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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.

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 or appendices, attachments and diagrams.

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

McDonnell Douglas DC-8-54F, N8053U, at Detroit,
Michigan, United States, on 11 January 1983.
Report No. NTSB/AAR-83/07 released by the
National Transportation Safety Board, United States.

SYNOPSIS

On January 11, 1983, United Airlines Flight 2885, a McDonnell Douglas DC-8-54F, N8053U, was being operated as a regularly scheduled cargo flight from Cleveland, Ohio, to Los Angeles, California, with an en route stop at Detroit, Michigan. United 2885 departed Cleveland at 0115 and arrived at the Detroit Metropolitan Wayne County Airport at 0152, where cargo for Detroit was unloaded, the airplane was refueled, and cargo for Los Angeles was loaded. At 0249:58, United 2885 called for clearance onto runway 21R and was cleared for takeoff at 0250:03. Visual meteorological conditions prevailed at the time, and the company had filed and been cleared for a standard IFR flight plan.

According to witnesses, the takeoff roll was normal, and the airplane rotated to takeoff attitude one-half to two-thirds of the way down runway 21R. After liftoff, the airplane's pitch attitude steepened abnormally, and it climbed to about 1,000 feet above ground level. The airplane then rolled to the right and descended rapidly to the ground. An explosion and fireball occurred at impact. The airplane was destroyed by impact and by the postimpact fire. The flightcrew, consisting of the captain, the first officer, and the second officer, were killed.

The National Transportation Safety Board determines that the probable cause of the accident was the flightcrew's failure to follow procedural checklist requirements and to detect and correct a mistrimmed stabilizer before the airplane became uncontrollable. Contributing to the accident was the captain's allowing the second officer, who was not qualified to act as a pilot, to occupy the seat of the first officer and to conduct the takeoff.

1. FACTUAL INFORMATION**1.1 History of the Flight**

On January 10, 1983, a McDonnell Douglas DC-8-54F, N8053U, was being operated by United Airlines, Inc., (UAL), as a regularly scheduled domestic cargo flight under 14 CFR 121. The flight departed O'Hare International Airport, Chicago, Illinois, as United Airlines Flight 2894 (United 2894) on schedule at 2215 central standard time, destined for Cleveland, Ohio. The en route portion of the flight was uneventful, and United 2894 arrived at Cleveland at 0009 1/ eastern standard time. At Cleveland, the flight number was changed to United Airlines Flight 2885 (United 2885) for the regularly scheduled cargo flight from Cleveland to Los Angeles, California, with an intermediate stop at Detroit, Michigan. United 2885 departed Cleveland at 0115, arrived at the Detroit Metropolitan Wayne County Airport at 0152, and taxied to the UAL freight terminal on the northwest side of the airport. Cargo for Detroit was unloaded, the airplane was refueled, and cargo for Los Angeles was loaded. Included in the cargo was a shipment of Special Form Americium 241 in the form of solid metal pellets. UAL freight handling personnel reported that the turnaround went smoothly; however, one cargo "igloo" was

1/ All times are eastern standard time based on the 24-hour clock unless otherwise noted.

inadvertently not loaded on the airplane (see 1.6.1 Weight and Balance). The freight handling personnel also indicated that they observed the second officer inspecting the exterior of the airplane after the refueling was completed.

The flightcrew of United 2885 called Detroit Clearance Delivery at 0231:26 for air traffic control clearance to Los Angeles, stating that they had received Automatic Terminal Information Service (ATIS) message Foxtrot. United 2885 had filed a standard IFR flight plan and was cleared as filed. According to the cockpit voice recorder (CVR), the flightcrew completed the before engine start checklist, started the engines, and then called for taxi instructions at 0245:58. During the taxi, the flightcrew accomplished the before takeoff checklist, and at 0248:42, the second officer called "trim" and the first officer responded "set." ^{2/} According to the CVR, beginning at 0249:16, the captain, the first officer, and the second officer discussed the idea of the first officer switching seats with the second officer. According to the CVR, the first officer and the second officer had completed switching seats about 0249:40, 24 seconds later. (See appendix E.) United 2885 called for clearance onto runway 21R at 0249:58 and was cleared for takeoff at 0250:03. The before takeoff checklist was completed, and the second officer, now seated in the right pilot seat, called for the "flight recorder," and the first officer, now seated at the engineer's panel, responded "lights out," indicating that the flight data recorder was turned on. The CVR indicated that the throttles were advanced for takeoff at 0251:05 and that power stabilized 7 seconds later. The CVR also showed that "eighty knots" and "Vee One" were called by the captain and that the airplane broke ground about 0251:41.

Twenty-five persons were interviewed and it was determined that 16 had actually seen or heard the airplane. (See figure 1.) Most of the witnesses indicated that the takeoff appeared normal to rotation and that the airplane rotated approximately one-half to two-thirds of the way down the runway near the intersection of runway 21R and runway 9-27 to a normal or fairly nose-high attitude. Several witnesses reported normal engine noise and one reported that the noise of the engines was at a lower pitch than normal. One witness reported hearing a strange engine sound, which he described as sounding like an F-15 going into afterburner. Most witnesses indicated that the aircraft broke ground without dragging the tail skid, that the angle of ascent was abnormally steep, and that the airplane climbed rapidly.

According to the witnesses, approximately 5 seconds after the takeoff and as the airplane was climbing, flames could be seen behind the engines on both wings. Witnesses described the flames variously as coming from one, two, or three of the engines; as coming in two short bursts and then ceasing; as looking like "sparks;" and as looking like a "fireworks show which lit up the sky." According to most witnesses, the airplane continued to climb with wings level to about 1,000 feet. The airplane then rolled to the right in a gradual right turn until it was in a wings vertical position (right wing down, left wing up). One witness, who was located 1 mile east of the takeoff point, thought the angle of ascent was normal and that the airplane banked to the right about 30° from the horizontal and never increased above that angle. Another witness, who was located 1,000 feet beyond the end of runway 21R, stated that the airplane started a sharp right turn at 300 to 500 feet. Most witnesses could not recall the attitude of the airplane from the time it reached the wings vertical position until it crashed, and simply said that the airplane "dropped from the sky" at that point. Two witnesses who had head-on views reported that the airplane came back to a wings horizontal (nose slightly down) attitude from the wings vertical attitude just before the crash. When queried about whether they could have been looking at the airplane in an inverted horizontal position at this point, these two witnesses said they were not positive. They could not recall the position of any of the airplane's external lights when it was in the horizontal position. All of the witnesses stated they saw an explosion which was followed by a fireball and intense ground fire.

^{2/} The checklist response is "3 set" which refers to aileron, rudder, and elevator trim settings.

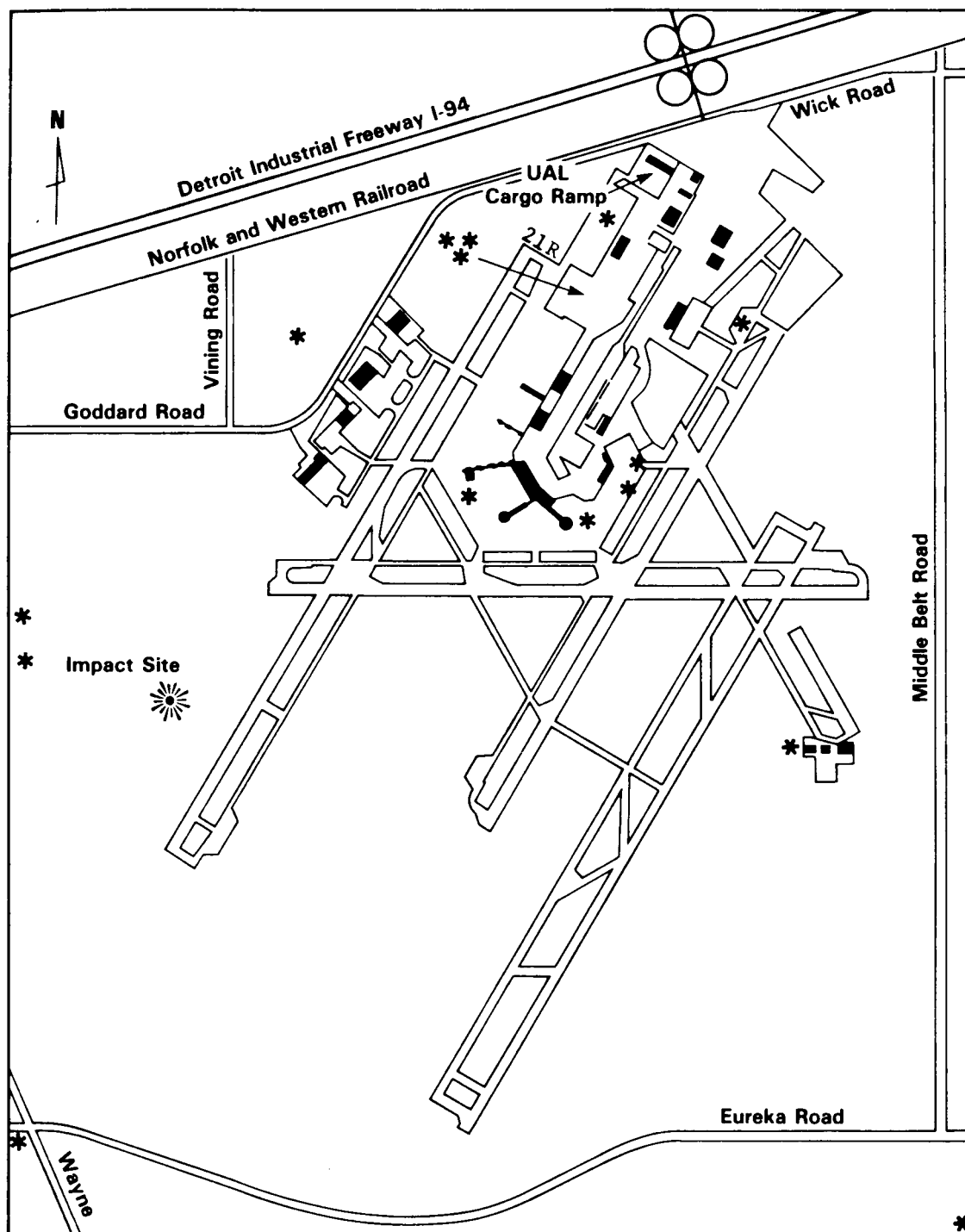


Figure 1.--Detroit Metropolitan Wayne County Airport runway/terminal layout, accident site, and witness locations.

