and 1149:52, flight 498 contacted Aeromexico operations at L.A. International on the company's radio frequency with its arrival message and the Aeromexico station agent gave the gate assignment to the flight.

At 1150:46, the AR-1 controller advised flight 498 that there was "traffic, ten o'clock, one mile, northbound, altitude unknown." Flight 498 acknowledged the advisory, but it never advised the controller that it had sighted the "traffic". (This radar target was not that of the Piper PA-28.) At 1151:04, the AR-1 controller asked the flight to reduce its airspeed to 190 KIAS and cleared it to descend to 6,000 feet. Flight 498 acknowledged receipt of the clearance. At 1151:45, the AR-1 controller asked flight 498 to maintain its present airspeed.

The flightcrew asked the controller what speed he wanted and added that it was "reducing to . . . one niner zero." At 1151:57, the controller told the flight "to hold what you have . . . and we have a change in plans for you." At 1152:00, flight 498 stated that it would maintain 190 KIAS. At 1152:18, the AR-1 controller advised flight 498 to "expect the ILS runway two four right approach . . ." flight 498 did not acknowledge receipt of this message, and the 1152:00 radio transmission was the last known communication received from flight 498.

At 1151:18, after flight 498 was cleared to descend to 6,000 feet, the pilot of a Grumman Tiger airplane, N1566R, contacted the AR-1 controller. At 1151:26, after radio contact was established, the Grumman pilot informed the controller that he was on a VFR flight from Fullerton to Monterey, California, via the Van Nuys, California, VORTAC, that his requested en route altitude was 4,500 feet, and that he would like ATC flight following services. The AR-1 controller did not answer this transmission until 1152:04 when he requested the pilot to set his transponder to code 4524, a discrete transponder code within the 4500 series used by approach control for VFR flights. At 1152:29, the controller asked the Grumman pilot if he was at 4,500 feet and the pilot answered that he was climbing through 3,400 feet. At 1152:36, the AR-1 controller told the Grumman pilot that he was in the middle of the TCA and suggested that "in the future you look at your TCA chart. You just had an aircraft pass right off your left above you at five thousand feet and we run a lot of jets through there right at thirty-five hundred."

The AR-1 controller testified that about 1152:36 he also noticed that the ARTS III computer was no longer tracking flight 498. After several unsuccessful attempts to contact flight 498, he notified the arrival coordinator that he had lost radio and radar contact with the flight.

At about 11:52: 09, flight 498 and the Piper collided over Cerritos, California, at an altitude of about 6,560 feet. The sky was clear, the reported visibility was 14 miles, and both airplanes fell within the city limits of Cerritos. Fifty-eight passengers and 6 crewmembers on flight 498 were killed as were the pilot and 2 passengers on the Piper. The wreckage and postimpact fires destroyed five houses and damaged seven others. Fifteen persons on the ground were killed and others on the ground received minor injuries. The coordinates of the main wreckage site were 33° 52'N latitude and 118° 03' "W longitude.

1.2 Injuries to Persons

	Crew	Passengers	Other	Total
Fatal	7*	60**	15	82
Serious	0	0	0	0
Minor	0	0	8	8
None	0	0	0	0
Total	7	60	23	90

*Includes the pilot of the Piper PA-28
**Includes the passengers on the Piper PA-28

1.3 Damage to the Airplanes

The DC-9-32 was destroyed by the collision, ground impact, and postimpact fire. The Piper PA-28 was destroyed by the collision and ground impact. The estimated values of the Piper and the DC-9 were $28,000 and $9,500,000, respectively.

1.4 Other Damage

Five houses were destroyed and seven others were damaged by airplane wreckage and/or postimpact fires.

1.5 Personnel Information

The flightcrew and cabin crew of flight 498 were qualified in accordance with applicable Mexican, United States, and company regulations and procedures. The examination of the training records of the Aeromexico crew members did not reveal anything extraordinary . Further, the investigation of the background of the flightcrew and their actions during the 2 to 3 days before the accident flight did not reveal anything remarkable.

The air traffic controllers who provided ATC services to flight 498 were qualified in accordance with current regulations. The examination of their training records did not reveal anything extraordinary . In addition, the investigation of these controllers' background and their activities during the 2 to 3 days before reporting for duty on August 31 did not reveal anything extraordinary .

The pilot of the Piper PA-28 was qualified in accordance with applicable United States regulations. During the investigation, the Safety Board interviewed persons who had flown with the pilot of the PA-28, as well as his flight instructors. Friends, relatives, and colleagues who had flown with the Piper PA-28 pilot described him as a conscientious and careful pilot. One friend said that he was "old maidish" with his preflight checklist, sometimes "too careful" about rules, and aware of his "low-time" experience as a pilot.

The Piper pilot's primary flight instructor stated that he had been a diligent and attentive student. He said that he had taught the Piper pilot to scan for other airplanes by starting his scan pattern "at the left, scan, look at instruments, scan to the right, look at instruments," and then repeat the procedure. He stated that the Piper pilot was familiar with the airplane's wing leveler equipment and that he used the wing leveler "as it was intended" to be used when looking at maps, reviewing charts, or doing other in-cockpit activities.

Another flight instructor who had provided instrument flight training to the Piper pilot stated that they had discussed and used sectional charts during training and that the training had included the numbers used on these charts to show the floor and ceiling altitudes of a TCA. He said the Piper pilot was familiar with VFR hemispherical altitudes, 4/ that he was a "VFR pilot who liked to look out," and that he was more inclined to navigate by visual reference to the ground than by use of navigational radio aides. The flight instructor also stated that he and the Piper pilot had discussed TCAs and other types of restricted airspace, the equipment requirements for flying within restricted airspaces, and the arrival and departure procedures used in the Los Angeles area.

The Piper pilot had moved to Los Angeles from Spokane, Washington, in October 1985. On December 14, 1985, he received Los Angeles area familiarization training and flew an area familiarization flight with a flight instructor. In March 1986, he flew his airplane, N4891F, from Spokane to Los Angeles. Since December 1985, he had flown seven flights in the Los Angeles area and had logged about 5.5 hours on these flights.

1.6 Airplane Information

The DC-9-32, XA-JED, was owned and operated by Aeromexico. Examination of the DC-9's flight and maintenance logbooks did not reveal any airplane discrepancies or malfunctions that would have contributed to the accident. Examination of the flight's dispatch documents showed that the airplane was operating within its allowable weight and balance limitations. The DC-9 was treated aluminum with orange and blue trim.

The DC-9 had nose gear landing and taxi lights; one wing landing light in each wing; anti-collision lights on top and bottom of the fuselage; ground floodlights in the left and right side of the fuselage; and wing and nacelle flood lights on the left and right sides of the fuselage. In accordance with company procedures, except for the nose gear landing light, all lights are turned on when the airplane is below 10,000 feet.

The Piper PA-28-181, N4891F, a single engine fixed landing gear type airplane, was owned by the pilot involved in the accident. Examination of the airplane's flight, maintenance, and engine logbooks did not reveal any discrepancies that would have contributed to the accident. Reconstruction of the airplane's fuel, baggage, and passenger seating locations on the accident flight showed that N4891F was operating within its allowable weight and balance limitations. N4891F was equipped with a NARCO Model AT-50A transponder without a mode C altitude encoder. Given this transponder configuration, N4891F could provide position but not altitude information to Los Angeles Approach Control. The evidence showed that the transponder was functioning properly during the accident flight.

N4891F was painted white with a double yellow stripe running longitudinally along the fuselage. The registration number was blue and there were blue stripes on the wheel pants. N4891F was equipped with navigation lights, a white anticollision strobe light on each wingtip, a rotating red beacon atop the vertical stabilizer, and a landing light on its nosegear. All the light switches were found in the "on" position in the airplane wreckage.

4/ Pursuant to 14 CFR Part 91.109, each person operating an aircraft under VFR in level flight more than 3,000 feet above the surface and below 18,000 feet shall maintain the following altitudes: on a magnetic course of zero° through 179°, any odd mean seal level (MSL) altitude plus 500 feet (such as 3,500, 5,500); on a magnetic course of 180° through 359°, any even thousand feet MSL altitude plus 500 feet (such as 4,500, 6,500).

N4891F was equipped with an Autocontrol IIIB autopilot, which is also called a "wing leveler." The autopilot was a lateral control system, which provided only roll control inputs to the airplane's controls. The airplane would hold a selected heading when the autopilot's heading switch was engaged. The autopilot did not incorporate a radio coupler and, therefore, the airplane could not fly with reference to a radio defined course. The position of the autopilot's control switches could not be determined during the postaccident investigation.

Flight simulations were conducted during the investigation to determine N4891F's climb performance. A Piper PA-28-181, N4305V, configured similary to N4891F on the accident flight, was flown from Torrance Municipal Airport toward the location of the collision using three different climb speeds: 76 KIAS, 80 KIAS, and 85 KIAS. N4305V reached the accident location and 6,500 feet in 11 minutes 31 seconds, 11 minutes 30 seconds, and 11 minutes 45 seconds, respectively. On the day of the simulation, the temperatures aloft were almost identical to those recorded on the day of the accident; the speed of the winds aloft were negligible from the surface to 7,000 feet, whereas on the day of the accident the Piper may have had about a 9-knot tailwind component between about 5,300 feet and 6,500 feet.

1.7 Meteorological Information

The terminal forecast for LA International, issued by the National Weather Service (NWS) Los Angeles Forecast Office at 0818, August 31, 1986, and valid from 0900 August 31, to 0900 September 1, stated in part that after 1100 on August 31, the weather would be clear. Infrared photographs taken by the Geostationary Operational Environmental Satellite (GOES) at 1031 and 1131 on August 31 did not show any clouds over the land areas of southern California.

The 1146 surface weather observation at Fullerton Airport (about 4 miles east of the accident site) stated in part that the weather was clear and the visibility was 15 miles. The 1149 surface weather observation at Long Beach Airport (about 6 miles southwest of the accident site) stated in part that the sky was clear and the visibility was 15 miles. The 1150 surface weather observation at L.A. International (about 18 miles west of the accident site) stated in part that the sky was clear and the visibility was 14 miles.

San Diego, California, was the closest point to Los Angeles where NWS upper air sounding data were available. The 0400 San Diego sounding showed a strong *subsidence inversion* 5/ *with a base at 1,925 feet and a top at 3,102 feet; the atmosphere* was dry above the inversion. The 1600 sounding also showed the subsidence inversion. The base was at 2,122 feet, the top at 3,070 feet, and the atmosphere was dry above the inversion.

At the time of the accident, the elevation of the sun was 61° 55' above the horizon with an azimuth (bearing from true north) of 148°. This is computed from 34° 0' N latitude, 117° 56' W longitude.

1.8 Navigational Aids

There were no known navigational aids difficulties.

5/ *Temperature normally decreases with increasing altitude. An increase in temperature* with altitude is defined as a temperature inversion. A subsidence inversion is a temperature inversion produced by the warming of a layer of subsiding (descending) air.

1.9 Communications

There were no known communications difficulties.

1.10 Aerodrome Information

Torrance Municipal Airport, elevation 101 feet, is 3 miles southwest of Torrance, California. The airport is served by two runways: 29L/11R, and 29R/11L. The Piper PA-28 departed from runway 29R, which is 5,000 feet long and 150 feet wide.

Los Angeles International Airport (L.A. International), elevation 126 feet, is served by two pairs of parallel runways; runways 25L/7R and 25R/7L are on the south side of the airport's terminal complex, and runways 24L/6R and 24R/6L are on the north side. Runways 25L, 25R, 24L, and 24R are served by ILS approaches.

L.A. International is located near the center of its TCA. Except for a triangular segment in the vicinity of Long Beach, California, the apex of which extends northward from its southern boundary, the TCA is essentially a parallelogram. Its western and eastern boundaries are about 20 nmi and 25 nmi, respectively, from the western edge of L.A. International. The TCA's northern and southern boundaries are essentially parallel to the extended centerlines of L.A. International's four runways and are each about 10 nmi from the center of the airport.

Vertically, the TCA resembles an "upside down" wedding cake, beginning at the surface at L.A. International and rising to a ceiling of 7,000 feet. Proceeding westward from the airport and aligned with the extended centerlines of the airport's runways, the floor of the TCA remains at the surface. Between 11 nmi and 20 nmi west of the airport, the floor rises to 2,000 feet. A similar gradient exists along the eastward extensions of the four runway centerlines. To the north and south of the airport and the extended centerlines of the four runways, the floor of the TCA rises sharply.

The lateral and vertical dimensions of the Los Angeles TCA are depicted on the Los Angeles VFR Terminal Area Chart. On one side of the chart, the TCA is superimposed on a Lambert Conformal Conic Projection map; the chart's overleaf contains a Charted VFR Flyway Planning Chart of the TCA. In addition to depicting the numerous airports in the Los Angeles area, the plan view also depicts prominent landmarks within and adjacent to the TCA. For example, the planning chart shows that Disneyland and the Anaheim Stadium are just east of the TCA's eastern boundary. It also depicts and names the freeways located within and around the TCA. Finally, the planning chart depicts the north-south VFR flyway over L.A. International and the altitudes to be flown when using this flyway.

The TCA charts show that Torrance Municipal Airport is under the southern edge of the TCA and that the floor of the TCA above the airport is 5,000 feet. The Piper pilot bought a Los Angeles Sectional Chart and a Los Angeles VFR Terminal Area Chart on the morning of the accident. The Terminal Area Chart, folded to display the combined map and TCA diagram, was found in the Piper's cockpit wreckage; course lines had not been drawn on either side of the chart.

1.11 Flight Recorders

The Piper PA-28 was not equipped with nor was it required to be equipped with flight recorders.

The DC-9-32 was equipped with a Sunstrand model F-542 Flight Data Recorder (FDR), serial No.5818, and a Sunstrand model V-557 Cockpit Voice Recorder (CVR), serial No. 1829. Both recorders were brought to the National Transportation Safety Board's flight recorder laboratory in Washington D.C. for examination and readout.

The FDR had been damaged mechanically and by fire. Examination of the foil magazine and the foil recording medium showed that the foil had been torn through, was discolored from intense heat, and that all recorded traces were faint because of improper stylus pressure. The faint traces and the heat discoloration made the recorded traces difficult to read.

The DC-9's latest FDR calibration data sheet was dated February 9, 1983, and these data were used during the readout of the FDR's foil. As a result of inconsistencies in the recorded altitude data, adjustments were incorporated to obtain actual altitude values. The field elevation at flight 498's previous departure point, Tijuana, was 499 feet and the FDR's indicated altitude at Tijuana was -8 feet; therefore, a correction of 507 feet was added to the altitude data and the barometric pressures at Tijuana and Los Angeles were assumed to have been 29.97 in Hg. No other corrections were made to any of the other recorded parameters and a readout of the last 9 minutes of the flight was made, a graphic display of which is appended to this report.

During the investigation, the Safety Board's Performance Group used the recorded ATC radar data to reconstruct flight 498's ground speed and indicated airspeed, which they compared to the indicated airspeed recorded by the FDR. The FDR-indicated airspeeds were about 25 KIAS to 30 KIAS faster than the indicated airspeeds derived from the recorded radar data. The Safety Board believes that the indicated airspeeds derived from the radar data are more accurate; therefore, 25 KIAS to 30 KIAS should be subtracted from the FDR indicated airspeed.

The CVR was damaged slightly by impact forces and heavily by the post-impact fire. The CVR tape was not damaged physically and received only minor heat damage. The CVR recording started about 1122:17, just after the engines were started at Tijuana. The Safety Board CVR Group listened to the entire 30-minute recording and a verbatim transcript was made of the last 11 minutes of the flight. The verbatim transcript begins at 1141:21 when flight 498 was level at 10,000 feet and in radio contact with Coast Approach Control. The transcript continues to the end of the recording at 1152:32. The flightcrew's primary language for all intra-cockpit conversation and for the radio calls to the company was Spanish. All ATC radio calls were in English. Identification of the crewmembers' voices was made by members of the CVR Group, who were familiar with the captain and first officer.

The quality of the entire recording was consistently poor. The sound on the cockpit area microphone (CAM) channel was extremely distorted, and it faded in and out randomly. The distortion and noise were so evident that the CVR Group found it very difficult to understand the intra-cockpit conversation. This difficulty was exacerbated by the flightcrew's use of the cockpit's overhead speakers to receive ATC communications. Since these speakers are very close to the CAM, the large number of radio transmissions in the Los Angeles area, coupled with the loud volume of the radios, also impaired the intelligibility of cockpit conversation recorded by the CAM.

The poor quality of the CVR recording was not caused by either impact or fire damage. This model CVR has a history of tape tension and recording quality problems. Random storage of the tape causes permanent creases in the recording tape because it folds in the same places many times as it is pushed into the storage sleeve. In addition, if the pressure pad is not set to provide the proper tension, the tape rides up on the record head as it is pulled up by the capstan, and the quality of the recording can be degraded.

Because of the poor quality of the CVR recording, it was necessary to include ATC transmissions from the ATC transcripts to enhance the intelligibility of the CVR transcript. The selected ATC transmissions were checked against the CVR recording to verify that the selected transmissions were broadcast from the overhead speakers. Only those verified ATC transmissions were included in the appended 11 minute CVR transcript.

The CVR transcript showed that the flightcrew received the L.A. International Automated Terminal Information Service (ATIS) message at 1146:46. Thereafter, the flightcrew began to prepare for landing and the intracockpit conversation relating to these tasks ends at 1148:16 when the first officer said, "Flight director up," in response to the captain's challenge.

Between 1148:16 and 1152:10, six transactions were recorded by the CAM. At 1148:31, an unintelligible word was recorded; at 1149:41, a tone was recorded; at 1150:05, an unintelligible female voice was recorded; at 1151:20, an unintelligible word was recorded; at 1151:30, the captain said, "Thank you;" and, at 1152:10, the captain said, "Oh, this can't be." The 1152:10 remark was the last known remark made by either the captain or first officer.

The CVR recording ended at 1152:32. Between 1152:10 and 1152:32, three ATC broadcasts were recorded, one of which was addressed to flight 498. At 1152:18, the AR-1 controller advised the flight that its landing runway was being changed to runway 24R; the flightcrew did not respond to this transmission. With regard to air-to-ground radio communications, the captain made all radio transmissions from flight 498 to ATC facilities.

1.12 Wreckage and Impact Information

The main wreckage sites of both airplanes were within the city limits of Cerritos and within 1,700 feet of each other.

Piper PA-28-181, N4891F—Except for the upper portion of the fuselage cockpit assembly, engine, vertical stabilizer, and instrument panel, the Piper remained relatively intact after the collision. The major portion of the Piper crashed in an open schoolyard and did not catch fire after impact.

The engine of the Piper PA-28 separated from the fuselage and was found in the yard of a residence about 1,650 feet north of the Piper's main wreckage site. The engine had been damaged extensively by impact forces. Inboard of the No. 3 cylinder, there was a 3 by 6-inch hole in the top of the engine case. A 5 by 8-inch piece from the upper vertical stabilizer of the DC-9 was lodged in this hole.

The propeller had separated from the engine. One propeller blade had broken off about 18 inches from the propeller hub. This blade was bent aft and was gouged and damaged heavily in the area of separation and on its leading edge. About 6 inches of the tip of the opposite blade had broken off. The remainder of this blade was bent aft and its leading edge in the mid-span area had been damaged by impact forces.

Both wings were attached to the fuselage and their undersides were buckled. The top of the right wing was relatively undamaged. The top of the left wing had numerous large deep gouges, scratches, and orange paint marks extending from the outboard bulkhead to the wingtip. The gouges, scratches, and paint transfers were aligned at a 30° angle from the wing's leading edge.

The aft section of the fuselage separated just behind the cockpit assembly aft bulkhead, but it remained attached to the forward portion by control cables and the battery shelf attachments. The roof and upper portion of the cockpit assembly was severed from the lower portion of the cockpit assembly along the bottoms of the cockpit assembly windshields and side windows. The separation extended from the engine firewall aft to the cockpit assembly's aft bulkhead.

The entire vertical stabilizer and rudder separated from the fuselage. However, except for a small aft section of the vertical stabilizer, these pieces were recovered. Most of the recovered pieces were buckled and torn severely. The lower portion of the vertical stabilizer's leading edge was dented, distorted, and torn by the impact force.

The stabilator remained attached to the fuselage. The right stabilator was not damaged by impact forces; however, the leading edge of the left stabilator was dented about 18 inches inboard of its outboard tip rib.

The nose landing gear separated from the airplane. The strut tube had broken in a rearward direction about 8 inches above the towing block.

The servo clutch of the Piper's auto control system (wing leveler) was disengaged; however, the clutch is designed to disengage when electrical power to the system is removed.

Examination of the airplane's altimeter showed that its 100-foot, 1,000-foot, and 10,000-foot pointer assemblies were missing, and that its barometric gear train was moved easily with light finger pressure. Paint transfers similar to the paint used on altimeter pointers were found on the dial face (needle slapping) and the "slap" marks corresponded to the 6,560-foot position on the altimeter dial.

The airplane's radios and transponders were recovered by outside personnel and were delivered to the wreckage collection site in the schoolyard adjacent to the Piper's main wreckage site, where they were examined by team members. The following pertinent readings were observed:

> The transponder was set to code 1200.
>
> The No.1 navigational radio was tuned to 115.7 Mhz; this was the published radio frequency of the Seal Beach VORTAC. The OMNI Bearing Selector (OBS) was set on 091°.
>
> The No.2 navigation radio was tuned to 112.2 Mhz; this was the published radio frequency of the Paradise VORTAC. The OBS was set on 067°.

DC-9-32 - The majority of the DC-9's wreckage fell within an area about a 600 feet long by about 200 feet wide. The wreckage in this area had disintegrated and was extensively burned. The largest piece of wreckage was a section of the lower aft fuselage. Both engines were found in this area and examination of their rotating components showed that both were operating at high power at impact.

Collision damage on the DC-9 was confined to the vertical and horizontal stabilizers. Pieces of the vertical stabilizer were scattered throughout the wreckage area. Pieces from the upper part of the vertical stabilizer were found near the Piper's wreckage. Most of the pieces from the lower part of the vertical stabilizer were in the DC-9's main wreckage site.

Pieces broken from the upper part of the vertical stabilizer's leading edge were positioned in their normal relative locations to each other. Examination of the repositioned area disclosed a propeller slice, which began about 20 inches below the top of the vertical stabilizer and was about 7 inches left of the airplane's centerline. The plane of the slice was almost parallel to the longitudinal axis of the DC-9.

Recovered sections of skin from both sides of the vertical stabilizer were examined. There was no evidence of impact damage on skin sections from the right side of the stabilizer; however, some of skin areas from the left side had blue paint transfer and tire marks. The blue paint color was consistent with the paint on the nosewheel fairing of the Piper. The smear marks extended aft and upward at a 28° angle relative to the rear spar of the vertical stabilizer and the marks were continuous with smear marks on the left side of the rudder. A gouge on the left side of the rudder extended upward at an angle of 28° relative to the rudder's front spar. The end of the gouge crossed the top of the rudder about 30 inches aft of its front spar and all of the rudder's support hinges were fractured.

The horizontal stabilizer separated during the collision and descended intact to a location about 1,700 feet east of the DC-9's main wreckage site. The leading edge of the horizontal stabilizer left side was crushed, battered, and torn in several areas. The damage began about 1 foot outboard of the vertical stabilizer and extended to a point about 13 feet outboard of the vertical stabilizer. Human remains, debris from the fuselage skin, and insulation from the upper right area of the Piper cabin just aft of the main door frame were embedded in this area of the DC-9's horizontal stabilizer. In addition to the damage described above, the left side of the horizontal stabilizer was scratched and was smeared with white paint consistent in color with that of the Piper. The scratches swept back from the leading edge at a 15° angle relative to the front spar of the horizontal stabilizer. Yellow and blue paint smears were also found at the outboard end of the left horizontal stabilizer.

The horizontal stabilizer's right side leading edge was crushed, but less than the leading edge of the left side of the stabilizer. Between 20 and 40 inches to the right and outboard of the vertical stabilizer, the lower surface of this leading edge was crushed and sliced consistent with damage resulting from a propeller strike. The line defined by the slice swept back at an angle of 29° relative to the front spar of the horizontal stabilizer. Outboard of this damage, there were yellow paint smears and scratches on the right horizontal stabilizer. The yellow paint color was consistent with the Piper's yellow paint and the scratch marks swept back at a 35° angle relative to the front spar of the horizontal stabilizer.

1.13 Medical and Pathological Information

The captain and first officer of the DC-9 were killed by the ground impact forces involved in the accident. Their bodies were fragmented too severely to permit either an autopsy or toxicological test to be performed. The passengers and cabin crew members on the airplane received multiple blunt force trauma injuries from the impact forces and were burned in the postcrash fire.

The pilot and two passengers in the Piper were found in the remains of the airplane's cabin; they were strapped in the left front seat, the right front seat, and the right rear seat. All three occupants had been decapitated.

An autopsy was performed by the Los Angeles County coroner on the pilot of the Piper. With regard to the pilot's general medical state, the medical examiner found "generalized arteriosclerosis, slight to moderate and coronary arteriosclerosis, moderate to focally severe with complete proximal occlusion of the main right coronary artery." The autopsy report issued by the Coroner of Los Angeles County ascribed the death of the pilot of the Piper to "multiple injuries due to or as a consequence of blunt force."

The Armed Forces Institute of Pathology (AFIP) also reviewed the autopsy protcol and the heart of the pilot of the Piper. With regard to their examination of the pilot's heart, the AFIP pathologists found severe coronary atheriosclerosis but "no necrosis or other evidence of acute myocardial infarction identified."

Toxicological tests conducted during the postmortem examination of the Piper pilot were negative for drugs and alcohol. The carbon monoxide saturation level was well below the levels required to produce incapacitation.

The AR-1 controller agreed to and, on September 2, 1987, was tested for the presence of drugs and alcohols; both tests were negative.

1.14 Fire

The DC-9-32 caught fire after it struck the ground. The postimpact fire contributed to the destruction of the airplane. The Piper PA-28 did not catch fire either in flight or after it struck the ground.

1.15 Survival Aspects

The DC-9-32 was configured for a two-man flightcrew and 115 passengers. Passenger seats were arranged into 23 rows of two seats located on the left side of the cabin and 23 rows of three seats located on the right side of the cabin. A double aft-facing flight attendant seat was in the forward cabin near the main cabin door; another double forward-facing flight attendant seat was located on the cabin's aft bulkhead. The entire cockpit and passenger cabin area of the DC-9 was destroyed by impact forces and subsequent fire. Only one passenger seat was found intact; it had been thrown clear of the fire and had penetrated a garage door.

The cockpit-cabin area of the Piper PA-28-181 was configured with side-by-side pilot seats and side-by-side passenger seats aft of the pilot seats. The roof of the cockpit-cabin area was torn from the airplane and found away from the remainder of the fuselage.

The accident occurred a considerable distance from any major airport and thus response to the scene was the responsibility of municipal fire departments and law enforcement agencies. Examination of the response times of these agencies showed that they arrived at the accident scene promptly. For example, one Los Angeles County Fire Department engine company received the alarm at 1153; at 1154, the engines were dispatched; and at 1158, the engines arrived on the scene.

1.16 Tests and Research

1.16.1 Visibility and Vision Studies

A visibility study was conducted to determine the physical limitations to visibility from the pilot and copilot seats of the DC-9-32 and from the Piper PA-28-181. To accomplish this, the time histories of both airplanes' flightpaths and attitudes, as contained in the radar track plot, and the performance information on flight 498's FDR were combined with binocular photographs 6/ of the respective cockpits. The viewing angles for each airplane were then calculated and plotted at 5-second intervals in relation to the design eye reference (DER) points for each airplane's windshields. The study showed that between 1150:56 and 1152:01, the Piper was about 15° to 30° left of the DER point on the captain's windshield and between 15° to 30° left of the DER point on the first officer's windshield. For the first officer, assuming that he did not move, the Piper airplane was located on the airplane's center windshield and in an area where, for about 50 percent of the time, he could see it with both eyes. Assuming the captain did not move, the Piper was located primarily in an area where he could see it with both eyes.