The accident occurred about 0252:11 during hours of darkness at 42° 13' N latitude and 083° 22' W longitude.

1.2 Injuries to Persons

<u>Injuries</u>	<u>Crew</u>	<u>Passengers</u>	<u>Other</u>	<u>Total</u>
Fatal	3	0	0	3
Serious	0	0	0	0
Minor/None	0	0	0	0
<u>Total</u>	<u>3</u>	<u>0</u>	<u>0</u>	<u>3</u>

1.3 Damage to Airplane

The airplane was destroyed by impact forces and postcrash fire.

1.4 Other Damage

There was impact damage to a farmfield. In addition, about 1 acre of the field was contaminated by debris and fuel.

1.5 Personnel Information

The crewmembers were properly certified and qualified for their respective assigned positions for the flight (see appendix B). There were no flight attendants on board the airplane.

The captain resided in Seattle, Washington. On January 9, 1983, he "deadheaded" to Chicago on UAL Flight 150 and arrived at 1910 c.s.t. He spent the night at his son's home and was in bed by 2200 c.s.t. The following morning the captain took his son to work and conducted personal business. That evening, the captain and his son went to a basketball game involving the captain's daughter. The captain arrived at O'Hare International Airport about 2100 c.s.t. His son reported that his father was in good spirits.

The first officer resided in Henderson, Nevada. He did not travel as scheduled on January 10, 1983, but "deadheaded" from Las Vegas, Nevada, on UAL Flight 218 at 1340 P.s.t and arrived in Chicago at 1900 c.s.t, about 3 hours 15 minutes before takeoff. The first officer reportedly had retired about 2100 P.s.t. on January 9, 1983.

The second officer resided in Westlake Village, California. On January 10, 1983, he "deadheaded" as scheduled from Los Angeles on UAL Flight 118 and checked into the layover hotel at 0645 c.s.t. on January 10, 1983. He was observed at UAL's O'Hare Dispatch office around 2100 c.s.t., and the dispatchers stated that he appeared alert and rested.

The second officer entered DC-8 first officer upgrade training in June 1979. Simulator training began July 1, 1979, and continued through August 6, 1979, during which he received 41 hours as pilot at the controls. Instructor comments on his training records included: "scan very weak; procedural knowledge poor; tendency to overcontrol on takeoffs and landings; heading, altitude, and airspeed control poor." On July 7, 1979, the instructor commented, "Takeoff - pulled up into stick shaker and over-controlled. . . ." On August 6, 1979, instructor comments included, "Inconsistent bank in steep turns weak scan, stall series need(s) more work. (Unsure of recovery speeds and getting secondary stall). . . Still basic flaws in scan pattern (inadvertent 45° - 50° bank)." On August 8, 1979, after the second officer had completed 19 simulator training periods, his training was terminated, as it was considered doubtful that he could successfully complete the DC-8 first officer upgrading course.

The second officer reverted to his former duties on the DC-8 and performed satisfactorily. He was precluded from bidding for any first officer vacancies for 6 months, because of his inability to complete the first officer upgrade course. He was also restricted to bidding B-737 or B-727 equipment. On February 27, 1980, he entered first officer training in the B-737. He successfully completed this upgrade training in March 1980; however, his training records indicated that extended training time was required because of "...inconsistency in maneuvers due to getting behind in planning and attitude instrument flying." As a result of his initial line check, he was scheduled for additional trips with a flight manager safety pilot. On May 3, 1980, he was released to line flying but was placed in an accelerated check program. En route proficiency checks on July 8 and 15, 1980, were satisfactory, and check pilot comments concerning his improvement and anticipated progress were included, e.g., "...been on the B-737 for three months, but is developing into a very smooth pilot." Following an unacceptable approach, go around, and hard landing, the check airman commented, "From this point on en route (check) ...showed rapid improvement." Similarly, on February 10, 1981, the check airman commented, "Flying technique has improved greatly." On March 18, 1981, the check airman again commented on slow scan, excessive control inputs, and power changes and assigned him to a training captain in April. During this period, a flight proficiency program was established for him which included special scan training at Denver and special en route proficiency, with line checks through September 1981. On April 29, 1981, he failed to pass an en route check and was removed from line flying. The check airman cited "2-dot" deviations on the ILS localizer and glide slope (the captain completed approach) and a tight base with a high sink rate during a visual approach. He summarized, "...attitude could not be better and he is a hard worker, however, he has not made normal progress in his first full (year) as first officer. His command ability is below (average) and has exhibited poor operational judgement both IFR and VFR."

The second officer entered special B-737 training on May 8, 1981, but after 6:15 hours of simulator time, he received an unsatisfactory proficiency check. The instructor commented that, "repeated a back course ILS and holding patterns for satisfactory performance, but after two repeats, engine failure on takeoff still was unsatisfactory. ...was late retracting the gear, and his directional control was weak because of over and under control with the rudder." As a result of an informal meeting with UAL training staff, the B-737 Fleet Manager in San Francisco confirmed in writing that, "In view of the continuing problems in reaching the desired level of pilot proficiency, you have voluntarily agreed, in writing, to forego bidding any future pilot vacancies on United Airlines and remain in second officer status for the balance of your flying career." On May 17, 1981, he was assigned to a DC-8 second officer requalification class and his performance at these duties was satisfactory.

1.6 Aircraft Information

The airplane, a McDonnell Douglas DC-8-54F, N8053U, was owned and operated by United Airlines, Inc. (See appendix C.) The DC-8-54F is a freighter airplane, used solely for cargo. The passenger area is divided into 14 compartments or "pits" numbered consecutively front to back. Pit No. 1 is forward of the cargo door, pit No. 2 is opposite the cargo door and normally is not used, pits Nos. 3 through 13 extend toward the rear of the cabin, and pit No. 14 is not used for cargo.

1.6.1 Weight and Balance

The captain received a dispatch release for United 2894/10 (Chicago-Cleveland) and United 2885/11 (Cleveland-Detroit-Los Angeles) at Chicago, with no maintenance deferred items. The flight proceeded without incident to Detroit, where a revised flight plan to Los Angeles was issued. The revised release increased the fuel load for the Detroit-Los Angeles leg from 54,700 to 56,500 pounds because of anticipated additional cargo and its effect on performance.

The airplane was refueled with 931 gallons of Jet-A kerosene, 108 gallons more than requested, which is within refueling standards that are based on total airplane fuel load. Consequently, the fuel aboard was about 731 pounds more than planned prior to taxi. The planned taxi burn was 400 pounds.

Further, a discrepancy in the loading computations resulted from a misunderstanding between the UAL loading supervisor and the loading transporter operator at the UAL freight terminal in Detroit. The supervisor advised the operator to get the "igloo" from line No. 3 3/ as the last load for the airplane. The operator misinterpreted the supervisor's instructions. At the time the instructions were given, the operator was transporting an "igloo" for pit No. 3 of the airplane and believed that to be the igloo to which the supervisor was referring. The "igloo" on line No. 3 was never loaded. It contained 3,502 pounds of mail which was to have been placed in pit No. 1 (forward-most position in the cabin area). As a result, the crew departed with an erroneous weight and balance. The following computations reflect the difference between the planned and actual loading:

	<u>Planned</u>	<u>Actual</u>
Operating Empty Weight	130,978 pounds	130,978 pounds
Weight Cargo	59,458 "	55,956 "
Fuel	56,500 "	57,230 "
Ramp Weight	246,936 "	244,164 "
Taxi Fuel	-400 "	-400 "
Takeoff Gross Weight	246,536 "	243,764 "
Center of Gravity	29.8%	32.5%

Although the structural gross weight limit for the DC-8-54F is 318,000 pounds for taxi and 315,000 pounds for takeoff, the controlling weight limitation in this instance was the maximum landing weight at Los Angeles, which was 240,000 pounds. Accordingly, based on a fuel burnoff of 46,700, the maximum allowable takeoff gross weight for United 2885 was 286,700. The allowable center of gravity limits were 16.8 and 34.1 percent MAC.

The second officer prepared the takeoff data card based on the company provided weight and balance data and the current ATIS information. Since the airplane's takeoff gross weight was in error, the takeoff data used by the flightcrew were inaccurate. The data card for Flight 2885 was not recovered, but the following is a comparison of planned data and the actual takeoff data which was based on the postaccident determination of weight and center of gravity of the airplane. 4/

	<u>Planned</u>	<u>Actual</u>
Flaps	15°	15°
Center of Gravity	29.8%	32.5%
Stabilizer Setting	1.9 ANU	0.2 ANU
V ₁ <u>5/</u>	120.5 knots	120 knots
V _R <u>5/</u>	136	135
V ₂ <u>5/</u>	150	149.5
Engine Pressure Ratio	1.76 (1.87) <u>6/</u>	1.76 (1.87)

3/ The freight handling area at the Detroit Metropolitan Airport has an assembly array of rollers divided into "lines" on which cargo pallets or "igloos" can be built-up and staged for efficient loading.

4/ Based on information received from Douglas Aircraft Company, May 12, 1983.

5/ V₁ - Critical engine failure speed, V_R - rotation speed, V₂ - takeoff safety speed.