With regard to the Piper pilot, between 1150:56 and 1152:01, the DC-9 was about 50° to the right of the DER point and could only be seen by him on the far right side of the copilot's windshield. For someone seated in the Piper's right seat, the DC-9 was about 55° to the right of the DER point on the right windshield and, assuming no repositioning of the head, would have appeared at the left edge of the right side window. However, neither of the two passengers on the Piper had received any type of aviation or scan training.

1.16.2 Target Acquisition Performance

The ability of pilots to sight other airplanes in flight was evaluated during two test programs conducted by the Lincoln Laboratories of the Massachusetts Institute of Technology (MIT). These tests were part of a general research project and were not conducted as a result of this accident. In addition to counting the number of times that these pilots either acquired or failed to acquire an intruder airplane visually, the tests determined the distance at which the targets were acquired.

One test evaluated pilot performance during unalerted search. The tests were conducted during a series of triangular round robin flights from Hanscom Field, Massachusetts, using two VORTACS near, but not inside, the Boston TCA as waypoints. The subject pilots were not alerted that there would be intruder aircraft or that scanning behavior was the focus of the study. Each leg was flown at a different altitude and the pilot was required to perform his own navigation and answer various questions asked by the evaluator during the flight. The planned angles of the intercepts were head-on, 90°, and 135°, and the intercepts were predominantly from the left (the pilot's side of the airplane). Data were obtained for 64 unalerted encounters. Visual acquisition was achieved in 36 encounters (56 percent of the total), and the median acquisition range for these 36 encounters was .99 nmi. The greatest range of visual acquisition was 2.9 nmi.

The other test program evaluated the performance of pilots who had been alerted to the presence of an intruder airplane. Data for 66 encounters were collected during the testing of the TCAS II. The subject pilots were aware that intercepts would be conducted and they received traffic advisories on a TCAS II cathode ray tube (CRT)

6/ Photographs taken by a camera with two lenses. The spacing between the lenses is equal to the average distance between the human eyes.

display. The subject pilots acquired the intruder visually in 57 of the 66 encounters (86 percent of the total). In five of the nine failures, the failure was partially due to the pilot's response to a TCAS resolution advisory. The median range of the visual acquisitions was 1.4 nmi.

The performance of the pilots was used to provide data for a mathematical model of visual acquisition. This model is based on the experimental observation that the probability of visual acquisition in any instant of time is proportional to the product of the angular size of the visual target and its contrast with its background. The cumulative probability of visual acquisition is obtained by integrating the probabilities for each instant as the target approaches.

The data cited herein were developed by a project leader on the Air Traffic Control Division, Lincoln Laboratories, MIT, who had conducted research on human visual performance and flight testing of collision avoidance systems. At the Safety Board's request, the project leader constructed Probability of Visual Acquisition Graphs based on the extrapolation of pertinent data contained in the facts and circumstances of the collision between the Piper PA-28 and flight 498 with the data described above.

The graphs are based on the closure rate between flight 498 and the Piper and on the results achieved by pilots having an unobstructed view of the intruder. The graphs do not account for such limiting factors as cockpit structure and the possibility that the airplanes might be positioned so that they can be seen with only one eye. However, the information in this report is of significance in that it provides a baseline for further evaluation.

* 1.17 Other Information

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* 1.18 New Investigative Techniques

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ANALYSIS

2.1 GENERAL

Both airplanes were maintained in accordance with all applicable regulations and, with regard to the DC-9, company procedures. There was no evidence that any airplane malfunction contributed to the collision.

The captain and first officer of flight 498 were certificated properly, trained, and qualified to perform their assigned duties. There was no evidence of any preexisting physiological or psychological disability that would have decreased their abilities to perform their inflight duties.

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* *ICAO Note.*— Sections 1.17 and 1.18 were not reproduced.

The pilot of the Piper PA-28 was properly certificated and qualified to conduct the intended flight to Big Bear. There was no evidence of any preexisting psychological disability that would have decreased his ability to conduct the intended flight; further discussion of preexisting physiological conditions that could have affected the conduct of the flight is contained in a later section of this analysis.

The AR-1 controller was certified, trained, and qualified to provide the required ATC service. There was no evidence of any preexisting physiological or psychological disabilities that would have decreased his ability to perform his required duties.

The evidence was conclusive that the collision occurred within the Los Angeles TCA; that the Piper pilot had entered the TCA without having been cleared to do so; that the AR-1 controller did not advise flight 498 of the position of the Piper; and that neither pilot tried to perform any type of evasive maneuver before the collision. Given these data, the major thrust of the Safety Board's analysis was to identify those factors that led to the events cited above and the resultant collision.

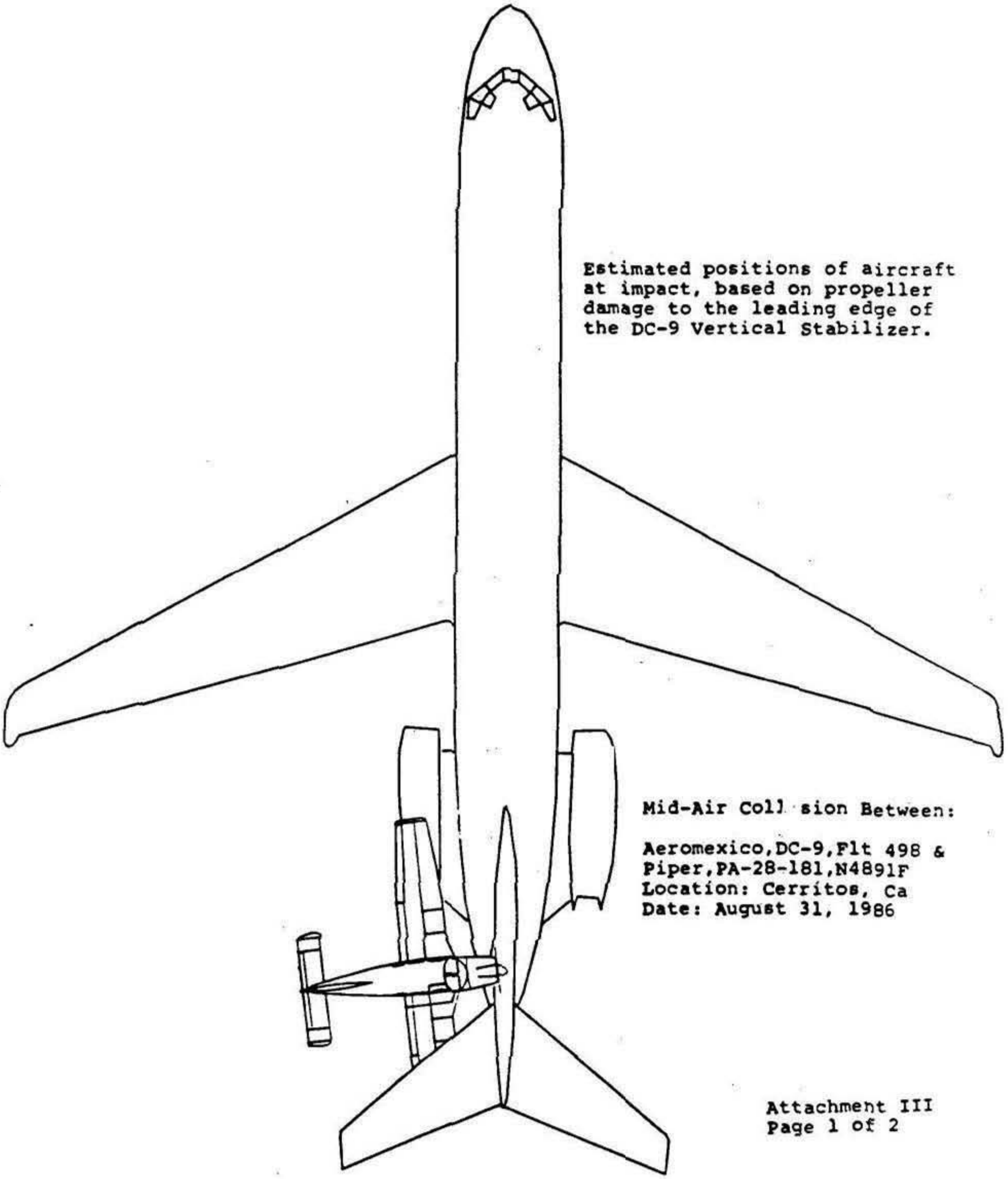
2.2 The Accident

Collision Geometry—The collision occurred as flight 498 was descending through about 6,560 feet. The radar data showed that the DC-9 was on a northwesterly track and the Piper on an eastbound track that traversed the DC-9 track from left to right.

The collision damage on the DC-9 was confined to its vertical and horizontal stabilizer. Although much of the structure of the DC-9 forward of the empennage was consumed by fire, there was no evidence of midair collision damage on those pieces of structure that were not consumed by the fire.

The damaged areas on the DC-9 vertical and horizontal stabilizers contained propeller slice marks, paint transfer marks from the nose wheel area and vertical stabilizer of the Piper, and embedded pieces from the cabin roof area of the Piper. The location and angles of these marks and damage on the DC-9, when matched to their respective locations on an intact Piper PA-28, showed that the front of the Piper had struck the left side of the DC-9 vertical stabilizer and that the impact angle was perpendicular to the longitudinal axis of each airplane. (See figure 6.) The impact angle was generally consistent with the flight tracks of the airplanes shown on the radar data plots.

The absence of any impact marks or damage on those portions of the DC-9 left wing and fuselage forward of the empennage that had not been consumed by fire and the damage to the DC-9 vertical and horizontal stabilizers, showed that the PA-28 airplane was about 8 to 10 feet above the top of the DC-9's fuselage and about 15 to 17 feet above its wings when the collision occurred. The damage also indicated that the longitudinal axis of the Piper was almost level at impact and that the initial impact was with the DC-9 vertical and horizontal stabilizers. The debris from the Piper cabin roof, embedded in the leading edge of the DC-9 horizontal stabilizer, and the fact that the roof of the Piper was sheared off at about the same height on both sides of its fuselage, confirmed the fact that the DC-9's horizontal stabilizer struck the top of the Piper's fuselage and that the Piper was in the almost wings-level attitude at impact.



Estimated positions of aircraft at impact, based on propeller damage to the leading edge of the DC-9 Vertical Stabilizer.

Mid-Air Collision Between:

Aeromexico,DC-9,Flt 498 &
Piper,PA-28-181,N4891F
Location: Cerritos, Ca
Date: August 31, 1986

Attachment III
Page 1 of 2

Figure 6.--Collision geometry as viewed from above the DC-9.

Even though the Piper was a much smaller and lighter airplane, its engine, a relatively massive object, struck the DC-9 horizontal stabilizer's main support structure, causing it to fail and the horizontal stabilizer to separate. Longitudinal control and stability was lost when the horizontal stabilizer separated and further controlled flight was impossible.

Survival Factors — Flight 498 fell to the ground from about 6,560 feet and the occupiable area of the airplane's cockpit and passenger cabin was destroyed by massive impact forces and postcrash fire. Although the occupants of the DC-9 survived the midair impact, this was an unsurvivable accident for the passengers and crew because of the massive ground impact forces.

The DC-9's horizontal stabilizer sheared off the top of the Piper's cabin and its leading edge contained embedded pieces of human remains and hair along with pieces of the Piper's cabin roof. The evidence showed that the three occupants of the Piper were injured during the initial impact and that the injuries were not survivable.

The crash, fire, and rescue units involved in the response performed in a timely and efficient manner. The accident occurred at 1152; the alarm was received at 1153; units were dispatched at 1154; and the first vehicles arrived at the scene at 1158. In addition to the units described above, local law enforcement units were on the scene within 6 minutes after the accident. The crash scene fire was contained within 30 minutes after the first fire engines arrived and was extinguished 35 minutes later.

2.3 Entry into the Terminal Control Area

Since the Piper pilot entered the Los Angeles TCA without an ATC clearance, the Safety Board sought to determine if the entry had been deliberate or inadvertent.

The occurrence of a myocardial infarction (heart attack) is disclosed during an autopsy examination by areas of dead or dying coronary tissue caused by the obstruction of the blood vessels. Although the data contained in the Piper pilot's autopsy protocol did not contain any evidence of this type of tissue damage and thus showed that he had never suffered a heart attack, medical authorities agreed that it was beyond current medical technology to determine from autopsy evidence whether the pilot could have experienced a myocardial infarction during the time immediately preceding the collision. For the area of necrotic tissue produced by a myocardial infarction to appear in an autopsy, the infarction would have had to occur at least 12 hours before death. Given these facts, and the existing moderate to severe arteriosclerosis found within the blood vessels of the Piper pilot's heart, the Safety Board sought to determine if the pilot had suffered a disabling heart attack and, thereafter, entered the TCA inadvetently.

The Piper pilot had no history of heart problems and had passed his Electro cardiograph (ECG) tests on every previous physical examination (including a resting ECG 8 months before the accident). Even in the highest statistical risk categories for his age, the predicted probability that the Piper pilot would experience a fatal heart attack was less than 5 percent annually 9/.

9/ Schatzkin, A.; Heeren, T.; Morelock, L.; Muscatel, M.S.; and Kannel, W.B. (1984). The *Epidemiology of Sudden Unexpected Death: Risk Factors for Men and Women in the* Framingham Heart Study. American Heart Journal 107, 1300-1306.

The recorded radar data showed that the Piper PA-28 pilot proceeded almost directly to the collision point after he took off from Torrance. Based on the time the Piper PA-28 left Torrance—about 1141— the airplane's rate of climb from takeoff to impact averaged about 550 fpm. Based on the three flight simulations, this average climb rate was within the airplane's performance capability. In addition, the recorded radar data of the Piper's progress does not contain any type of dramatic disturbance of either heading or groundspeed that might be expected if the pilot had experienced a disabling heart attack. Except for a couple of small turns, the fact that the airplane maintained an almost constant heading and groundspeed indicated that its progress was being monitored and managed.

In addition, if a disabling heart attack allowed the Piper PA-28 to enter the TCA and climb to the 6,560-foot collision altitude, given the average 550 fpm rate of climb, the pilot had to be disabled at least 2 to 2 1/2 minutes before the accident. Based on his proposed route of flight and assuming that the pilot was still alert, the last available proper VFR altitude for flight below the floor of the TCA was 5,500 feet. The Piper would have reached 5,500 feet 1 minute before entering the TCA and 2 minutes before reaching the collision altitude. Since the pilot did not level off, the Safety Board, if it is to accept the hypothesis of a heart attack, must conclude that the pilot was incapacitated before the Piper reached 5,500 feet and that the airplane itself maintained a constant heading and climb rate for more than 2 minutes. The Safety Board believes that it would be improbable for the airplane to maintain a constant heading and climbing flightpath unassisted by lateral and longitudinal control corrections.

The Piper pilot's primary flight instructor stated that the pilot used the "wing leveler" when looking at maps or charts, or when doing other in-cockpit activities. Had the "wing leveler" been engaged at 5,500 feet and the pilot disabled, the airplane would have maintained heading and, depending on how accurately the pilot had trimmed out the elevator forces to maintain the climb rate, could have reached collision altitude unassisted. However, the recorded radar data showed two turns in the Piper airplane's track. About 1148:14, a left turn that corresponded to about 5° bank was started. The turn lasted about 20 seconds and, thereafter, the airplane returned to wings-level flight. The second, a slight turn to the right corresponding to a 5° bank, began at 1149:50 and ended about 1150:05 when the airplane was again returned to wings-level flight. At the end of the second turn, the airplane would have climbed to about 5,500 feet. The data from the flightpath seem consistent with the control inputs of a conscious pilot.

Two additional points bear on this issue. First, there is no evidence that an emergency radio call was made from the Piper. Second, the occupants of the Piper were found in the wreckage with their seatbelts fastened. If the pilot had suffered a major medical problem, the Safety Board believes that one or both of the remaining occupants would have unfastened their seatbelts and possibly the pilot's seatbelt while attempting to assist him. The evidence points strongly to the fact that there was no disturbance in the cockpit and that the flight was proceeding normally when the collision occurred. The Safety Board concludes that the weight of the evidence showed that the pilot of the Piper did not suffer a heart attack and that the Piper's entry into the Los Angeles TCA was not caused by any physiological disability of its pilot.

Although the pilot of the Piper had flown about 5.5 hours in the Los Angeles area, the Safety Board could not establish the routes of those flights and therefore how familiar he might have been with the boundaries of the TCA in the vicinity of Long Beach and the Seal Beach VORTAC. However, the pilot was not a total stranger to the Los Angeles TCA and his discussions with other pilots demonstrate that he was well aware of the flight procedures required either to enter the TCA or to avoid it. The pilot discussed the route to Big Bear with another pilot, who advised him on how to stay out of the TCA. This pilot was intimately familiar with the area's freeway complex and relied on these underlying highways as landmarks to denote the geographical boundaries of the various segments of the TCA and resultant altitude requirements. In their discussion of the route to Big Bear, this pilot mentioned using freeways to stay clear of the TCA; however, the pilot of the Piper was not as familiar with these freeways and therefore might have used the wrong freeways instead of relying on the more prominent checkpoints, such as Disneyland and the Anaheim Stadium, to identify his position in order to control his altitude and avoid entering the TCA.

The pilot of the Piper was described as methodical and professional in his approach to flying, and as a pilot, more inclined to navigate by visual reference to the ground than to use navigational radio aides. The fact that he tried to obtain advice concerning the Los Angeles area and the TCA before the flight and had purchased a Los Angeles Terminal Area Chart, which was found opened in the cockpit wreckage, tend to confirm this assessment of his approach to flying. Given these facts, the Safety Board believes that it is extremely unlikely that he would intrude deliberately into the TCA. In the absence of any positive evidence to the contrary, the Safety Board concludes that the pilot intended to avoid the TCA but that he probably misidentified his navigational checkpoints and entered the TCA inadvertently.

The entry of the Piper pilot into the TCA stripped his airplane and flight 498 of the precise protection the TCA was designed to provide. Its entry into this prohibited airspace created an exposure to risk that should never have existed and, therefore, the Safety Board believes that the intrusion into the TCA was a causal factor in the ensuing accident.

Before the accident, the Los Angeles TRACON forwarded TCA intrusion cases to the Los Angeles FSDO for enforcement action at a rate of about one per month; after the accident, the rate increased to about 10 per month. The pre-accident rate may be indicative of the difficulties involved in detecting, tracking, and identifying a TCA intruder cited in the TCA Task Group's report to the Administrator. However, the post-accident increase in the rate under the same conditions that existed before the accident indicates a less-than-efficient pre-accident effort by personnel in the Los Angeles TRACON to detect and identify TCA intruders. In addition, the TCA Task Group's report also concluded that, nationwide, "many, if not most, violations observed by the FAA are not referred for enforcement action because the aircraft and the pilot involved cannot be identified."

The Safety Board believes that if the TCAs are to continue to provide the protection they are designed to provide to the aviation community, the FAA must ensure that the regulations supporting this protected airspace are well known within that community, and most important, that it can and will enforce these regulations. The Safety Board believes that the recommendations in the Administrator's TCA improvement plan, if placed in effect promptly and executed properly, will inform the aviation community of the FAA's intent to maintain and enforce the integrity of the TCA airspace.

The evidence indicated that the Piper pilot was aware of the Los Angeles TCA, the regulations regarding its use, and the need to avoid it. Since there is no evidence that he entered the TCA in defiance of the prohibitory provisions of the relevant regulations, the Safety Board concludes that the enforcement efforts of the Los Angeles TRACON to support the TCA was not a casual factor in this accident.

2.4 The ARTS III

Without mode C altitude information, the AR-1 controller could not determine whether VFR code 1200 targets displayed within the horizontal boundaries of the TCA were within its vertical limits and, therefore, actually within it. Although he could assume that since these targets had not been cleared to enter they were not in the TCA, and therefore, not a factor to the airplanes under his control within the TCA, he testified that he would not make that assumption. He testified that, workload permitting, he would provide a traffic advisory concerning any target he considered to be a factor to any airplane under his control and, thus, had he seen a VFR code 1200 target at the Piper's location, he would have provided a traffic advisory to flight 498. He testified that he did not provide that advisory because the Piper's target "was not displayed," and further that it was his "belief that he was not on my radar scope". Therefore, the Safety Board sought to determine what targets, if any, were displayed on the AR-1 controller's display at the time of the collision, and especially whether the Piper radar target was displayed.

The evidence showed that an overloaded ARTS III computer will not display targets in excess of its display storage capacity. As a display overload condition occurs, the computer will print out messages announcing it is overloaded and identify the types of targets it is not displaying. None of these messages were printed at or before the time of the accident, nor any message that the computer was within 85 percent of its tracking capacity. In addition, none of the TRACON's controllers reported the occurrence of "flicker", which indicates the onset of display overload. The evidence was conclusive that, during the time interval encompassing the collision, the ARTS III computer was not overloaded and was still placing target data into its tracked and untracked target buffers. Of greater significance is the fact that there was no aspect of the ARTS III computer hardware or software that would supress the display of a tracked or untracked target from the controller's displays.

The recorded radar data showed that beacon returns for both flight 498 and the Piper had been received, processed by the ARTS III Data Acquisition System, processed by the ARTS III computer, and presented to the display. When recorded radar data were inserted into the Retrack Program Computer, which was programmed to perform the functions of the Los Angeles TRACON's I/O Processor, the alphanumeric symbols representing the Piper and flight 498 were reproduced on the display. Since the DEDS used during the retrack test was configured as was the AR-1 controller's DEDS at the time of the accident, the alphanumerics presented on the retrack display were identical to those that would have been presented on the AR-1 controller's display. The AR-1 controller testified that numerous other VFR code 1200 targets were on his display at the time of the collision and the Retrack Program Computer displayed what were probably these targets. Since there was no functional way the AR-1 controller could have selectively removed any one of several VFR targets from his display, and since there was no functional reason why targets that have been processed by the I/O Processor for display would not be displayed, the Safety Board concludes that the alphanumeric data recovered from the recorded radar data tapes were displayed on the AR-1 controller's display at the time of the accident.

The Retrack Program also duplicated the "stitching" movement of the targets. When the progress of the Piper's target and flight 498's target across the retrack display was monitored, it was obvious that, regardless of "stitching," their proximity to each other would have required the controller, had he observed them and had workload permitted, to issue a traffic advisory to flight 498. Since the Safety Board has concluded that, at the least, the alphanumeric symbology denoting the location of the Piper was displayed on the AR-1 controller's display, the Safety Board therefore sought to determine why the AR-1 controller did not observe the Piper's target.

2.5 ATC Procedures

The procedures contained in the Controllers Handbook require ATC controllers to prioritize the services they provide. First priority must be given to IFR airplanes, to which controllers must provide traffic separation service. The training given to controllers at the FAA Academy in Oklahoma City, Oklahoma and during on-the-job facility training emphasize this priority. Thus, except for an aircraft safety alert, a traffic advisory is an additional service to be provided "workload permitting," and, "contingent only upon higher priority duties...."

With regard to the Aircraft Conflict Alert advisory, the Handbook limits the application of that procedure to situations where the controller is "aware of another aircraft at an altitude which you believe places them in unsafe proximity." The Piper did not provide any altitude data to the controller and therefore, did not present a condition that required the controller to give this type of advisory. Although the AR-1 controller said he intended to provide traffic advisories concerning the type traffic the Piper airplane represented, the Safety Board believes that the reason he did not observe its target may have been caused by his attempt to adhere to the priorities and procedures he had been taught. Consequently, the Safety Board concludes that the ATC procedures were causal to the accident in that they set the stage for the controller to "overlook" or "not see" the Piper's target on his display.

The AR-1 controller's radio conversations with the various airplanes to which he was providing services indicated strongly that his attention was directed toward the area east of L.A. International wherein traffic was descending to land. At 1150:46, he advised flight 498 of traffic at "ten o'clock" and then watched it pass behind the flight. He testified that after he saw the traffic pass flight 498, he "saw no traffic along its projected route of flight that would be a factor". It would appear from his testimony that the controller had developed an expectation that there was no traffic between flight 498 and the airport. Between 1151 and 1152, the traffic situation changed. During this time, N1566R's pilot called and requested flight following along a route to Van Nuys at 4,500 feet. At the same time, the controller was told that flight 498 would now land on runway 24 right.

Although the AR-1 controller did not assign a discrete VFR transponder code to N1566R until 1152:04, it was obvious, based on his insertion of N1566R's identification into the ARTS III at 1151:37 and his testimony that he was concerned that N1566R was going to enter the TCA, that its route of flight would take it across the landing approaches to L.A. International, and that he would have to provide flight following services. Once the controller made that decision, N1566R would have to be treated as an IFR airplane for the purpose of separation while it was in the TCA. The controller testified that during this period he scanned along N1566R's proposed route of flight to try to locate its VFR target return, and he also looked at the adjacent AR-2 display to see if any traffic inbound to runways 24L and 24R would affect flight 498. Given these conditions, it was entirely possible that his scan of his display may have focused on the area east of the airport and, in addition, when he returned his scan to the flight 498's radar return to check its projected flightpath and groundspeed toward the landing runway his scan may have concentrated more on the groundspeed readout in its data block than anything else.

Perception, stress, and motivational research studies show a relationship between workload and operator performance. At some point, workload can increase so that it physiologically or psychologically overloads the operator to the extent that relevant cues will be unintentionally missed or disregarded. This causes operators to tunnel or narrow their perception or attention. Under high workload situations, it has been demonstrated repeatedly that the operator will focus on the primary or "priority" tasks, and his attention to secondary tasks will deteriorate. 11/

While in this case, the AR-1 controller's total workload was neither numerically large nor did it suddenly increase significantly, the change of runways for flight 498, coupled with the sudden appearance of N1566R, required a shift in his focus of attention and brought additional airplanes for consideration into his separation tasks. In addition, his admonition at 1152:36 to the pilot of N1566R concerning his intrusion into the TCA seemed to indicate that the controller was annoyed by the additional tasks imposed on him by the abrupt intrusion. Consequently, evidence indicates that the controller's scan of his display was focused almost exclusively on an area that did not include the location of the Piper's target. The Safety Board concludes that this may have been why he did not see the Piper's radar target.

The ATC Handbook required the controller to "give first priority to separating aircraft. . . ." Therefore, except for certain participating VFR aircraft, the major amount of the controller's traffic separation duties were directed to IFR aircraft which had been assigned appropriate discrete transponder codes and had presented on the cntroller's display a full data block in addition to their primary radar returns, beacon control slashes, and appropriate alphanumeric symbols. Furthermore, even participating VFR aircraft would have been assigned an appropriate discrete VFR transponder code, indentified in the ARTS III computer for tracking, and, thus even these aircraft would have presented more data on the controller's display than an untracked code 1200 VFR target. (N1566 was handled in this manner.) The Safety Board believes that the priorities placed on the controller to provide traffic separation to these type aircraft could have lessened his awareness to the presence of the code 1200 VFR targets around the periphery of the area or areas containing the higher priority targets to which provide separation protection. Consequently, he might not perceive a developing threat posed by a code 1200 VFR target to one of his priority targets until they are in close proximity, or he might not, particularly if his assessment of the information presented on his display is affected by other factors such as the presence of a positive control type airspace, perceive the developing threat at all and thus not "see" the target. The Safety Board concludes this prioritizing procedure may have been, particularly when a code 1200 VFR target without accompanying altitude information was located within the lateral confines of the Los Angeles TCA, a reason why the controller did not perceive or see the Piper's radar target.