6/ UAL company procedure provides a maximum allowable EPR setting as well as a "normal de-rated" thrust setting (based on fuel and maintenance considerations) either of which the captain may select on each takeoff.

1.7 Meteorological Information

Based upon the 0100 and 0400 surface weather maps prepared by the National Weather Service, the Detroit area was under the influence of a deep low-pressure system centered over upper Michigan at 0100 and over southern Canada north of Lake Huron at 0400. Conditions in the Detroit area were characterized by overcast stratiform clouds and moderate southwesterly winds.

The weather at the time of the accident was as follows:

Time--0254; type--local; ceiling--measured 1,900 feet overcast; visibility-- 10 miles; temperature--38°F; dewpoint--33°F; wind 220° 10 knots; altimeter--29.56 inHg; remarks--aircraft mishap.

The flightcrew had received ATIS message Foxtrot which was broadcast on 124.55 MHz, beginning at 2345:49:

Detroit Metro Information Foxtrot, zero four three seven zulu special weather, ceiling measured two thousand eight hundred broken, eight thousand overcast, visibility one zero, temperature four zero, dew point three three, winds two three zero at one zero, altimeter two nine five seven, ILS approaches to runways two one in use, landing and departing runways two one, advise you have Foxtrot.

The current applicable directive for providing ATIS in selected terminal areas is FAA Handbook 7210.3F, dated October 1, 1981, Paragraph 1230, Automatic Terminal Information Service. This directive requires that a new ATIS be made upon receipt of any new official weather report regardless of content change and reported values. The Detroit terminal facility receives hourly local surface weather observations provided by the National Weather Service.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

There were no known communications difficulties.

1.10 Aerodrome Information

Detroit Metropolitan Wayne County Airport, elevation 639 feet mean sea level (m.s.l.), is located in Romulus, Michigan, 6 miles southwest of Detroit. The airport is certified in accordance with 14 CFR 139, Subpart D.

The landing area consists of four runways--3L/21R, 3C/21C, 3R/21L, and 9/27. Runway 21R is 10,501 feet long, 200 feet wide, and has a grooved, concrete surface. The runway has medium intensity approach lights with runway alignment indicator lights, high intensity runway edge lights, and centerline lights.

The Detroit Metropolitan Airport is serviced by a Terminal Radar Approach Facility (TRACON) and a Air Traffic Control (ATC) Tower. The TRACON is equipped with an airport surveillance radar. The control tower is equipped with two bright radar indicator tower equipment (BRITE) scopes which allow viewing of radar information under high ambient lighting conditions. The local controller in the tower at the time of United 2885's takeoff stated that at about 0251:48, he noted a target on his BRITE scope over the runway 21R area, indicating 1,200 feet. The Cleveland Air Route Traffic Control Center radar also acquired a target over Detroit runway 21R, indicating 1,100 feet, at about 0251:48. The airport has an operational Low Level Wind Shear Alert System (LLWSAS); there were no alerts issued before or after the accident.

1.11 Flight Recorders

The airplane was equipped with a Fairchild model 5424 flight data recorder (FDR), Serial No. 6099, and a Sundstrand model V-557 cockpit voice recorder (CVR), Serial No. 2641. The FDR and CVR were located in the tail of the airplane and were not damaged. Both were removed and taken to the Safety Board's Washington, D.C., laboratory for examination and read out.

Examination of the FDR's foil recording medium disclosed that all parameter and binary traces were being recorded apparently in a normal manner prior to the time of United 2885's takeoff. However, examination of the parameter traces for United 2885's takeoff indicated that movement of the foil medium had slowed to a near stop for about 55-60 seconds beginning approximately 23 seconds after the recorder was turned on. The aircraft was on a magnetic heading of 305° during this 23-second period with changes of +0.5°. The foil began to move at normal speed again approximately 15 seconds prior to ground impact with no other indications of foil slowdown. The maximum altitude reached was measured to be 1,650 feet m.s.l. or 1,010 feet above the takeoff runway elevation.

Eleven previous flights were recorded on this foil prior to the accident flight, and all were examined for evidence of similar slow down of foil movement with negative results.

The recorder, including the foil medium and its magazine, were taken to the manufacturer's facilities in Commerce, California, for further examination on April 6, 1983. A new foil recording medium was installed in the magazine, which was then connected to an electrical power source but was not connected to any parameter input since the examination was concerned only with timing. The recorder began operating immediately, and the foil could be seen to advance continuously at the proper speed. The recorder was turned upside down for about 1 minute and then upright again for about 1 minute before the foil magazine was removed. When the recorder was first inverted, the binary traces shifted and approximated the appearance of those on the accident foil. The binary trace shift, an unusual occurrence, was 0.001 inch, the same as the shift seen in the accident foil traces. During the examination, the recorder failed to begin operation twice when electrical power was applied. However, in each case, the timing control and foil began moving after the timing control was tapped.

The FDR readout for United 2885's landing at Detroit indicated that the airplane had maintained a constant rate of descent from about 3,000 feet above ground level (AGL) to touchdown, that the airplane heading on final approach was 220° to 214°, and that the final approach speed was about 146 knots.

A transcript of the CVR tape was made which began when United 2885 requested air traffic control clearance at 0231:26 and ended with the sound of impact at 0252:11.4. The timing on the transcript (see appendix E) was as accurate as could be read on a digital clock.

The CVR transcript showed that the takeoff roll started at 0251:05 and that the airplane broke ground at 0251:41. The sound of a stickshaker ^{7/} started at 0251:41.2. There was a second stickshaker sound at 0251:51, and the captain yelled, "Push forward, push forward" at 0251:53.

A CVR sound spectrum analysis was performed to determine as much information relative to the performance of the airplane as possible. The signals from the cockpit area microphone (CAM) and radio channels were examined aurally and electronically. The times of changes in engine RPM, stickshaker occurrences, and sounds similar to engine surges were established within the limitations of the equipment as follows:

^{7/} An aural warning to notify flightcrew that the airplane is approaching stall.

- o Engine acceleration began at 0251:05.2.
- o Engines stabilized at 0251:12.6 at 103 percent RPM, N1, which corresponded to an exhaust pressure ratio (EPR) of 1.81. All four engines were running about the same RPM. However, slight differences in engine RPM resulted in smearing of the frequency trace, which made exact determination of engine RPM difficult.
- o Following the initial application of thrust, the engine RPM remained essentially stable, about 103 percent, N1, until the end of the second stickshaker sound at 0252:01.2. At this time, the spectrum printout became indistinct. Sounds similar to engine surges could be heard beginning at 0252:06.6 and continuing for approximately 1 second.
- o The stickshaker could be identified during the following intervals:
 - a. 0251:41.2 until 0251:42.8
 - b. 0251:51.0 until 0252:01.2
 - c. 0252:09.2 until 0252:10.4 - It remained off until impact at 0252:11.4.

1.12 Wreckage and Impact Information

The accident site was a freshly plowed farmfield within the airport boundary. The center of the impact area was located about 1,200 feet west (right) of the centerline and about 8,800 feet from the approach end of runway 21R. The wreckage pattern was roughly fan shaped, between 180-300 feet wide and 350 feet deep, from east to west. (See appendix D.) Five ground craters, indicating the impact of the airplane's four engines and nose, were found at the eastern edge of the wreckage site. The impact marks indicated that the airplane struck the ground about 70° - 80° nose down with about 200° right roll. Most of the wreckage was damaged by ground fire.

The largest piece of intact structure was a portion of the aft fuselage with the empennage assembly attached. All cargo tie down fittings (bear traps) had been sheared off in the forward direction. The rear cabin doors (left and right) were found intact, attached, and open. The aft fuselage pressure bulkhead was intact with no evidence of structural or fire damage.

The right and left main landing gear and the nose gear retract mechanisms were damaged indicating that the landing gear was down and locked upon impact. Flap actuators from both the left and right flaps were recovered and were measured and compared with another DC-8F. The actuator piston rod extensions were consistent with 15° trailing edge flap extension. The leading edge slats were destroyed by impact and fire. The flight control tab and geared trim tab were in place and intact on the right elevator and damaged on the left elevator.

The external surface of the aft fuselage skin had marks that indicated the position of the horizontal stabilizer's leading edge at impact. The distance from the reference rivet on the left side of the fuselage (forward of the stabilizer) to the center of the impression left by the stabilizer's leading edge was 12.5 inches down. The stabilizer jackscrews, chains, and sprockets on both the left and right sides were intact, continuous, and well lubricated. The power control unit was intact with no evidence of hydraulic fluid leakage. Measurements were taken on the jackscrews in accordance with the United Airlines DC-8 Maintenance Manual. The exposed threads were measured from the drive nut's upper stop to the upper end of the threads: left jackscrew -- 8-3/4 to 9 threads;

right jackscrew -- 9 threads. These measurements corresponded to 7 1/2 units of nose-up horizontal stabilizer trim.^{8/} The aft fuselage section was rolled over to examine the lower fuselage structure and the tail skid area. The lower fuselage was undamaged and the blue paint on the tail skid was unmarked.

The rudder and rudder trim tab were intact and attached to the separated section of vertical stabilizer. One spoiler actuator and a portion of another were the only components of the spoiler system that were identified; however, the position of the spoilers at impact could not be determined.

Several components were removed from the aft fuselage and empennage area and were examined and functionally checked under Safety Board supervision at the United Airlines Maintenance Facility in San Francisco, California. Functional checks were made on the power control unit which was disassembled for inspection. The power control unit hydraulic pump/motor was connected to a hydraulic test stand. Hydraulic pressure was then increased to 3,000 psi and the following noted:

- o No external leakage was observed.
- o Manual operation of the control arms simultaneously forward and aft resulted in rotation of the upper and lower sprockets at the proper rate in both the clockwise and counterclockwise directions. There was no evidence of brake slippage.
- o Operation of the control arms opposite to each other (one forward, one aft) resulted in no rotation of the sprockets.
- o Manual operation of the control arms individually in both directions resulted in no rotation of the sprockets.
- o Internal leakage was checked with the unit pressurized to 300 psi and was found to be within tolerances.
- o All test results were within specified limits.