With regard to the TCA, the Safety Board is also concerned that the depiction of numerous VFR non-mode C-equipped aircraft within the horizontal confines of the TCA may, unintentinally, encourage controllers to form certain expectations. It is obvious that all of these airplanes cannot be within the vertical and horizontal confines of the TCA. Further, since VFR traffic must, by FAA regulations, avoid entering the TCA without an ATC clearance, a strong presumption exists that the VFR traffic displayed within the horizontal confines of the TCA is not within its vertical confines and therefore no threat to aircraft legitimately within the TCA. Therefore, notwithstanding the AR-1 controller's assertion that he would issue traffic advisories for all such targets even though he had not cleared them into the TCA, the Safety Board believes that the controller may have unconsciously decided that the airplane represented by the Piper's radar target was not within the vertical confines of the TCA and therefore, was no threat to flight 498. The controller might then have decided without conscious realization that he

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11/ Easterbrook, J.A. Effects of emotion on cue utilization and organization of behavior. Psychological Review, 1959.

had done so, to forego issuing a traffic advisory to flight 498 concerning the Piper airplane's target. In that regard, the Safety Board commends the FAA's present rule-making effort to require that all aircraft to be operated within 30 nmi of a TCA airport be equipped with and use a mode C altitude encoder. The addition of altitude information to the VFR codes will enable controllers to identify those VFR aircraft that threaten controlled traffic within the TCA. It will also enhance the FAA enforcement program, since controllers will be able to recognize aircraft that enter the TCA without proper clearance and to begin the procedures required to track and identify the intruder.

One other factor may have contributed to the AR-1 controller's failure to see the Piper's radar return. During the September 3 flight inspection, the flight inspection airplane's primary target on the display was unusable for at least six revolutions of the radar antenna (about 30 seconds) before the airplane reached the midair collision point. Although the refractive index was greater on the day of the flightcheck than it was on the day of the accident, it is possible that the primary radar return from the Piper airplane was either not displayed or its persistence on the display was compromised during the critical period of time when the AR-1 controller was adjusting flight 498's airspeed. Given the configuration of the TRACON's 10-channel decoder, if the primary return did not appear, the only evidence of the Piper's position would have been the ARTS III-generated alphanumeric triangle, which is much smaller than a VFR aircraft primary radar return. Since all other VFR aircraft in other areas of the display would have been marked by the larger primary return, it was also possible that the AR-1 controller, not realizing that the Piper's primary radar return was no longer being displayed, would have been relying on its presence to mark traffic during his scan of the display. Given his concentration on the area to the east of the airport during this critical time, it is possible and understandable that he might miss the far less prominent alphanumeric triangle when he scanned that area of his display.

On March 11, 1987, the ASR-4 radar reception of the flight inspection airplane's primary target was better than on September 3. On March 11, the refractive index gradient in the Los Angeles area was not as great as it was on September 3 and, in the area of the accident, the primary target was missed once and its target strength was always usable. On the day of the accident, the refractive index gradient was greater than it was on March 11, but less than on September 3, and the ASR-4 should have performed better on August 31 than it did on September 3. Given these data, the Safety Board cannot conclude that the Piper's primary radar return either did not appear or that its persistence was decreased to the point that it was unusable; however, it also cannot entirely rule out either possibility. Therefore, the Safety Board also believes that the decision of the managers of the TRACON to configure the 10-channel decoder as described herein may have decreased the prominence of the Piper's radar return. The Safety Board does not believe that the evidence supports the assertion of the TRACON's facility chief that configuring the decoder to provide beacon control slashes in addition to the primary radar return for code 1200 aircraft would produce unacceptable clutter on the facility displays. The beacon control slash is longer than the primary target and the alphanumeric symbol which is superimposed over the beacon control slash. Thus, the use of the beacon control would provide a slightly larger and more intense radar return.

One of the purposes of the transponder-beacon system is to provide a target for controllers when the primary target is unreliable. If, in this instance, the primary target either was missed or its persistence compromised, the presence of a beacon slash would have denoted prominently the location of the Piper airplane. In addition, a beacon can be used for traffic separation; the ARTS III alphanumeric symbol cannot. The configuration of the 10-channel decoder on the day of the accident removed a redundant display feature from the ATC environment.

The decreased prominence of the Piper's target on the controller's display as a consequence of the standard configuration of the equipment in the Los Angeles TRACON may have been a factor in the controller's failure to observe the target. The decreased target prominence was a consequence of the facility decision to inhibit display of the analog beacon return for VFR targets whose transponders were set on code 1200. This decision was reportedly implemented to reduce the clutter on the display which would result from the large number of VFR aircraft in the Los Angeles basin. The Safety Board acknowledges that the positive and negative aspects of displaying code 1200 beacon slashes must be considered by the controllers and facility managers in the establishment of procedures and equipment set up.

Given the evidence concerning the radar and ARTS III presentation and the controller's actions, the Safety Board concludes that the positions of the Piper airplane were depicted on the AR-1 controller's display by, at the least, an alphanumeric triangle, but that the controller did not observe the Piper's radar target. The Safety Board has cited the following three factors that could have caused the controller to overlook the Piper's radar return: the possible distraction of his attention from the critical area of his radar display caused by the projected entry of N1566R into the TCA and the change of landing runways for flight 498; the possibility that the controller may have unintentionally discounted the non-mode C VFR radar return of the Piper as a threat because it was located within the lateral confines of the TCA; and the possibility that the primary radar return of the Piper either did not appear on his display or the strength of the return was compromised by atmospheric interference. The evidence does not permit the Safety Board to select which factor or combination of factors caused this to occur. Therefore, the Safety Board concludes that the failure of the controller to observe the Piper's radar target could have been caused by any one of the three cited factors, or by a combination of any two these factors, or by all of them. As a result, the controller did not provide a timely traffic advisory alerting flight 498 to the presence of and relative position of the Piper PA-28.

The failure of the controller observe the radar return of the Piper and, thus, to provide a timely traffic advisory to flight 498 placed that flightcrew in the same position as all other VFR pilots flying in visual meteorological conditions (VMC); their ability to see and avoid other airplanes depended on their alertness, the quality of their scanning procedures, and the conspicuity of the targets they were seeking to acquire.

The Safety Board cannot state with certainty that this collision would have been prevented by a timely traffic advisory; midair collisions have occurred after pilots have received relevant ATC traffic advisories. 12/ However, a traffic advisory would have alerted the Aeromexico pilots of a specific threat and provided a relative bearing from their airplane along which they could concentrate their attempts to see the threatening airplane. The Safety Board believes that had this advisory been provided, it would have increased the Aeromexico flightcrew's chances of seeing the Piper in time to avoid the collision. Although the Federal Aviation Regulations 13/ required the Aeromexico flightcrew to maintain continous vigilance to see and avoid other aircraft, a timely traffic advisory would have increased their ability to exercise this responsibility efficiently. Therefore, since the failure to provide this warning decreased the Aeromexico flightcrew's chances to locate the Piper, the Safety Board concludes that this failure was a contributory factor in the accident sequence.

12/ Pacific Southwest Airlines Boeing 727 and a Cessna 172, San Diego, California, September 25, 1978 (NTSB-AAR-79-5).

13/ 14 CFR Part 91.67(a) states in part, "When weather conditions permit, regardless of whether an operation is conducted under Instrument Flight Rules or Visual Flight Rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft in compliance with this section."

2.6 See and Avoid

Based on the cockpit visibility study , both airplanes were within the pilot's fields of vision for at least 1 minute 13 seconds before the collision—but with certain limitations. The visibility study showed that the Piper was visible through the center windshield of the DC-9 as viewed from the first officer's seat, and about half the plots showed that the Piper was located in the first officer's monocular vision field. In addition, since the captain was making all air to ground radio communications, the Safety Board concludes that the first officer was flying the airplane. Over half of the position plots for the Piper airplane show that it was visible to the captain through windshield and was within his normal binocular vision field.

The Safety Board determined that the person occupying the right seat in the Piper was not a pilot and had never received scan training. Therefore, for this analysis, the Safety Board assumed that only the pilot was or could have scanned for other airplanes. Based solely on the relative size of the two airplanes, the Probability of Visual Acquisition Graphs show that the Piper pilot had a better chance of seeing the DC-9 than the Aeromexico flightcrew had of seeing the Piper. However, the location of the DC-9, as depicted on the Piper visibility study, showed that the DC-9 was visible through the Piper's right windscreen and near the outer limits of a left-right scanning pattern. Since the Safety Board cannot assume that any of the passengers would have been involved in an active scan for airplanes, the location of the DC-9, despite its greater size, would have reduced the Piper pilot's ability to see it. Further, given the available evidence, the Safety Board cannot reach any conclusion concerning his alertness to the conduct and maintenance of an active scan for other airplanes.

Aeromexico regulations do not contain specific procedures limiting cockpit conversation and prohibiting flight attendants from entering the cockpit during critical phases of flight as do those for U.S. air carriers. However, its regulations do require the cockpit door to be closed during flight and they state specifically who may occupy the cockpit jumpseat. The available evidence does not permit any conclusions that the flightcrew's attention to required duties was compromised during the descent.

Based solely on the location of the Piper on their airplane's windows and windshields, the Aeromexico flightcrew should have had an almost unobstructed view of the Piper PA-28. Although the first officer was flying the airplane, the autopilot, in accordance with company policy and procedures, should have been engaged, thus freeing him from some of the duties associated with hand-flying the DC-9. Of greater significance was the fact that the Piper was approaching the DC-9 from the non-flying pilot's side with less than a 30° offset to the left; thus, the Piper was in an area where the captain's natural scan and attention should have been focused. Mitigating against these advantages was the smaller size of the Piper and the fact that it was visible to the first officer only through the center windshield. In addition, because the airplanes were on a collision course, the relative motion of the Piper would presumably been minumal and, therefore, it would have been more difficult to detect.

In addition to the limitations imposed by cockpit structure, the physiological capability of the human eye to identify targets also limited the ability of the pilots to see the other airplane. Data indicates that, as a minimum, targets should subtend a visual angle of 0.2° (12 minutes) of arc to reasonably ensure accurate recognition. 14/ The Piper would have subtended a visual angle of 0.2° of arc when it was a little over 1 nmi away or 15 seconds before the collision. The DC-9 would have subtended this visual angle when it was about 6 nmi away or about 1 minute 23 seconds before the collision.

14/ Van Cott, H. and Kinkade, R. "Human Engineering Guide to Equipment Design," Revised Edition; American Institute for Research, Washington, D.C., 1972.

The visual acquisition charts further illustrate some of the difficulties pilots face in seeing and avoiding other targets. To be effective, the pilot must see the other aircraft in time to initiate and complete an evasive maneuver. FAA Advisory Circular (AC) 90-48C, which is based on military-derived sources, states that the total time necessary for a pilot to see an object, to recognize it as a potential midair target, and then to execute an evasive maneuver is 12.5 seconds. The TCAS resolution maneuver is supplied to the pilot between 25 to 30 seconds before the airplane reaches the projected collision point. Given these data, the Safety Board believes that, for this discussion, 15 seconds would be a reasonable time for a pilot to recognize a potential target and execute an evasive maneuver.

The visual acquisition chart indicated that the Piper pilot had an 80 percent probability of seeing the DC-9 at 15 seconds before the collison. With both pilots of the DC-9 looking, the probability of their sighting the Piper airplane 15 seconds before the collison was 30 percent and with one pilot looking, the probability diminished to 15 percent. With regard to "see and avoid," the evidence indicated that the pilot of the Piper had a high probability of sighting and avoiding the DC-9, whereas the probability of the Aeromexico flightcrew sighting and avoiding could only be characterized as marginal, at best. However, while these data indicate that "see and avoid" is not a totally acceptable concept, other evidence indicates that its viability cannot be dismissed summarily.

During 1985 and 1986, pilots reported a total of 1,598 near midair collisions (NMAC) to the FAA. 15/ During this 2-year period, 341 NMACs were classified critical, 887 potential, and the remainder were either adjudged no hazard, "unclassified," or "open." The 887 potential NMACs indicate that pilots do see and do avoid other airplanes while flying in visual flight conditions.

Regardless of the above considerations, both airplanes were operating in visual flight conditions and therefore were required by regulations to see and avoid each other; however, in this case, their failure to do so must be evaluated in context with the limitations placed on the pilots by the angles of closure, the size of the targets, the conspicuity of the targets, and the physiological capabilities of the human eye to accomplish this task.

The charts showing probability of visual acquisition also demonstrate the value of alerting pilots to the presence and location of a collision threat. The chart indicates that had a TCAS alert been provided to the DC-9 pilots, the probability of acquisition with both pilots looking would have increased from 30 percent to 95 percent. However, the 95 percent probablilty of acquisition was based on a TCAS alert that provided the target's relative bearing, range, and altitude. In this instance, the Aeromexico flightcrew would have been provided only the Piper's relative range and bearing. While the absence of altitude information would have made the pilot's task of visually acquiring the target more difficult, the probability of acquisition still would have exceeded that of an unalerted flightcrew.

In conclusion, the Safety Board has recommended the development of TCAS and the establishment of TCAs as a means to lessen the risk and possibly to eliminate the occurrence of midair collisions near major air traffic hubs. The evidence shows that, first, had flight 498 been equipped with a TCAS, the accident might not have occurred and second, had the Piper been mode C-equipped, the collision probably would have not occurred. The Safety Board believes that the TCAS development program must be expedited and the installation of TCAS must be mandatory on all air carrier and

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15/ Selected Statistics Concerning Pilot Reported Near Mid-Air Collisions; U.S. Department of Transportation; FAA; Office of Aviation Safety; Safety Analysis Devision.

commuter airline aircraft, at the very least. In this regard, the Safety Board is also gratified to note that Piedmont Air Lines has begun airborne testing of the TCAS II during line operations and that United and Northwest Air Lines will begin similar programs in the near future.

The Safety Board also believes that the TCA remains a very viable concept for decreasing the midair collision risk at major airports. The program to strengthen these restricted airspaces, as approved by the FAA Administrator , addresses many of our concerns. The FAA's June 11, 1987, NPRM addresses a requirement for mode C altitude reporting transponders within a 30-nmi radius of the primary airport in all TCAs. The Safety Board strongly supports this action and, in fact, believes that even more stringent transponder requirements should be imposed. The Safety Board believes that mode C transponders should be required for all aircraft sharing airspace with air carrier aircraft that will eventually be equipped with TCAS. This could be accomplished to a large extent if the requirements for entry into an Airport Radar Service Area were strengthened to include transponder mode A and C requirements.

The Safety Board believes that the potential for midair collisions between VFR and IFR aircraft will continue to exist so long as the avoidance of such collisions totally depends on the alertness of pilots and air traffic controllers without supplementary features to warn of impending conflict. The implementation of the conflict alert feature in en route and terminal radar control computers has undoubtedly contributed to the avoidance of collisions between two IFR aircraft. The en route Air Route Traffic Control Center (ARTCC) systems are being expanded to include conflict alert for transponder-equipped VFR targets as well as discrete IFR targets. The Safety Board understands that present terminal area control computer capacity is inadequate for such enhancements and that future implementation of VFR conflict alert within the terminal area is not planned to be implemented until the mid 1990s as a feature of the Advanced Automation System (AAS). However, the Safety Board believes that the software computer logic for terminal area conflict has been developed and could be implemented if additional processing capability were added to existing ARTS IIIA equipment. The procurement of additional processors would probably infringe on other FAA priorities and would be viewed as an interim measure to the ultimate installation of the AAS. Nonetheless, the Safety Board believes that the benefit of expediting VFR conflict alert features in terminal computers would merit such expenditure.

The facts and circumstances of this accident demonstrated the necessity of providing both controllers and pilots with automated warning systems that can assist them in avoiding midair collisions. These systems should alert the ATC controller of an impending traffic conflict and the pilots' system should alert them to the presence and location of any aircraft that poses a collision threat to his aircraft. If either the pilots or the controller had available this type of equipment to assist them, this collision might have been avoided. Therefore, the Safety Board concludes that the lack of automated redundancy to assist the pilot and controller was a causal factor in this accident.

CONCLUSIONS

3.1 Findings

1. The airplanes collided at a 90° angle, at an altitude of about 6,560 feet, and in visual meteorological conditions. The collision occurred inside the Los Angeles TCA.

2. Both pilots were required to see and avoid the other airplane. There was no evidence that either pilot tried to evade the collision.

3. The pilot of the Piper was not cleared to enter the Los Angeles TCA. His entry was inadvertent and was not the result of any physiological disablement.

4. The unauthorized presence of the Piper in the TCA was a causal factor to the accident.

5. The positions of the Piper were displayed on the AR-1 controller's display by, at the least, an alphanumeric triangle; however, the Piper's primary target may not have been displayed or may have been displayed weakly due to the effects of an atmospheric temperature inversion on the performance of the radar. The analog beacon response from the Piper's tranponder was not displayed because of the equipment configuration at the Los Angeles TRACON.

6. The AR-1 controller stated that he did not see the Piper's radar return on his display, and, therefore, did not issue a traffic advisory to flight 498. His failure to see this return and to issue a traffic advisory to flight 498 contributed to the occurrence of the accident.

7. The Los Angeles TRACON was not equipped with an automated conflict alert system which could detect and alert the controller of the conflict between the Piper PA-28 and flight 498.

3.2 Probable Cause

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.

4. RECOMMENDATION

4.1 Recommendations Addressing Midair Collision

Since 1967, the Safety Board has issued 116 recommendations as a result of its investigations, special studies, and special investigations of midair or near midair collisions. A review of these 116 recommendations identified 56 that are pertinent to the accident at Cerritos.

The 56 recommendations suggested changes and/or improvements that the Safety Board believed would decrease the midair collision risk. The areas addressed in these recommendations included among others: radio communication procedures; development of ATC procedures to provide separation between high-and-low performance aircraft in high-density terminal areas; improvement of ATC radar capability; improvement of aircraft conspicuity, particularly the development and installation of anti-collision light systems and the requirement to use these lights day and night; and the development of airborne collision warning systems.

On November 4, 1969, the Safety Board convened a public hearing to investigate the subject of mid-air collisions. As a result of the hearing, 14 safety recommendations were sent to the FAA. Recommendations A-70-5 through -15 were sent to the FAA on February 22, 1971. These 14 recommendations addressed the area cited in the previous paragraph.

During this 19-year period, the remainder of the recommendations sent to the FAA have continued to stress these areas of concern and, where warranted by facts developed during other investigations, to amplify and reiterate matter and materials contained in some of the earlier recommendations. The history of these 56 recommendations and the actions taken by the FAA in response to them is contained in detail in appendix H.

As a result of this accident investigation and a review of the FAA's ongoing activities, the Safety Board reiterates the following recommendations to the FAA:

> Expedite the development, operational evaluation, and final certification of the Traffic Alert and Collision Avoidance System (TCAS) for installation and use in certificated air carrier aircraft. (Class II, Priority Action) (A-85-64)
>
> Amend 14 CFR Parts 121 and 135 to require the installation and use of Traffic Alert and Collision Avoidance System (TCAS) equipment in certificated air carrier aircraft when it becomes available for operational use. (Class III, Longer Term Action) (A-85-65)

In addition, the Safety Board recommends that the FAA:

> Implement procedures to track, identify, and take appropriate enforcement action against pilots who intrude into Airport Radar Service Areas (ARSAs) without the required Air Traffic Control (ATC) communications. (Class II, Priority Action) (A-87-96)
>
> Require transponder equipment with mode C altitude reporting for operations around all Terminal Control Areas (TCAs) and within an Airport Radar Service Area (ARSA) after a specified date compatible with implementation of Traffic Alert and Collision Avoidance System (TCAS) requirements for air carrier aircraft. (Class III, Longer Term Action) (A-87-97)
>
> Take expedited action to add visual flight rules conflict alert (mode C intruder) logic to Automated Radar Terminal System (ARTS) III A systems as an interim measure to the ultimate implementation of the Advanced Automation System (AAS). (Class III, Longer Term Action) (A-87-98)

Chairman filed the following dissenting statement regarding probable cause and contributing factors:

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. Contributing to the accident was the inadvertent and unauthorized entry by the pilot of the PA-28 into the Los Angeles terminal control area and his failure to see and avoid the DC-9 prior to the collision.

ICAO Note.— Sections 1.17 and 1.18, Figures 1 to 5 and 7, and the Appendices were not reproduced. Minor editorial changes were made.

ICAO Ref.: 246/86

No. 7

Airbus A300-600, HS-TAE, accident over Tosa Bay, Japan, on 26 October 1986. Report released by the Aircraft Accident Investigation Commission, Japan.

SYNOPSIS

On HS-TAE, an Airbus Industrie A300-600, of the Thai Airways International Ltd. which was in flight from Manila International Airport to Osaka International Airport as Flight 620 on October 26, 1986, an explosive exploded about 1100 hours (in UTC; 2000 hours in JST) over Tosa Bay within the aft lavatory causing fracture of the aft pressure bulkhead followed by rapid decompression in the cabin, resulting in an emergency landing at Osaka International Airport.

There were two hundred and thirty-three passengers (including three infants) and fourteen crewmembers (two hundred and forty-seven in total) on board the aircraft, of which one hundred and six passengers were seriously or slightly injured and three cabin attendants were seriously injured.

The aircraft was substantially damaged but no fire occurred.

Accredited Representatives and their advisors of Thailand, the state of registry, and France, the state of manufacture, of the accident aircraft participated in the investigation.

1. FACTUAL INFORMATION

1.1 History of Flight

HS-TAE, an Airbus Industrie A300-600, of Thai Airways International Ltd. departed Bangkok International Airport as Scheduled Flight 620 (Manila—Osaka) at 0405 hours (UTC, the same applies hereinafter) Oct. 26, 1986, and arrived 0717 hours at Manila International Airport (hereinafter referred to as "Manila Airport "). The aircraft took off Manila Airport 0758 hours for Osaka International Airport (hereinafter referred to as "Osaka Airport").

The flight plan submitted to Manila Airport Authorities indicates: destination was Osaka Airport on IFR with a cruising speed of 480 knots (TAS), at flight level 330 (altitude about 33,000 ft. The same applies hereinafter), via Balesin—A582—Erabu VOR—Shimizu VOR—V71 and estimated flight time to Osaka Airport was 3 hours and 17 minutes with New Tokyo International Airport as the alternate.

According to ATC communication records, the aircraft passed over Shimizu VOR 1056 hours at flight level 330, and descent to 12,000 ft was approved at 1100 hours by Tokyo Area Control Center (hereinafter referred to as "Tokyo Control"). According to records of the flight recorder of the aircraft as well as statements of cabin attendants, an explosion occurred about 1100:10 hours in the vicinity of the aftmost lavatory on the left side, and the passenger cabin was brought into a rapid decompression.

At 1102 hours Tokyo Control observed deviation of the aircraft from Airway V-71 by radar and instructed a direct course to Goboh VOR. Tokyo control realized soon thereafter that an abnormal situation was taking place on the aircraft, from the fact that the aircraft continued to deviate to south of the course and that the altitude was rapidly decreasing, at which time the control repeated calling to the aircraft, but no effective reply was received from the aircraft. At 1107:15 hours the aircraft reported to Tokyo Control that the aircraft had been descending in an emergency condition due to rapid decompression.

Tokyo control monitored by radar that the aircraft continued further descent and instructed magnetic heading for providing radar navigational guidance to Osaka Airport. At 1108−1109 hours, Tokyo Control instructed all other traffic in communication on the same frequency to change the frequency to 125.6 MHz in order to secure communication with the aircraft. Tokyo Control continued radar navigational guidance to the aircraft, and transferred radio communication of the aircraft to Osaka Terminal Control (hereinafter referred to as "Osaka Approach").

At 1124 hours, Osaka Approach received from the aircraft request to make an emergency landing. Osaka Approach informed all units concerned within the airport of the request of the aircraft without delay. At 1134:04 hours Osaka Approach cleared an instrument approach to Runway 32L, and transferred radio communication of the aircraft to Osaka Aerodrome Control Tower (hereinafter referred to as "Osaka Tower").

Osaka Tower cleared the aircraft to land 1135:43 hours. The aircraft touched down on Runway 32L at 1140 hours and came to a stop on the runway between Taxiway W7 and W8, and was towed to No.5 Spot for parking.

Since the report had been received from the captain that there were injured within the aircraft, together with the request to arrange for ambulances, the injured were carried to hospitals by ambulances waiting for them, upon arrival of the aircraft at No.5 Spot.

1.2 Injuries to Persons

	Persons on board		Others
Injuries	Crew	Passengers	
Fatal	0	0	0
Serious	3	5	0
Minor	0	101	0
None	11	127	

1.3 Damage to Aircraft

1.3.1 Extent of Damage

The aircraft was substantially damaged.

1.3.2 Damage to Aircraft by part

(1) Fuselage

(a) In the pressurized structure portion of the fuselage, wrinkly deformation was found at the skin in the vicinity of Stringer 25L located at about 8 o'clock position of Fuselage Frame 79.

Penetrated holes were found on the forward side of Frames 80/82 to which the aft pressure bulkhead is attached; one on the skin between Stringer 9L and Stringer 10L near 10:30 o'clock position, one on the skin between Stringer 12L and 13L near 10 o'clock position, and three on the skin between Stringer 15L and 16L near 09:30 o'clock position.

Remarks: The o'clock position referred to herein indicates the position as seen from rearward and clockwise from the uppermost central point regarded as 12:00 o'clock thinking of the object as the dial of a clock (the same applies hereinafter).

(b) It was found that furnishings in passenger cabin, baggage brought in by passengers and materials mainly heat-insulating materials installed on the pressurized side of the aft pressure bulkhead were extensively dispersed in the non-pressurized area from the aft pressure bulkhead attached to Fuselage Frame 80/82 to the APU fire wall of Fuselage Frame 95.

(c) Many bullet-mark-like scratches including pierced holes were found on the fuselage skin ranging from Fuselage Frame 83 to 86.

Moreover, on frame structures in the area much damage was found involving fracture of frame chord materials and deformation of shear webs.

(d) It was found that the equipment compartment access door 312AR made of an aluminum alloy, and located between Fuselage Frame 84 and 85 was deformed to swell.

(e) As to the equipment compartment access door 312AL made of a carbon fibre reinforced plastic and located between Fuselage Frame 92 and 94, only its hinged portion was found remaining on the fuselage. The door which would have been damaged and separated from the airframe during flight was not recovered.

(2) Aft Pressure Bulkhead

(a) The aft pressure bulkhead is a dome-shaped structure with a diameter of 3,860 mm and a radius of curvature of 2,250 mm. The pressure bulkhead is of such a structure that 6 fan-shaped plate (dished segments, 1.05−1.40 mm thick) and one disk-shaped plate placed at the center (dished plate, 1.50−2.50 mm thick) are arranged in a dome-shape and rivet-jointed together, setting 5 ring sections concentrically, one ring frame, and 6 straps and 24 stiffeners radially.

As to the aft pressure bulkhead, its right half bulkhead ranging from 12 o'clock position to 6 o'clock position remained attached in the original condition, but in the left half a fractured line run from the dome center to 9 o'clock position, dividing the bulkhead roughly into three portions. The left half of the bulkhead which was divided into two was damaged to make a large opening rearward leaving its peripheral portion on Fuselage Frames 80/82 to which it was attached.

(b) The disk-shaped plate at the dome's center was fractured for 3/4 of the circumference, and was bent rearward and remained being not separated from the right half of the bulkhead.

(c) A considerable number of pierced holes about 5 mm in diameter and oriented from the pressurized cabin toward the non-pressurized area were found on the aft pressure bulkhead, highly concentrated on the crossing of the strap of 10 o'clock position and the ring frame to fix the dish plate at the dome center.

(3) Cabin

(a) As to decompression panels installed on the side wall near the cabin floor for use in case of rapid decompression, four panels after the 37th seat row (between fuselage frame 69−73) on the left side of the fuselage were found opened. Meanwhile, on the right side of the fuselage, three panels were opened after the 38th seat row (between Fuselage Frame 68−71). These panels are located near the aftmost portion of the passenger cabin for both sides.

(b) Lf and Lg Lavatories located aftmost of the fuselage were substantially damaged; especially the aft dressing table of Lf Lavatory was damaged to such an extent as its original form could not be traced.

Moreover, damage due to a number of bullet holes was found on the side wall facing Ld and Lg Lavatory and the door of Lf Lavatory.

(c) It was found that the supporting strut of the center portion of the cross beam of floors of Lf and Lg Lavatories of Fuselage Frames 80/82 was damaged by cracking.

It was also found that the supporting strut of the upper portion of the lavatories were deformed.

(d) On the aluminum honeycomb panel facing Ld Lavatory of G4 Galley, damage by pierced holes having orientation from aft to fore was found at more than ten locations.

(e) Damage by pierced holes was found at several locations on the back rest of the cabin attendant swivel seat located on the aisle to Ld and Lf Lavatories aft of left-side aftmost doorway 4L of the cabin.