The power control unit was removed from the hydraulic test stand and delivered to the UAL electrical shop where electrical power was applied to the motor resulting in the sprockets being driven smoothly at the proper rate and in both directions. Brake operation was normal.

The power control unit was partially disassembled to facilitate examination of the sprocket shear rivets and shaft bearing. The six shear rivets, three upper and three lower, were intact, and the shaft bearing was in good condition. Manual rotation of the gearbox input spline resulted in rotation of the driver sprockets. The gearbox manufacturer's original inspection seal was attached to the gearbox housing.

Jackscrew examinations revealed that they were in good condition with no visual damage noted to the drive sprockets, and the measurements taken on site were verified.

Four component parts of the rudder system were examined and/or functionally checked -- the rudder power actuator, the rudder system shutoff valve, the rudder system pressure reducer, and the rudder trim tab actuator. All components were found to be satisfactory.

^{8/} Airplane stabilizer trim is expressed in units as aircraft nose up (ANU) and aircraft nose down (AND).

Five of the six wing flap actuators were disassembled and inspected. Impact and fire damage precluded functional testing. The elevator position transmitter was found to be satisfactory. The right aileron control unit, the right aileron tab lockout cylinder, the right manual reversion unit, and the left aileron control unit were functionally checked and performed satisfactorily. The right spoiler actuator was also functionally checked and performed satisfactorily. Fire and heat damage precluded functional testing of the left spoiler actuator.

The airplane's battery was tested and all cells read at least 1.2 volts, and the battery maintained 24 volts when subjected to a 5-ampere load. The flight data recorder bracket connectors and wiring were examined visually and a continuity check did not reveal any open circuits.

The four Pratt & Whitney JT3D-3B engines were documented at the accident site and removed to the Eastern Air Lines hangar at Detroit Metropolitan Airport for further investigation. All engines incurred severe damage, and internal components displayed rotational damage indicating that they were operating at impact. The No. 2 engine was shipped to the United Airlines Maintenance Facility in San Francisco for a teardown disassembly inspection under Safety Board supervision. The inspection did not reveal any preimpact discrepancies.

1.13 Medical and Pathological Information

All three flightcrew members sustained fatal injuries as a result of the accident. The pathological examinations disclosed no abnormal conditions, and the toxicological tests were negative for alcohol and drugs.

1.14 Fire

The airplane exploded on impact and was subjected to an intense postaccident ground fire.

1.15 Survival Aspects

The accident was not survivable because impact forces exceeded human tolerances.

The Detroit Metropolitan Airport Fire Department responded to a direct crash alarm at 0252. A fireman on duty in the fire station watchtower saw the impact explosion and fire and immediately initiated an alarm switch which was audible in the fire station equipment room and sleeping quarters.

The first fire truck was en route to the scene within 1 minute 18 seconds of the alarm. Seven pieces of equipment, manned by the total complement of the fire station, nine men, responded to the alarm. The vehicles responding were four fire trucks, one pumper, one mini-pumper, and an ambulance. The vehicles proceeded down runway 21R, turned onto a gravel road, and diverted into the plowed field to go directly to the accident site. Three fire trucks became mired in mud and were unable to reach the burning airplane. One fire truck, with 4,000 gallons of water and 515 gallons of AFFF, ^{9/} had taken a slightly different route and was able to reach the site. The pumpers and the ambulance remained on the gravel access road and did not reach the site.

Three to four minutes elapsed from the time the fire department was notified to the time response personnel arrived on scene. The initial large fire was knocked down and the primary fire of burning fuel was controlled at 0259. There were about

^{9/} AFFF—Aqueous film forming foam.

8,000 gallons of Jet-A fuel on board. Some of the cargo -- paper catalogues -- continued to burn in small isolated fires. These small fires did not hamper the firefighters' search for survivors.

In addition to the seven airport units, six units and 20 men from mutual aid departments responded to the accident. Several mutual aid firemen joined in the firefighting effort. About 0405, the on-scene commander was notified that there was Americium 241, a hazardous material, on board the airplane. He pulled all the firemen from their duties to prevent radiation exposure, since there was no possibility that any crewmember had survived the impact and there were no passengers. When the amount of radioactive material and dose rate information became known 20 minutes later, he ordered the firefighting and rescue efforts to resume. Since the accident occurred on the airport property, there were no security problems.

The total amount of firefighting materials expended in extinguishing the fires was:

650 gallons of AFFF, 12,000 gallons of water, 300 pounds of dry chemical, 60 pounds of metal X, 34 pounds of Halon, and 40 pounds of CO₂.

1.16 Tests and Research

1.16.1 Human Performances

Twelve United Airlines flight crewmembers who had flown with United 2885's crew in the 6-month period prior to the accident were interviewed. These crewmembers included three captains, five first officers, and four second officers.

According to these crewmembers, the captain had been an above average, skillful pilot who normally made smooth landings using trim in the flare. He was described as being comfortable in his position, with a friendly, easy-going manner. One of the crewmembers interviewed stated that the captain had once suggested a seat swap, and another crewmember stated that the captain was generous in permitting second officers to fly the airplane. The crewmembers stated that the captain was a confident person who expected active participation from each crewmember. There were a number of observations that the captain had a happy home life.

The first officer was described as an average pilot. According to the crewmembers interviewed, he was not consistent in airplane control, flying smoothly on one flight and flying roughly on the next flight. He was also described as a somewhat mechanical pilot. The crewmembers stated that the first officer sometimes performed checks out of sequence and was not consistent in resetting the trim after landing. A few of the crewmembers noted that the first officer had been preoccupied with a number of outside business interests that accounted for much of his time. He had once volunteered to a different captain on a previous flight, "If you want the flight engineer to fly, I can work the panel."

The crewmembers interviewed described the second officer as a competent, professional, conscientious flight engineer. He was also described as being a quiet, conservative, person who seemed satisfied as a second officer. Most of the interviewed crewmembers were not aware of any other flying activities by the second officer besides those related to his employment with United Airlines.

The 12 United Airlines flight crewmembers who were interviewed were questioned about seat swapping, deadheading, and trim setting, and the safety of passenger flight versus freighter flight operations.

Most of the crewmembers interviewed stated that seat swapping was occurring less than it had in the past, but that they were aware of limited seat swapping in freighter or ferry flight operations. A reason given for the decrease in seat swapping was that second officers no longer received pilot training at United Airlines.

Four of the crewmembers interviewed said that they always deadheaded according to the published schedule. Seven said that they generally deadheaded according to the published schedule, and that when they did deviate from the schedule, it was on the Los Angeles-Baltimore trip that has about a 28-hour layover. Some crewmembers said that they would get a good nights sleep at home and then deadhead later than the published schedule and still have time for a good nap prior to the start of the flight sequence. All of the crewmembers who were interviewed lived near their base domicile and did not commute long distances.

Most of the crewmembers who responded to questions regarding trim setting believed that at night a penlight was necessary to see the cockpit reading. Three crewmembers stated they had developed the habit of confirming the setting by feeling the position of the trim indicator. Also, three crewmembers said that they would doublecheck the paper work if it called for 4 or more units of trim.

All of the crewmembers who commented on the safety of passenger versus cargo flight operations agreed that the operations were equally safe except for two factors. They reported a greater fatigue factor in cargo operations since most flights are at night. The other factor was the nonuniformity of the cargo flight manifest between stations.

1.16.2 Landing at Detroit

Based on the airplane's zero fuel weight at Cleveland (165,681 pounds) and the fuel remaining prior to refueling at Detroit (52,400 pounds), the airplane landing weight at Detroit was approximately 218,081 pounds with a cg of 28 percent MAC. The Vref for a full flap landing was 138 knots. Hands-off elevator setting for 138 knots is about 4.0 units ANU.

1.16.3 Simulator Tests

Simulator testing was accomplished in two phases. The first phase took place shortly after the accident using a DC-8-61 simulator at the UAL Training Center in Denver, Colorado, to reconstruct flight conditions and circumstances which might have been involved in the accident flight. A simultaneous attempt by both simulator pilots to trim the stabilizer in opposing directions resulted in nonmovement of the stabilizer.

In the second phase, UAL training personnel modified the DC-8-61 simulator to DC-8-54F characteristics, and on June 10, 1983, a series of takeoffs and landings were performed. The takeoffs simulated the accident takeoff and the landings simulated the landing at Detroit. The conditions and results of both phases were similar. All of the simulator tests were flown by pilots, and the takeoff and landing simulations of June 10, 1983, were performed by a DC-8 simulator test pilot and a current DC-8 line pilot. Simulator conditions were:

Gross weight:	243,400 pounds ^{10/}
Center of gravity:	32.5 percent MAC
Winds:	220°/10 knots
Stabilizer trim:	7.5 units ANU

^{10/} Actual gross weight was about 243,764. The difference is not significant and has negligible effect on characteristics.

Eleven takeoffs were performed with the modified simulator; the last 10 of the takeoffs were recorded. After three takeoffs were performed to familiarize the cockpit crew with the simulator characteristics, five takeoffs were made with stabilizer trim settings of 7.5 and 10.0 ANU. Three takeoffs were then made coordinating CVR-derived timing, transmissions, and aural cockpit signals. On these three takeoffs, pilot technique was (1) to push the control yoke forward at 80 KIAS for the elevator check, (2) to neutralize the yoke, (3) to exert enough forward pressure to hold the nose down to prevent the airplane from lifting off prematurely, (4) to rotate with positive movement of the yoke aft at V_R , (5) to push the yoke forward to establish a 10° nose-high climb attitude since rotation was faster than normal due to the stabilizer trim setting, and (6) to push full forward on the yoke to prevent the abnormal nose-high attitude and to attempt recovery. Stabilizer trim was not changed. The stickshaker activated on all takeoffs, and in some instances, the time of onset was identical to stickshaker onset derived from the CVR of United 2885. As the simulated airplane gained airspeed after liftoff, it was impossible to hold the proper climbout attitude with full forward control wheel input. The nose of the airplane rose from 30° to 40° noseup, with accompanying stickshaker, and simulated a stalled condition.