(4) Under-Floor Cargo Compartment

(a) One blow-out panel in the wall (located at Fuselage Frame 20) between the electronics compartment and forward cargo compartment was blown out forward into the electronics compartment. The aft side wall of the cargo compartment (located at Fuselage Frame 38.2)was deformed so as to swell foreward as a whole.

(b) One blow-out panel of the side wall (near No.41R container position) installed right and foremost of the aft cargo compartment was blown into the cargo compartment.

Besides, there were found several blow-out panels where a gap was made to become a partial opening.

(c) Two blow-out panels in aft wall (located at Fuselage Frame 70) between the bulk cargo compartment and the under-floor equipment compartment located aft there of were separated, and found in the under-floor equipment compartment located thereof.

The upper edge of the aft wall of the bulk cargo compartment was pushed back from the horizontal structure with which it is fixed and supported, and pushed backwards 3—4 cms.

(d) No irregularities were found on the under-floor equipment compartment aft of bulk cargo compartment except in the vicinity of Fuselage Frame 80. Irregularities were found such as dents and bents considered to have been caused by damage to the aft pressure bulkhead on the shield tube protecting the fuel supply pipe to the auxiliary power unit (APU) located at Fuselage Frame 80, but there was found no evidence of fuel leakage.

(5) Horizontal Fin

(a) A visual inspection was made by opening the trailing edge panels after the rear spar of the horizontal stabilizer, which indicated that an amount of light materials including lavatory inner board material and insulative materials brake into the area for the whole wing span.

(b) The lower apron fairing on the left horizontal fin's root was damaged in part and bent, but it was not of such an extent as to disturb the function of the horizontal fin.

(c) A scar due to collision with a scattered object was found on the root section of the under surface of the right elevator.

(d) There was found a trace of fluid of the hydraulic system considered to have leaked from the under surface of the apron fairing at the under surface root section of the right elevator.

(6) Vertical Fin

There was evidence of oil leakage considered as fluid of the hydraulic system for an area ranging from part of the fairing installed on both sides of the root of the vertical fin to the fuselage, but there was found neither deformation nor damage to the fairing.

(7) Auxiliary Power Unit

(a) Damage to the APU firewall attached to Fuselage Frame 95 was found such as wrinkly deformation for its whole portion. The upper part of the firewall was deformed in such a manner as it was pushed backwards as a whole. Several scratches like bullet marks were found on the lower part of the firewall.

(b) The top and the second stiffeners, out of 5 horizontal stiffeners which reinforce the firewall, were buckled in their right side portion.

The center stiffener was buckled for its whole length, and fractured at the portion where the right side supporting strut of the firewall is attached, and separated about 20 mm from the firewall.

The lower stiffeners were also buckled in the similar manner, and the second stiffener from the bottom was fractured at the righ-side bracket portion and separated.

(c) Both the right and the left fire wall of the APU compartment were bent inward, wrinkles being made at the upper and lower corners.

(d) The fire wall located at the ceiling in the APU compartment from Fuselage Frame 95 to 97 was deformed downwards.

(8) Hydraulic System, Flight Control System, etc.

(a) Three independent hydraulic systems of "green", "blue" and "yellow" are provided on the aircraft and the operation of flight control surfaces and others are all dependent upon them. The hydraulic fluid of the "blue" and the "yellow" system, out of the three hydraulic systems, was lost, with their hydraulic reservoir indicating zero remaining amount. In the "blue" hydraulic system were found breakage of the return line of the rudder servo located aft of the center of the aft pressure bulkhead and the yaw damper actuator, as well as several pierced holes. In the "yellow" hydraulic system, there was found several pierced holes on the return line of the horizontal stabilizer actuator located on the ceiling in the vicinity of the Fuselage Frame 85 as well as on the return line of the yaw damper actuator located aft of the center of the aft pressure bulkhead.

There was found no specific damage on the "green" system.

(b) The path of the horizontal stabilizer trim control cable passing beneath the floor of the passenger cabin was deviated due to damage to the aft pressure bulkhead. The rudder control cable was also deviated to such a extent that it contacted with covering in its vicinity and its movement was stiff.

(c) Due to fracture of the aft pressure bulkhead, electric wiring in its vicinity was subjected to breakage at more than 20 locations.

1.4 Other Damage

None

1.5 Crew Information

Captain Male, aged 46

Licence: Airline Transport Pilot License No.D-0149
acquired on May 2, 1973
Type rating: Douglas DC-8 acquired on December 16, 1980
Airbus A300-B4 acquired on March 4, 1982
Airbus A300-600 acquired on March 5, 1986
Medical certificate: Class 1 valid until April 5, 1987
Total flight experience: About 15,000 hours
Flight experience on type: 692 hours
Flight time last 30 days: 48 hours 10 minutes

Copilot: Male, aged 39

Licence: Commercial Pilot License No.D-0030
acquired on June 16, 1971
Type rating: Douglas DC-8-33 acquired on May 21, 1975
Douglas DC-8-63 acquired on November 24, 1976
Airbus A300-B4 acquired on April 4, 1982

Airbus A300-600	acquired on October 29, 1985
Medical certificate: Class 1 valid until	July 16, 1987
Total flight experience:	12,156 hours
Flight experience on type:	200 hours
Flight time last 30 days:	85 hours

1.6 Aircraft Information

1.6.1 Aircraft

Type:	Airbus A300-600
Serial number:	395
Date of Manufacture:	October 9, 1986
Certificate of Airworthiness:	130/2529 issued October 9, 1986
Total time:	100 hours 29 minutes
Total Landings:	30

1.6.2 Engines

The aircraft was equipped with two General Electric CF6-80C2-A1 engines.

Engine No.	Serial No.	Total hours
1	690133	100 hours 29 minutes
2	690137	100 hours 29 minutes

1.6.3 Weight and Center of Gravity

The weight of the aircraft at the time of the accident is calculated as 127,600 kg, and the center of gravity as 31.5% MAC, both being within the allowable limits (the maximum take-off weight is 165,000 kg:the center of gravity corresponding to the weight at the time of accident is within 15.0—36.0% MAC).

1.6.4 Fuel and Lubrication Oil

The fuel on board was JET A-1 and the lubrication oil was Exxon Turbo Oil 2380, both being regular products for the aircraft use.

1.7 Meteorological Information

1.7.1 Synoptic Weather Conditions

According to the Meteorological Agency, the synoptic weather conditions along the flight route of the aircraft about 0800—1300 hours were as follows:

(1) Manila—Amami Oshima

The neighboring waters to Okinawa and Philippines were covered by a Pacific High, and the weather from Manila to Amami Oshima was fine except for cumulus and stratocumulus which existed in very limited areas. The wind at altitude of about 10 km was stronger as they went northward, and in the area from Naha to Amami Oshima it was westerly with a velocity of 20—30 m/sec as a whole.

(2) Amami Oshima—Osaka

During the said time zone, a Low accompanied with a front was advancing eastward south of Kyushu; and a cold front extending south-west from another Low whose center was located near Saghalien was moving southward over Honshyu Island. For this reason, area from north of Amami Oshima to Osaka was covered by dense cirus, altostratus and cumulus, and active convective clouds were spotted from place to place. The altitude of the active convective clouds was 10—12 km. The weather for the area from Amami Oshima to Osaka was rainy or cloudy. The wind at the altitude of about 10 km was stronger as they went northward, and in the area from Amami Oshima to Osaka it was westerly with a velocity of 30—60 m/sec.

1.7.2 Weather Observations

The 1130 surface aviation weather observation at Osaka Airport was:

wind from 330° at 5 knots, visibility 6 km, rain, 2 oktas SC 5,000 ft, 8 oktas AS 9,000 ft, temperature 16° C, dew point 14° C QNH 29.89 inches(Hg), remarks mist.

The 1200 surface aviation weather observation at Kochi Airport located at about 50 km north of the point where the rapid decompression may have occurred was as follows:

wind from 360° at 4 knots, visibility 7 km, rain, 2 oktas CU 2,000 ft, 4 oktas CU 2,800 ft, 8 oktas AS 9,000 ft, temperature 17° C, dew point 15° C, QNH 29.88 inches(Hg), remarks mist.

1.7.3 The Nephos Analysis in Asia by Meteorological Satellite (ANAS) at 1200 hours of the day is as in Attached Chart 2.

1.7.4 The Asia 300hpa Upper Analysis (AUAS30) corresponding to the altitude of about 30,000 ft at 1200 hours of the day is as in Attached Chart 3.

1.8 Communications

The aircraft was in communication with Tokyo Control on frequency 132.4 MHz at the time the rapid decompression occurred.

The communication was discontinued after the occurrence of the rapid decompression until it was recovered 5 minutes thereafter, when the emergency of the aircraft was reported. At 1108 hours Tokyo Control requested other traffic on the same frequency to change their frequency to 125.6 MHz, an alternate frequency in order to secure communication with the aircraft.

At 1124 hours the aircraft switched the frequency to 124.7 MHz in accordance with instruction of Tokyo Control and established communication with Osaka Approach.

At 1134 hours the aircraft was transferred to Osaka Tower on 118.1 MHz and the aircraft landed on Runway 32L of Osaka Airport at 1140 hours.

Communication records of ATC units with the aircraft is attached to this report as Attachment 1 "Communication Records with ATC Units".

1.9 Flight Recorders

On board the aircraft were installed a 980-4100-DXUN Digital Flight Data Recorder of US Sundstrand Data Control,INC.(hereinafter referred to as "DFDR"),and an A100 Cockpit Voice Recorder of Fairchild Co.(hereinafter referred to as CVR). The recorders, installed in the aft under-floor equipment compartment (aft of the bulk cargo compartment), were both recovered.

On board the aircraft was also installed a Digital Aircraft Integrated Data System Recorder (hereinafter referred to as "DAR") of Enertec Schlumbeger Co. of

France, of which cassette tape (Serial No.21208) was recovered.

The DFDR and DAR were recovered without damage to their covering case, but record of the DFDR was lacking for about two minutes after the rapid decompression occurred. The DFDR record, supplemented by DAR record, of which contents were almost the same as those on the cassette tape of DAR, was shown as DFDR in Attachments 3−1 to 3−4.

Since the recording of the time in DFDR, which is the same as the time displayed on the clock at the captain's seat, is not always accurate, collation was made by the following method:

In DFDR there are recorded keying times of the microphone switch used at the time of communication with the ATC Unit, while on the ATC communication tape there are recorded time signals of the Japan Standard Time. Collation of the keying times was conducted on the basis of the standard time, which revealed that there was about 10 seconds delay in DFDR record time. The attached DFDR record is displayed on the time scale before the collation was made.

On CVR there remained no record relating to the accident, because the recorder was left in continuous running during 40 minutes flight after the accident, movement to the spot by towing car, and also during confirmation of the damaged portion after passengers were disembarked; thus far exceeding the recording cycle (about 30 minutes) of CVR.

Remarks: The DAR is not equipment of which installation is legally obligatory, but an optional recorder on a cassette tape of information necessary in respect of operations, maintenance, engineering, etc. with its function and operational conditions set at the discretion of the airline.

1.10 Medical Information

Out of a total of two hundred and forty-seven persons on board the aircraft, consisting of two hundred and thirty-three passengers and fourteen crewmembers, five passengers and three crewmembers were seriously, and one hundred and one passengers slightly injured.

Seating locations of the seriously injured were: two persons near the foremost row, three near the center, and three near the aftmost row, of which two persons were injured by explosion of the explosive.

The break-down of injuries to the seriously and the slightly injured is as follows:

(1) The break-down of the eight persons who were seriously injured is two persons externally injured by the explosive, two externally injured in head during the dive, two sprained in neck, one bruised all over, and one subjected to aeronautical tympanitis. Three cabin attendants and two passengers out of the eight persons were not wearing the seat belt.

(2) The break-down of one hundred and one slightly injured persons was eighty-

eight subjected to aeronautical tympanitis, five externally wounded in the head, four bruised on the breast, three sprained in the nock, and one bruised all over the body.

(3) The injured were accommodated in eleven medical facilities after the aircraft arrived at Osaka Airport, and diagnosis by the doctor was conducted. Most of them, including the slightly injured, were hospitalized in the facilities where the diagnosis was conducted, because it was already midnight, and left the facilities on the following day. Those who were hospitalized more than 48 hours were eight including persons who were hospitalized after they returned home.

1.11 Information on Search, Rescue and Evacuation relating to Survival, Fatality and Injuries

Tokyo Control received at 1108 hours the report of emergency due to rapid decompression of the aircraft, and reported it without delay to the Rescue Coordination Center (RCC) at Tokyo Airport Office of Tokyo Regional Civil Aviation Bureau.

The RCC received at 1114 hours the information on the emergency of the aircraft from Tokyo Control and reported it to Maritime Safety Agency and other organizations concerned.

Confirming the request of an emergency landing from the aircraft at 1124 hours, Osaka Airport Office of Osaka Regional Civil Aviation Bureau dispatched the fire engines, and requested the neighboring municipalities to dispatch their fire engines and ambulance cars.

1.12 Other Information

1.12.1 Situation in the Aircraft subsequent to the Rapid Decompression

According to the statement of a cabin attendant seated on the cabin attendant seat aft of the 4L door with the seat belt on, the situation within the aircraft after the explosive blew up was as follows:

Most of passengers were putting the belt on, because the "fasten seat belt" sign was lit up. A sound like "bang" was heard together with an impact on the right ear, with a feeling that the body would have been pushed from backward, and the chair leaned forward with a bang, and thereafter a wind came from forward so as to suck the body aft.

A white thing, something like fog or haze, was seen forward generating momentarily and the oxygen mask came to drop down. I left the chair after the wind subsided, but the aircraft started movement to all directions, and passengers and cabin attendants who had not put the seat belt on were floated and thrown away to be injured having no time to hold themselves on any fixture.

1.12.2 Responsive Actions taken by Flight Crew

Responsive actions taken by the captain and the copilot are summarized as follows according to their statement:

The aircraft departed at Manila and headed for Naha VOR via Kanduli, during which time no irregularities were encountered and communication was normal.