The following results were compiled from pilot comments, the recorded data from the simulator tests, the CVR, and Douglas' performance calculations.

- o With a stabilizer trim setting of 7.5 ANU, the airplane had an uncommanded rotation at approximately 114 knots unless forward control column pressure was applied.
- o With a stabilizer trim setting of 10 ANU, the airplane had an uncommanded rotation at around 100 knots, if forward control column pressure was not applied. A tail strike would occur during rotation.
- o In all cases, the airplane continued to rotate to stickshaker following rotation even with full nosedown elevator deflection.
- o Pitch rate following rotation could be slowed momentarily in all cases when nosedown elevator was applied.
- o With a stabilizer trim setting of 7.5 ANU, the airplane pitched up to stickshaker in approximately 8 seconds after rotation when the nose was held on the ground until V_R and the airplane was allowed to rotate with a zero control column force at rotation. Stickshaker onset was at approximately 25° to 30° ANU.
- o The takeoffs that were performed with positive control column input at V_R most closely matched United 2885's CVR timing of stickshaker onset.
- o The table below displays the timing of selected events as recorded on the CVR and the average times of simulator runs 7, 8, 11, 12, and 13, all of which used the following control inputs: the nose wheel was held on the runway until V_R , a normal elevator pull force was applied at V_R while using a stabilizer trim setting of 7.5 ANU.

<u>Event</u>	<u>CVR</u>	<u>Elapsed Time (seconds)</u>
		<u>Simulator (average)</u>
Sound of power	0	0
80 knots	20.3	20
V ₁	31.0	28.6
V _R	32.8	32.8
First stickshaker	36.0	37.8
Second stickshaker	45.8	41.4

- o The airplane, under the actual takeoff conditions, would not have sufficient pitch control authority solely from elevator input to maintain an angle of attack below stickshaker with the stabilizer trim setting of 7.5 units ANU, or with a stabilizer trim setting of plus 4.7 ANU more than the correct setting.
- o The airplane elevator does have sufficient pitch control authority at 7.5 ANU stabilizer trim setting to rotate to an attitude at which a tail strike will occur before attaining minimum takeoff speed.

Landings were made with the simulator configured to match parameters of the landing at Detroit immediately before the accident: gross weight -- 218, 000 pounds; center of gravity -- 28 percent MAC; and winds -- 220° at 10 knots. The technique used for landings was normal -- trim the stabilizer to produce zero control column force during the final approach, but with emphasis on making a smooth touchdown by using trim in the flare. Stabilizer settings on final approach approximated 4.0 ANU as forecast by Douglas. The final stabilizer trim settings as recorded for the landings were: 4.9, 6.23, 5.7, 7.8, 5.8 and 7.95. The highest stabilizer trim setting, 7.95, was accomplished when the approach and landing was made by a pilot who was currently flying the DC-8 on the line and not by the simulator test pilot.

1.17 Other Information

1.17.1 Pitch Control and Horizontal Stabilizer Trim

The United Airlines DC-8 Flight Manual and the McDonnell Douglas DC-8 Flight Study Guide both state:

Pitch control is provided by elevators hinged to the horizontal stabilizer aft spar. The elevators, which are interconnected to operate in unison, are actuated manually by the inboard aerodynamic control tabs. The outboard tabs are gear driven by relative movement between the elevator and the stabilizer and assist the control tabs in displacing the elevator. Initial control column movement displaces the control tab on each elevator.

After the control tabs reach full travel, further movement of the control column moves the elevators directly. An elevator position indicator (EPI) provides positive indication of the elevator position. The EPI is used while making a control check prior to takeoff to verify elevator movement.

Pitch trim is accomplished by varying the position of the horizontal stabilizer. The horizontal stabilizer is hinged at its rear spar and its position is adjusted by a pair of screwjacks attached to its front spar. Rotating nuts on the jacks are driven by roller chains from a central gear box which may be powered by either a hydraulic or an electric motor. The jacks have nonreversible threads without dependence on friction brakes or locking devices.

The gear box contains a differential planetary gear train. Both motors have brakes spring-loaded to the ON position. Actuation of either motor releases the brakes on that motor with the brake on the other motor remaining locked to provide for the differential gears.

The hydraulic motor provides the primary power for stabilizer adjustment. The DC-8-54F has a 13 horsepower motor and a trim rate of 1/2 unit per second. There is no trim-in-motion aural warning.

The hydraulic motor is controlled by two hydraulic slide valves interconnected such that both valves must be opened for the motor to run. Both valves are spring-loaded to the OFF position. The valves are connected by two independent cable systems to two side-by-side "suitcase" handles on the cockpit control pedestal. The two handles must be operated by a single control. Dual controls are used so that in case of the failure of one of the valves or of its hydraulic or cable system, the other valve closes and prevents stabilizer runaway.

The hydraulic motor may also be operated by dual switches on the control wheels. These switches control a pair of electric servo motors through independent electric circuits. The servo motors act on the cables connected to the "suitcase" handles and these handles will move when the wheel trim switches are used. Both switches must be operated simultaneously for the system to operate.

The electric motor is used for autopilot controlled trim and alternate trim. The trim rate using the electric motor is approximately 1/20 unit per second. The electric motor is controlled by two levers on the control pedestal. Each lever actuates a switch which is spring-loaded to the OFF position. One switch controls the motor current while the other switch controls the brake current, both acting through independent electric circuits. Thus, both levers must be operated in order for the motor to run. Again dual controls are used to prevent stabilizer runaway due to a single failure.

1.17.2 Company Procedures

The UAL DC-8 Flight Handbook includes normal, irregular, and emergency procedures as well as bulletins for the operating crews. The following is found in the general section of the normal procedures: "...it is recommended and would be considered good judgment if an exterior inspection is accomplished when time permits."

Normal procedures are indicated by phase of operation (e.g. cockpit preparation, before start, taxi out) and the flight crewmember responsible for accomplishing the operation. The Exterior Inspection - Second Officer section contains the following:

Recommended sequence is to start at the left forward fuselage and walk around the airplane in a clockwise direction. During the inspection, observe the general condition of the airplane, check all surfaces, fuselage, empennage, wings, flight controls, windows, antennas, engines and cowlings, looking for proper position, damage, fluid leakage and security of access panels. Check that the crew, passenger and cargo doors that are not in use are closed and door handles recessed.

The Preliminary Cockpit Preparation - Second Officer section contains the following: "Flaps, Stabilizer, Elevator Position Indicator...Observe Positions." However, such action is not required at en route stops. The Cockpit Preparation - Captain section includes the following:

LONGITUDINAL TRIM*TEST**

Simultaneously move LONG TRIM handles in opposite directions and hold in full travel position, while observing that the LONG TRIM indicator does not move and/or the HYD SYS PRESS does not decrease.

Test both sets of control wheel LONG TRIM switches for proper operation.

ALTERNATE LONGITUDINAL TRIM**TEST**

Move ALT LONG TRIM switches to NOSE UP and NOSE DOWN positions and observe proper movement of LONG TRIM indicator.

NOTE

Do not move the ALT LONG TRIM switches in opposite directions simultaneously.

HORIZONTAL STABILIZER TRIM*SET*****RUDDER TRIM****SET*****AILERON TRIM****SET**

[The asterisk indicates those items which must be accomplished even on en route stops, with no change of crew.]

The Taxi Out procedures prescribe, in part, that the following checks be performed by the identified crewmember: [C= captain, F/O= first officer, S/O= second officer]

C, F/O, S/O FLIGHT CONTROLS**TEST****C, F/O YAW DAMPER (-61/71)****ON****C YAW DAMPER (-61/71)****CHECK**

Must be off for DC-8F.

C HORIZONTAL STABILIZER TRIM**CHECK**

Recheck setting for final weight manifest information.

The Before Takeoff Checklist prescribes the following challenges and responses:

CHALLENGE (S/O)**RESPONSE (C, F/O, S/O)**

ANTI-SKID
GUST LOCK
FLAPS
CONTROLS

ARMED
OFF
_____ INDICATED, DETENT
CHECKED, PWR ON, LTS
OFF
3 SET
SET
SET

TRIM
EPR/N1 BUGS
V SPEEDS

The UAL Takeoff procedures assign specific functions to be performed by the appropriate crewmember, in part, as follows:

C, F/O THROTTLES	TAKEOFF THRUST
Smoothly advance throttles and assure that all engines are spooling up evenly before applying final takeoff thrust. On DC-8-61/8F set takeoff EPR less 0.03.	
S/O EPR, EGT, N1, N2, FUEL FLOW	CHECK
All indications normal.	
C BRAKES	OFF
S/O GROUND COOLING AND BLOWAWAY JET SHUTOFF BUTTON (-61/8F)	IN
Push button in after takeoff EPR set, approximately 5 seconds after start of takeoff roll. Note that button stays in and light is off.	
C, F/O FINAL THRUST	SET
Between 40-80 knots, after blowaway jet off, set thrust to value shown on takeoff data card.	
C, F/O ELEVATOR	CHECK
At approximately 80 knots, pilot flying check the elevator by applying positive forward control column pressure and note the appropriate airplane response.	
C, F/O AIRSPEEDS	CALL OUT
The pilot not flying call out V1, Vr, and V2 as those speeds are reached.	
C, F/O GEAR (ON ORDER)	UP
Either pilot call positive rate and other pilot confirm.	
Pilot flying call for gear up and pilot not flying retract gear.	