The aircraft passed Naha VOR, and in the vicinity of Tanegashima they lit up "fasten seat belt" sign because a clear air turbulence was encountered. All information on approach and landing at Osaka Airport including the runway in use had been obtained, and the flight operation was considered normal and complete in all aspects. The captain went to the lavatory aft of the cockpit. When he left the lavatory and was approaching his seat, a strong sound like "bang" was heard, and a lot of articles installed in the cockpit were seen thrown out afterwards, by which he judged that rapid decompression had occurred. When he returned to his seat, the copilot, with the oxygen mask put on, was going to start a dive. Immediate emergency descent was considered most essential thing to do in any way. Already a clearance "cleared to descend to 12,000 ft at any time" had been given by Tokyo Control after passing Shimizu VOR.

To make an emergency descent, the nose was brought down. Dutch roll occurred, the auto trim was inoperable, and the control column was felt extremely heavy needing strong push. The crew were cognizant that Tokyo Control was calling them, but they could not afford to respond, because they must have been concentrated on control of the aircraft under above mentioned difficult flight conditions. Various warning systems were activated simultaneously because the autopilot was "off" and the speed exceeded the maximum operating limit.

During the descent, operation was conducted in accordance with emergency procedures displayed on the CRT, in recognition that two of the three hydraulic systems went to low level in oil quantity and inoperative, however control of the aircraft was possible by the remaining one hydraulic system.

After flight conditions became stabilized, the pilot made contact with Tokyo Control, and reported the rapid decompression and loss of two hydraulic systems, requesting a radar navigational guidance to Osaka Airport.

Thereafter, the aircraft continued approach in accordance with guidance of ATC units, and landed safely at Osaka Airport with flap and landing gear operating normally. After landing, the flight crew requested arrangement for traction of the aircraft and ambulance cars for injured passengers and cabin attendants.

1.12.3 Responsive Actions taken by Cabin Attendants

Responding actions taken by cabin attendants after the rapid decompression are summarized as follows based on their statements:

After flight conditions became stabilized, they walked around within the cabin for inspection, and made explanation on how to wear and use the life jacket to persons who were looking for or had inflated the jacket.

First aid treatment was administered by cabin attendants to persons who fell down on the aisle or hit their head against the ceiling of the cabin and bled, or were complaining of pains in their body, with cooperation of other passengers freed from injury.

After the aircraft arrived at Osaka Airport and passengers were disembarked, one seriously injured passenger was found, being suspended with the head down, at the location (a) of para.1.3.2 (2).

1.12.4 Status within Cabin

(1) It was immediately after passengers had taken a meal that the rapid decompression occurred. There were found what passengers vomitted during the dive scattering for an extensive area.

(2) Oxygen masks located at upper part of the passengers cabin were all made ready for use.

1.13 Tests and Research for Recognition of Facts

(1) Damage caused by a number of pierced holes about 5mm in diameter was found on the fractured aft pressure bulkhead of the aircraft.

Distributioin of bullet marks including unpierced scars, classified roughly into three regions by degree of their concentration, is shown in Attached Chart 8.

(2) The following was confirmed by the investigation of the Scientific Crime Detection Laboratory of Osaka Prefectural Police:

(i) It was found that numerous pierced holes discovered in area from the aftmost portion of the cabin through the APU fire wall area oriented as a radial dispersion centered on the vicinity of a paper-stock shelf of the toilet table aft of Lf lavatory.

(ii) A lot of metallic particles which are comparatively uniform in size and as large as a rice-grain were collected from damaged portions which were not pierced through but dented, as it was found that they contain a high ferrous component, some of them being adhered abrasively to an aluminum component.

(iii) A black adhesive was found on the paper-stock shelf made of an aluminum alloy of Lf lavatory, the paper-waste dump's entry, the waste basket, etc. Analysis of the material revealed that it is residues of combustion of the gunpowder.

2. ANALYSIS

2.1 Tests and Research for Analysis

2.1.1 Analysis on Function of Flight Control Systems and others (refer to Attached Figure 10 and 11)

(1) *According to records on the cassette tape recovered from DAR, the autopilot* (CMD2) went off 8 seconds after the abnormal situation took place on the aircraft, and the function of spoilers operated by the "blue" and the "yellow" hydraulic system became irreguler, and stopped completely one minute and 19 seconds thereafter. The exact time the hydraulic systems stopped their function could not be determined by records of the yaw damper.

(2) Flight control systems of which function was lost or significantly deteriorated due to damage to the "blue" and the "yellow" hydraulic system of the aircraft are as follows:

(i) Systems of which function was totally lost
  a. autopilot
  b. yaw damper
  c. all speed brakes
  d. roll spoilers except No.6 spoiler

(ii) Systems of which function significantly deteriorated
  a. operation speed of the horizontal stabilizer trim deteriorated to about 1/2.

  b. operation speed of the flap and the slat deteriorated to about 1/2.

(3) Based on the status of damage to the aircraft and record on DAR, it is recognized that after the breakage of the aft pressure bulkhead "blue" and "yellow" hydraulic system were damaged and lost their function in a very short time and horizontal stabilizer trim control and rudder control cable movements got stiff. For these, speed brakes on the aircraft were not deployed when speed brake lever was actuated and longitudinal and lateral control got affected, so it is recognized that the aircraft control is somewhat fairly difficult when the flight crew made an emergency descent corresponding to a rapid decompression.

2.1.2 Analysis of DFDR and DAR

DFDR was inoperative for about 2 minutes after the rapid decompression occurred, but major items of the missing portion of DFDR were supplemented by data of DAR which was kept in operation, recording almost the same contents as DFDR. Out of the DAR records, only items necessary for flight analysis and accident analysis were picked up for use.

2.1.3 Estimated Flight Path

The estimated flight path of the aircraft after the rapid decompression occurred is as shown in Attached Chart 1. The chart was drawn: firstly estimating more precise ground speed vector, altitude and others through conducting numerical data procession on attitude angle, ground speed, pressure altitude, acceleration vector and angle of attack data and others in DFDR and DAR records; then obtaining locations on the earth by breaking down and integrating the ground speed vectors along the geographical coordinates.

2.1.4 Investigation on Outflow of Pressurized Air of Cabin

As described in para.2.3.2, on various parts were found fractures of airframe structures considered to have been caused by outflow of pressurized air of the cabin. The flow of the pressurized air of the cabin to the outside of the aircraft after the aft pressure bulkhead is fractured is estimated to have been as follows:

(1) The pressurized air of the cabin went through the aisle leading to the aftmost left-side Ld and Lt Lavatories, collapsed the door of Lf Lavatory and the toilet table aft thereof, and flowed out, through the fractured aft pressure bulkhead, to the non-pressurized area (Section 19, the Equipment Compartment) of the empennage.

(2) The pressurized air in the under-floor pressurized portion such as the under-floor equipment compartment flowed out into the non-pressurized area due to fracture of the aft pressure bulkhead.

(3) When the pressurized air of the cabin and the pressurized portion under the cabin floor flowed out, the pressure lowered in the under-floor pressurized portion faster than in the cabin because of comparatively less path resistance and less air volume of the former as compared with those of the latter, causing a pressure difference, and some of the decompression panels installed on the right and the left side wall near the floor of the aft cabin were opened, making part of the pressurized air of the cabin to flow into the under-floor area.

(4) The pressurized air in the pressurized portion under the cabin floor went through a space in the cabin floor structure, where the control cables and others are passing, as well as through blow-out panels of the aft cargo compartment and the bulk cargo compartment, flowed into the under-floor equipment compartment located directly beneath the aft lavatory, and through the aft pressure bulkhead, flowed into the non-pressurized area of the empennage.

(5) All the pressurized air which flowed into the non-pressurized area went out of the aircraft through the following portions:

(a) Fractured opening of Equipment Compartment Access Door 312AL located between Fuselage Frame 92 and 94.

(b) The trailing edge of the right and the left horizontal stabilizer, from the opening in front spar within the fuselage of the horizontal stabilizer.

(c) The muffler section of the tail cone, from the opening of the upper portion of the APU firewall.

2.2 Analysis

2.2.1 The captain and the copilot were properly qualified and had passed the established medical examination.

2.2.2 *HS-TAE had a valid airworthiness certificate.*

2.2.3 Flight History and Actions taken by the Flight Crew

(1) It is recognized that the aircraft had been in flight at flight level 330 without any abnormality up to the time that the rapid decompression occurred.

(2) It is estimated that the rapid decompression of the aircraft occurred approximately 1100:10 hours over the open sea in the vicinity of 33° 04′ 15″ N, 133° 36′ 02″ E.

(3) *It is estimated that although the flight crew intended to make an immediate* descent after their recognition of rapid decompression, they needed about one minute to comprehend the status of the controllability of the aircraft and stabilize the aircraft in unusual attitude, as the aircraft made the pitch movement from the effect of the air outflow of decompression through the *equipment compartment access door, and made the sideslip and took right bank* rather rapidly from effect of affected various aircraft components by rapid decompression such as temporary sticked rudder control cable.

(4) After the aircraft was stabilized, the flight crew went into a descent at about 15° nose-down pitch, by retarding engine throttle and using the speed brake lever, but dutch roll became significant, and at the same time because of malfunction of the speed brake and other reasons, the speed reached 370 knots (CAS), exceeding about 10% the maximum operation limit speed (VMO/MMO) and the rate of descent became as much as 12,500 ft/min. It is estimated that they tried *to shift to a level flight at about 25,000 ft to stabilize by raising the nose,* during which time a maximum acceleration of +2.6 G's would have applied to the aircraft.

(5) Thereafter the aircraft went into a level flight, but phugoid movement was energized, and in combination with the dutch roll *a complicated movement started.* It is estimated that the flight crew tried to correct this movement by closing the speed brake lever and advancing engine throttle, but the complicated movement did not subside, and the nose-up increased further as much as to 17° and therefore the crew conducted the nose-down operation again. It is recognized that during this period a pitch movement was brought to the aircraft, accompanied by a vertical acceleration coincident in cycle with the dutch roll, meanwhile an acceleration exceeding 2G's was caused for 8 seconds by the abrupt nose-up operation.

(6) It is estimated that almost the same time as above the aircraft began to bank to the right and it took about 10 seconds to correct for the right bank, consequently the heading became about 130° and the aircraft flew to the south-east.

(7) It is recognized that the flight crew again went into a descent by retarding engine throttle and using the speed brake lever, but during this period the speed reached 397 knots (CAS), about 19% above the maximum operation limit speed with the nose-down pitch of as much as about 20° at the descent rate as much as 13,600 ft/min, so reducing this speed, the aircraft was returned to a level flight temporarily at about 18,000 ft.

(8) It is estimated that during the descent the flight crew heard calls from Tokyo Control, and made efforts to respond it but they could not afford to make immediate effective response under such circumstances as priority shoud have been given to control the aircraft.

2.2.4 Status of Aircraft after Explosion within the Aft Lavatory

(1) It is estimated from DAR records that the cabin altitude (pressure of the cabin indicated by the pressure altitude equivalent thereto) became from about 5,600 ft to about 20,000 ft in about 9 seconds after the rapid decompression occurred. The change in the cabin altitude thereafter could not be clarified because DAR is of such a type that changes in altitude is unrecordable at altitudes higher than this, but it is presumed that the cabin altitude became equal to the flight altitude in a short period of time.

(2) A possibility is conceivable that the pressure in the cabin and the cabin under-floor area increased temporarily due to the explosion in the aft lavatory, but there was no record indicative of rise in pressure, because recording interval of DAR for the cabin altitude is every 4 seconds, and therefore, such possibility could not be clarified.

(3) It is recognized that the cabin air which outflowed aft of the aft pressure bulkhead exhausted out of the aircraft mainly throught the equipment compartment access door and trailing edge portions of the horizontal stabilizer. It is also recognized that, by pressure increase at this time in the aft fuselage, the APU firewall was pushed inwards and transfigured.

(4) It is estimated that due to fracture of the aft pressure bulkhead, rudder control cables were displaced and stuck so that the rudder moved about 3° to the right, and such a state was maintained for a certain period.

(5) It is recognized that soon after the rapid decompression occurred, the aircraft entered into two times a considerable right bank considered as due to the displacement and stick of the rudder to the right, but the attitude was recovered by recovery operation of the flight crew, and the rudder was brought to about the neutral position.

(6) It is estimated that the aircraft went into an abnormal descent despite the intention of the flight crew as longitudinal, lateral and directional control got affected and speed brake became inactive resulting from temporary stick rudder cable, displacement of the stabilizer trim cable and the "blue" and the "yellow" hydraulic system loss and so on.

(7) Irrespective of the situations above, it is recognized that the "green" hydraulic system was kept normally operative, and the aircraft was fundamentally controllable safely, although its longitudinal and lateral control had deteriorated.

2.2.5 Injuries to Passengers and Cabin Attendants

(1) The "fasten seat belt" sign was lit up before the rapid decompression occurred because turbulence was anticipated, and most of passengers had fastened the seat belt. It is estimated that this is the reason the injured were comparatively less than expected for the abrupt change in acceleration the aircraft was subjected to after the rapid decompression.

(2) It is estimated that since most of the passengers and cabin attendants who were bruised had not fasten the seat belt, they tumbled down or collided with the ceiling or seating, etc., floating from or dropping to the floor due to violent change in acceleration during the dive, abrupt climb, dutch roll, phugoid movement, etc. of the aircraft.

(3) A number of passengers, who wore the oxygen mask which came to drop upon occurrence of the rapid decompression, vomited what they ate and drank. It is estimated that it was caused by the violent change in acceleration due to the movement of the aircraft.

(4) It is estimated that the cause for which eighty-eight passengers suffered from the aeronautical tympanitis was a sudden pressure rise during the dive after the rapid decompression.

.2.6 Scars like Bullet-marks

(1) It is recognized, from the results of investigation in para.2.13 that an explosive including gunpowder blew up in Lf Lavatory of the aircraft.

(2) From the fact that the aircraft is not equipped with any explosive including gunpowder, it is recognized that the explosion which occurred in the lavatory was caused by an explosive brought into the aircraft.

3. CAUSE

It is recognized that the cause of this accident was that an explosive, brought into the aircraft, blew up in the left aft lavatory.

ICAO Note.— Minor editorial changes were made. The Attachments were not reproduced.

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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.

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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.

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