The Taxi In standard operating procedures require the first officer to retrim the stabilizer to 2° ANU.

1.17.3 Hazardous Materials

About 0800, the Special Form Americium 241 (Am 241) radioactive materials (RAM) package was found. The outer, cardboard layer of the package was almost completely burned, and the inner metal Department of Transportation type A container was scorched but intact. No release of radioactive materials occurred.

The shipment of Am 241 originated in Tonawanda, New York, and was en route to a manufacturing firm in Korea, via Los Angeles, California. Enclosed within the innermost plastic jars of the container was a total of 10,000 multilayered and

electroplated "foils" containing Am 241 and other metals, which were bonded to a metallic holder resembling a small pellet. Each of these pellets was to become a component of a smoke detector. The Special Form Certificate filed with the Department of Transportation describes the source and attests to the nondispersible nature of the Am 241 while in this composition -- under extreme conditions of heat, stress, or other ambient factors, the foils will not decompose into smaller particles subject to inhalation, ingestion, or surface contamination.

The outer container of this shipment was subject to the requirements of 49 CFR 178.205 for type 12B fiberboard boxes. There was no retrievable section of this container with which to verify compliance. The packaging of the RAM shipment was determined by the quantity of Am 241 as measured in curies. The maximum amount of Am 241 which may be transported in a type A package is 20 curies, according to 49 CFR 173.389. This package contained 0.015 curies, less than 1/1,000 of the allowable quantity.

The Transport Index (TI) for this shipment was 0.2. The TI is determined by measuring the radiation dose rate (in millirems per hour) at a distance of 3 feet from the external surface of the package. The maximum allowable TI for the air transport of a Class II radioactive shipment is 1.0 millirem per hour, or 500 percent of this package. The labels, placards, and shipping documents accompanying this package were in compliance with current regulations.

1.17.3.1 Hazardous Materials Notification

About 45 minutes after the accident, an airport operations employee went to the UAL cargo building to transport a UAL freight supervisor to the crash site. He overheard other UAL employees discussing the RAM shipment aboard United 2885 and notified the CFR station by radio about 0405 to alert the emergency response commander. Firefighting and rescue operations were suspended until 0425, when the on-scene personnel were advised of the type of RAM and the dose rate.

UAL freight personnel were aware of the RAM cargo within minutes of the crash from information on waybills and dangerous goods documents. They contacted UAL's Systems Operation Control Department (OPBOB) in Chicago and were advised that OPBOB would notify authorities concerning the RAM package. Discussions among UAL's senior management resulted in a call to the regional office of the U.S. Department of Energy (USDOE) to notify them of the RAM cargo. This occurred at approximately 0450, or 2 hours after the accident.

The USDOE notified the Michigan State Police (MSP) which is the state agency designated to receive radiological incident reports during non-duty hours. By prior arrangement, MSP notified the Radiological Health Services Division, Michigan Department of Public Health. Two health physicists, equipped with radiation monitoring devices, were dispatched to the scene and arrived about 0620.

UAL's notification flow-chart for a Hazardous Materials Incident (UAL Operations Manual, Chapter 45-11) directs the air freight employee to notify OPBOB immediately (as was done in this accident) and implies that OPBOB will make the other necessary calls. The instructions, however, require the local employee to immediately contact local emergency groups and then notify corporate officials. The phone numbers of local emergency officials and the Radiological Health Services Division (which was eventually notified and discovered the RAM) were available to UAL's Detroit Air Freight employees, but were not used.

Detroit Metropolitan Wayne County Airport is certified and inspected by the Federal Aviation Administration (FAA) according to the provisions of 14 CFR 139. In order to receive and maintain its certificate of operations, the airport must comply with the Emergency Plan requirements that the certificate holder prepare instructions for the response to a radiological incident, show that principal tenants of the airport have

participated in the development of the plan, and that all agencies specified in the plan can be notified during an accident (139.55(e)). However, a simulated drill of the emergency plan is not recommended or required. The radiological incident emergency plan for the Detroit Airport was approved by an FAA Certification Inspector on November 18, 1980.

The plan states that the FAA tower is required to notify the Airport Operations office, the Airport Fire Chief, and Airport Security of an in-flight radiological emergency on any aircraft landing at the airport. The Airport Operations Officer is required to notify the Radiological Officer who, in this case, was the Airport Fire Chief; the airline (carrier) or tenant is also required to notify the Airport Police office of a RAM incident and of the type, amount, and location of the material.

49 CFR 175 contains regulations specifying the actions to be taken by air carriers in the event of a release, or suspected release of radioactive materials. Chapter 45-11 of UAL's Operations Manual establishes employee procedures for handling hazardous materials and, along with 49 CFR 175, is available at all UAL Air Freight facilities. The manual provides specific guidance and notification procedures in the event of damage, spills, or aircraft accidents involving hazardous materials. These procedures require the Air Freight facility to maintain a current list of local emergency responders, to provide the notification sequence to emergency response and corporate officials, to list special instructions in the event of a radiological incident, and to name other agencies which must be contacted under various circumstances.

Federal reporting and notification requirements for an air carrier, contained in 49 CFR 175.45 and 175.700, state the conditions when the carrier must notify the nearest FAA Civil Aviation Security Official "at the earliest practicable moment." Circumstances include: "Fire, breakage, or spillage, or radioactive contamination involving shipment of radioactive materials," or "A situation exists of such a nature that, in the judgment of the carrier, it should be reported to the Department even though it does not meet the criteria, or a continuing danger to life exists at the scene of the incident." Paragraph 175.45(a)(7) states that if the air carrier reports the incident to the FAA, it is exempt from notifying the National Response Center (NRC), and the carrier's only telephonic responsibility is to the FAA.

1.18 New Investigative Techniques

None.

2. ANALYSIS

2.1 General

The airplane was certificated, equipped, and maintained in accordance with Federal regulations and approved procedures. There was no evidence of preaccident failure or malfunction of the airplane structures, systems, or powerplants. The flightcrew was properly certificated and qualified for this scheduled domestic cargo flight at their assigned positions. They held current medical certificates. Weather was not a factor in this accident. The hazardous materials shipment aboard the airplane met current packaging requirements, was not breached, and there was no spillage of radioactive materials. The FDR did not function on the accident flight and useful data were not recorded. The Safety Board reaffirms Safety Recommendations A-82-64 through -67, issued July 13, 1982, that would require installation of suitable digital flight recorder systems on air carrier aircraft.

2.2 Human Performance

Based on information obtained during interviews with 12 United Airlines flight crewmembers, who were familiar with the crew of United 2885, the Safety Board attempted to determine why the first officer and second officer switched seats.

The crewmembers interviewed described the captain as a confident, good natured pilot, comfortable and at ease in the airplane and "generous" in allowing second officers to fly. According to these crewmembers, the captain practiced an "open crew concept" and as such expected participation and involvement from each crewmember. Believing that second officers most likely desire to fly, the captain might have inadvertently influenced the second officer's decision to fly even though he might not have had a great desire to fly. Additionally, the first officer might have suggested the seat switch since one of the crewmembers interviewed reported that the first officer had offered to switch seats on a previous flight and to work the panel if the captain wanted the second officer to fly.

Although the second officer had attempted to qualify as a first officer, none of the crewmembers interviewed had ever heard the second officer express a desire to fly. It appears that the second officer was surprised when on taxi out the captain said, "Are you guys trading?" and the first officer replied, "Do it." The captain then repeated, "Are you guys trading?" and the first officer said, "Ready - you ready." The second officer replied, "go for it." The first officer then said, "ready to trade" to which the second officer replied, "oh we're going to trade now?" After the swap occurred and the takeoff roll was started, the second officer was still concerned about the last second officer checklist item (transponder on) and called for it twice during the takeoff roll.

Although the Safety Board could not determine precisely why the first officer and second officer switched seats, the Safety Board concludes that the first officer and second officer switched seats with the approval of the captain.

Apart from the violation of both FAA and UAL regulations, the more significant aspect of the seat swapping is that neither crewmember was qualified for the duties of the position he occupied on takeoff. Despite the fact that virtually all of the takeoff checklist had been completed before the swap, the cockpit conversation contained several reassurances, cautions, and reminders by various crewmembers indicating possible tentativeness or uncertainty on the part of the first officer and the second officer. In this regard, the most critical mismatch of duties versus qualifications existed in the second officer occupying a pilot position, rather than the first officer acting as a flight engineer.

The second officer had failed to meet the performance standards required of a UAL first officer in the DC-8 and the B-737. Despite many additional simulator hours, special scan training, and several "special check" flights, he continued to receive comments indicating overcontrol, poor command judgment, and an inability to monitor several factors at once. The check captain's comments indicated that the second officer, after nearly a year of B-737 line flying as first officer (May 1980 to April 1981), displayed poor judgment and failed to fly stabilized approaches both on instruments and visually. The instrument approach had 2-dot deviations in localizer and glide slope, and the visual approach involved a tight turn with a high sink rate. Even when the "unstabilized approach" was called out on the ILS, the second officer did not initiate a go-around, as prescribed in company procedures. On May 14, 1981, the second officer agreed in writing to revert to second officer status and complete his airline career in that capacity. This was the culmination of approximately 3 1/2 years of efforts to upgrade to a first officer.

The second officer's demonstrated inability to cope with the many changing parameters of flight during a landing suggests that he would similarly be unable to deal with the situation he faced during the accident takeoff. He might not have been capable of assessing the gravity of the rapidly deteriorating flight conditions on takeoff and might not have been capable of initiating corrective action for the unwanted and unexpected trim. This takeoff was at night and, with the reduced visual cues, required skills such as rapid scan and division of attention -- skills at which the second officer was considered to be deficient. There is no evidence to suggest that the captain was aware of the serious deficiency in the second officer's flying skills, especially in light of his performance as a

second officer. Had the captain been aware of the second officer's limited skills, he probably would have either not allowed the swap or would have closely supervised the takeoff and the cockpit procedures and configuration.

The seat swapping might have been suggested by either the first officer or the captain as a result of their being fatigued. At the time of departure, the first officer had been active a minimum of approximately 14 hours, and the captain had been active for 19 hours. The Safety Board concludes that the captain and first officer did not adhere to established crew rest procedures and that they might have been fatigued.

The Safety Board is concerned about the flightcrew's disregard of federal and company rules and regulations. The Board does not believe, nor do the interviews with United Airlines flightcrew members indicate, that seat swapping is a prevalent practice on that airline. A senior captain should allow seat swapping only as outlined in company procedures and with knowledge of the involved crewmembers' flying capabilities. The flightcrew members did not perform their checklist responsibilities in a professional manner. Adherence to crew rest requirements is a matter of personal discipline. This accident clearly illustrates the importance of compliance with established rules, regulations, and checklists. The Safety Board believes that compliance with written directives in today's sophisticated transportation system is mandatory and basic to safe, efficient operations.

2.3 Airplane Configuration

The most critical element of the accident sequence was the excessive noseup horizontal stabilizer position. Physical evidence in the form of postimpact stabilizer jackscrew positions and stabilizer leading edge witness marks on the aft fuselage skin clearly showed that the stabilizer trim was set at 7.5 units ANU at impact.

Ground impact and the ensuing postcrash fire destroyed the wings and forward fuselage structure which precluded establishing continuity in all channels of the mechanical flight control systems between the cockpit and the flight control surfaces. Functional testing of the hydraulic and mechanical actuator components of the flight controls for the pitch, roll, and yaw channels did not reveal any malfunctions or abnormalities. The Safety Board considered various failure modes that might have resulted in the misset trim.

One failure mode considered was a dual failure in the hydraulic or electrical stabilizer trim system forward of the power control unit which resulted in a "runaway" trim in the airplane noseup direction. The power control unit hydraulic pump/motor drives the stabilizer trim at a rate of 1/2 unit per second. The time intervals on the CVR tapes indicated that from the start of takeoff roll to impact enough time elapsed that a runaway stabilizer trim would have been driven full travel (10 units) during the accident flight rather than only 7.5 units. The probability of a dual failure having occurred and the runaway condition having gone unnoticed in the cockpit is considered extremely remote since the suitcase handles are located adjacent to the captain's right leg. Service history of the DC-8 airplane does not indicate any problem with runaway stabilizer trim. The electrical portion of the stabilizer trim drives the unit at a much slower rate (1/17 to 1/20 units per second). Using the above time interval, a failure of the electric trim would have resulted in a setting of about 4.5 units at impact. The Safety Board, therefore, believes that a dual failure did not occur on this accident flight.

The Safety Board considered the possibility of a mechanical failure in the stabilizer power control unit or jackscrew assemblies which prevented the stabilizer from being positioned to the takeoff setting and that this condition went unnoticed by the flightcrew during performance of the preflight and takeoff checklists. The power control unit, jackscrews, chains, and sprockets were continuous and in good condition prior to removal from the airplane onsite. Subsequent functional testing of the power control unit, electrically and hydraulically, was satisfactory. Partial disassembly of the power

control unit revealed that the gearbox was in good condition with no sheared rivets in the sprocket drive train or evidence of excessive shaft bearing wear. The operation of the power control unit and condition of the jackscrews, sprockets, and chains discounts the possibility of this type failure.

Another possible failure considered was a mechanical failure in the stabilizer position indicator on the cockpit pedestal which resulted in a false reading of stabilizer trim to the flightcrew. Since the suitcase handles move full travel when the trim switch is activated, the flightcrew's attention would normally be directed to the position indicator which is located next to the suitcase handles. If the flightcrew followed procedures, the stabilizer trim would have been set after landing and then the final setting made before takeoff. Any discrepancy would have been noted then. The Safety Board, therefore, discounts this type failure.

The Safety Board considered the possibility of the first officer or the second officer inadvertently having engaged the autopilot when they switched seats. Autopilot stabilizer trim power is powered by the electric motor that trims randomly at a rate of 1/20th unit per second. Since the autopilot switch is a three-position switch on the center pedestal and has to be moved forward, then sideways to the right at mid-point, and forward again to engage, it would have been necessary that the switch be inadvertently moved through two distinct motions. The Safety Board believes it is highly improbable that this happened, since any sideways movement of a person exiting the seat would be to the left and any person entering the seat would normally step over the pedestal. On the other hand, if the first officer had inadvertently engaged the autopilot switch when he boarded the airplane before 0230, the electric motor would have run for 21 minutes (1260 seconds) and the trim would have been driven to the limits. However, the flightcrew should have noted an engaged autopilot when they performed the before-takeoff flight control check at 0248+. Finally, the seat swap between the first and second officer was made at about 0249:16 and liftoff was about 0251:38, or 42 seconds later. The trim rate would have moved the stabilizer about 7 units, to about 8.9 units ANU. The electric trim motor was checked and did operate at the proper rate. Consequently, the Safety Board does not believe that the autopilot was inadvertently engaged by the first officer or the second officer during the seat swap.

Another possibility considered that could account for the misset trim was that the flightcrew neglected to reset the stabilizer trim after the landing at Detroit and the subsequent takeoff was attempted with the stabilizer trim at the final landing flare position. Both the captain and the first officer, who made the landing, were known to continue trimming noseup stabilizer as a means of smoothly flaring the airplane during the landing. About 4.0 units ANU would have neutralized the aerodynamic control force for the landing, and additional units ANU could have provided flare. Simulator flight testing indicates that a final stabilizer trim setting of 7.5 units ANU is feasible and in fact was achieved when a line DC-8 pilot made the landings using this technique. However, the presence of landing trim before takeoff presupposes the following missed opportunities for correction: (1) the prescribed first officer's standard operating procedure to retrim after landing to 2 units ANU; (2) the second officer's walkaround and preliminary cockpit preparation (not required on en route stop); (3) the captain's cockpit preparation; (4) the captain/first officer's setting of trim after start; (5) the captain's recheck setting versus final weight on taxi out; and (6) the first officer's check of trim on before-takeoff checklist.

The first officer's inconsistency in retrimming after landing, the short duration of taxi after the landing, the short duration of the turnaround, and the cold, dark night might have contributed to these oversights. The crew's activities in the cockpit prior to the takeoff, in particular the first officer and second officer's exchanging positions, was not a normal procedure and could have contributed to the oversight. Other crew factors such as fatigue and lack of flight qualifications for the positions occupied on takeoff could also have contributed to the oversight. The Safety Board concludes that the flightcrew

inadvertently overlooked setting the stabilizer trim at takeoff and that the 7.5 units ANU trim setting used in the previous landing was not removed after landing or detected while preparing for takeoff.

Contributing somewhat to the noseup tendency of the airplane was the further aft center of gravity resulting from the inadvertent omission of the cargo "igloo" for pit No. 1. The missing pallet would have been positioned in the forward most pit and its omission, along with the extra 731 pounds of fuel, shifted the center of gravity aft and changed the recommended stabilizer setting from 1.9 ANU to 0.2 ANU. While the omitted "igloo" was not causal to the accident, since the airplane would have been easily controlled with a proper trim setting, it did contribute to the noseup tendency of the airplane.

2.4 Airplane Performance

Acceleration, rotation, and liftoff.--Engine acceleration started at 0251:12.6, and the engines stabilized in 7 seconds at a setting equal to 1.81 EPR, which was .05 EPR higher than planned. Airplane acceleration was normal and the 80-knot check was made at the expected acceleration point. When the second officer pushed the control column full forward for the 80-knot check, he did not voice any concern over the handling characteristics of the airplane. Of course, with his limited flying skills and knowledge, the second officer might not have recognized any deviations or discrepancies.

The airplane was overrotated at liftoff. Witnesses' statements and the flightcrew's remarks on the CVR clearly indicated an unusually nose-high attitude at liftoff. This was due to the misset stabilizer trim and abetted by the aft center of gravity. Apparently, none of the crewmembers immediately recognized the precariousness of the situation, since there were no comments from any crewmember other than those referring to the attitude of the airplane.

The simulations of the takeoff conducted after the accident demonstrated that immediately after liftoff when nosedown elevator forces were applied, the rate of rotation slowed, giving the impression that it would be possible to arrest the rotation solely with forward control input. Recovery of the airplane at rotation was possible if immediate nosedown trim was applied along with full forward elevator input. However, once the airplane left the ground and started to accelerate, recovery was improbable.

Initial climb and attempted recovery.--The captain expressed apprehension approximately 10 seconds after rotation, but only 3 seconds before stickshaker activation. His delayed reaction time might have been a result of his not recognizing the hazardous situation or of his expectation that the second officer would correct the airplane's attitude. It could not be established if comments recorded by the CVR concerning trim were intended as commands to initiate an action or merely announcements reinforcing action already in progress. The simulator flights revealed that after liftoff, the airspeed increased until the nose reached about 15° ANU, the airspeed would stop increasing and then rapidly decrease as a 30° to 40° noseup attitude was reached. The airplane then entered a stall, and recovery was not possible. The FDR, the tower BRITE scope, and the Air Route Traffic Control Radar indicated the maximum height achieved was about 1,000 feet above ground level.

Out of control descent.--After the airplane climbed to about 1,000 feet, it rolled to the right and made an uncontrollable descent to impact. After the captain commented about going inverted, there were other exchanges between the captain and first officer suggestive of differing recovery ideas but impact occurred 8 seconds later. Recovery during this period was impossible. Analysis of the CVR tape indicated engine surges during this time period which would account for witnesses seeing flames near the engines.

The inability of the captain to recover the airplane at any time might have been complicated by some action of the second officer, such as freezing on the control column, holding noseup trim, or both. If the second officer's trim command was opposite the captain's input, there would have been no movement of the stabilizer.

2.5 Automatic Terminal Information Service

On the first call, the communicating pilot informed clearance delivery that United 2885 was in receipt of Automatic Terminal Information Service (ATIS) Foxtrot. ATIS Foxtrot was recorded at 2345:49 and was not updated to information Golf until 0249:45. Surface weather reports were received at 0047 and 0147. Although no appreciable content change was reflected in the reported weather, the ATIS should have been updated subsequent to receipt of the new surface weather reports as required by FAA Handbook 7210.3F, dated October 1, 1981.

Because the meteorological conditions existing at Detroit at the time of the accident were not representative of the type of meteorological conditions which reasonably can be categorized as hazardous to flight, the failure of tower personnel to update the ATIS is not considered to be an accident causal or contributing factor. However, the failure of air traffic control personnel to comply with existing directives to update the ATIS constitutes an operational deficiency. This deficiency could present a significant hazard to the safety of terminal flight operations if conditions such as convective activity are present in the area and are not included in the ATIS report. Such lax application of established procedures for updating ATIS is not consistent with the Safety Board's position which advocates that pilots always be provided with timely information on which to base their operational decisions.

2.6 Hazardous Materials Notification

At least five federal, company, or local regulations or agreements were in effect at the time of the accident that outlined hazardous materials airport notification procedures. None were followed, and it was only happenstance that the airport operations employee overheard a discussion concerning the RAM shipment and notified the onscene commander. Airport operators are required by the FAA to insure coordination among participants in airport emergency plans. However, there is no requirement to periodically exercise the plans, at any level. The Safety Board believes that some form of periodic exercise of airport emergency plans should be required. A major Safety Board study on airport safety, including emergency plan exercises, is in the final stages of preparation. The Safety Board will use the information developed in this study as well as the circumstances of this accident to make recommendations regarding the need for a requirement for emergency plan exercises and their form and scope.

Air carriers have an exemption from a requirement to immediately notify the National Response Center (NRC) in the event of a RAM release or threat of release. The exemption applies when the air carrier notifies an FAA security officer. The Safety Board believes that NRC notification procedures of carriers of RAM materials should be uniform in all modes of transportation and that this exemption is not appropriate.

3. CONCLUSIONS

3.1 Findings

1. The airplane was certificated, equipped, and maintained in accordance with Federal regulations and approved procedures.
2. There was no evidence of preaccident failure or malfunction of the airplane powerplants, systems, or structures.

3. The flightcrew was properly certificated and medically qualified for the flight at their assigned positions.
4. The flight data recorder did not function and information that would have been useful to the investigation was not recorded.
5. Weather was not a factor in this accident.
6. The hazardous materials shipment aboard the airplane met current packaging requirements, the container was not breached, and there was no spillage of radioactive materials.
7. The horizontal stabilizer trim was at 7.5 units ANU at impact.
8. Functional testing of the selected hydraulic and mechanical components of the flight control system which survived the accident did not reveal any discrepancies. The power control unit, sprockets, chains, and jackscrew assemblies of the horizontal stabilizer trim system were in good condition, the trim system was continuous, and operated normally when tested.
9. The three landing gear were down and locked at impact. The trailing edge flap setting was 15° with no asymmetry.
10. The first officer and second officer swapped duty stations about 65 seconds before takeoff with the approval of the captain.
11. The airplane was loaded with a more aft center of gravity than indicated in the dispatch papers.
12. The captain and first officer did not have the prescribed crew rest prior to the trip sequence and might have been fatigued.
13. The second officer, who attempted to make this nighttime, visual takeoff, had failed to qualify as a DC-8 first officer. Although the second officer had qualified as a first officer on the B-737, he required special training and surveillance and subsequently lost the qualification after a year on the line.
14. The second officer was permanently removed from all pilot duties by mutual written agreement with the company.
15. The flightcrew inadvertently overlooked setting the stabilizer trim for takeoff, and the setting of 7.5 units ANU was the previous landing trim setting.
16. Had any one of six distinct procedural requirements involving all three crewmembers been followed, the stabilizer landing trim should have been set within acceptable limits at takeoff.
17. After takeoff, the captain and the second officer were unable to arrest the pitchup and control the airplane.
18. The airplane climbed to about 1,000 feet above ground level.
19. The engines surged during the climb causing visible flames to emit from the engines.

20. Detroit Metropolitan Airport tower personnel did not update the Automatic Terminal Information Service information in accordance with current Federal Aviation Administration directives. This failure was not causal to the accident.
21. At least five federal, company, or local regulations or agreements outlining hazardous materials notification procedures were in effect at the time of the accident. None were followed.
22. Airport operations are required to insure participant coordination in airport emergency plans, but there is no requirement to periodically exercise the plans.
23. Air carriers have an exemption from the requirement to notify the National Response Center in the event of a radioactive material or hazardous materials incident. Carriers in other modes do not have an exemption.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the flightcrew's failure to follow procedural checklist requirements and to detect and correct a mistrimmed stabilizer before the airplane became uncontrollable. Contributing to the accident was the captain's allowing the second officer, who was not qualified to act as a pilot, to occupy the seat of the first officer and to conduct the takeoff.

ICAO Note: The Appendices were not reproduced.

ICAO Ref.: 003/83

No. 2

North American Rockwell Sabreliner 65, N99S, at Toronto, Ontario, Canada on 11 January 1983. Report No. 83-030901 released by the Canadian Aviation Safety Bureau.

SYNOPSIS

The accident was investigated by the Canadian Aviation Safety Bureau. The state of registry, the United States, provided an accredited representative who assisted in the investigation. This report was released on 14 October, 1983.

The aircraft was on a corporate flight from Philadelphia International Airport to Toronto International Airport when it crashed, 7.6. nm from the threshold of Runway 24R while being vectored for an ILS approach.

The aircraft was observed to descend steeply from cloud and execute a series of abrupt, rolling movements, before striking the ground in a nose low, inverted attitude. A severe fire followed. Two crew members and three passengers perished in the crash.

The cause or causes of the accident could not be determined.

1.

FACTUAL INFORMATION1.1 History of the Flight

At 1421 EST*, 11 January 1983, Rockwell Sabreliner 65, registration N99S, departed Philadelphia International Airport on a corporate flight to Toronto International Airport. On board were two crewmembers and three passengers. The captain was observed to be in the left seat at departure. The planned cruising altitude was FL 350 with an estimated enroute time of one hour.

Prior to departure, the captain telephoned Millville FSS and obtained weather and NOTAM information for the flight.

The flight went as planned with the crew contacting Toronto Centre at 1505 and Toronto Arrival at 1511. The arrival controller cleared the flight to descend to 6000 ft** ASL and proceed directly to the Toronto VOR. At 1515, the controller began issuing vectors for the ILS approach to runway 24R. The aircraft was directed through turns, speed reductions and further descent to intercept the ILS localizer from the south. At 1520 the flight was cleared for the approach and instructed to contact Toronto Tower at the outer marker. On radar, the arrival controller observed the aircraft intercepting the localizer at approximately 9 nm from the runway threshold at which time the digital radar display information went into "coast". (See Section 1.8)

At 1521:52 the controller asked the crew for their indicated airspeed. The only response received was "Mayday, Mayday". At this time the controller noted that the radar data block for N99S was indicating an aircraft altitude of 1000 ft ASL and a groundspeed of 120 kts. The data block then went into "coast" and radar contact was lost.

From eyewitness accounts, it was determined that the aircraft descended steeply out of cloud in a wings level, nose-down attitude, about 1 nm south of the centreline of the 24R localizer, 9 nm from the runway threshold. Its heading corresponded to the last assigned by the arrival controller. From this point until impact, N99S began a series of abrupt rolling and turning movements.

Initially, the aircraft banked sharply to the right and turned through about 40° as the steep descent continued. It proceeded in a generally straight path for about one-quarter mile then the rate of descent decreased. At this point it was estimated the aircraft was 500 ft AGL. It then banked sharply left, followed within one-half mile by a sharp right bank and a turn through about 90°. Crossing the localizer

* All times are given in EST (GMT-5) unless otherwise stated.
See glossary for all abbreviations and acronyms.

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

centreline heading north-northwest, the aircraft, still descending, was approximately 250 ft AGL. After travelling about 500 ft, it appeared to climb slightly, then bank sharply to the left and begin a turn through approximately 70°. While in this turn, at about 150 ft AGL, the aircraft suddenly rolled rapidly to the left, pitched down, and struck the ground inverted. On impact the aircraft exploded; the initial explosion was followed by a number of smaller contained explosions. A severe fire burned until extinguished by the fire department.

The crash site is located at 43°47'07"N, 79°30'52"W, at an elevation of 650 ft ASL.

The accident occurred during the hours of daylight at 1522.

1.2 Injuries to Persons

<u>Injuries</u>	<u>Crew</u>	<u>Passengers</u>	<u>Others</u>	<u>Total</u>
Fatal	2	3	0	5
Serious	0	0	0	0
Minor/None	0	0	0	0
Totals	<u>2</u>	<u>3</u>	<u>0</u>	<u>5</u>

1.3 Damage to Aircraft

The aircraft was destroyed by impact forces and the subsequent ground fire.

1.4 Other Damage

Several apple trees were damaged.

1.5 Personnel Information

The flight crew was qualified for the flight. Both pilots were based in Philadelphia and were familiar with the route and destination facilities, having flown to Toronto on previous occasions. Pertinent information is tabulated below:

	<u>Captain</u>	<u>First Officer</u>
Age	34	36
Licence	US ATPC	US ATPC
Ratings	SMEL	SMEL
Medical	Second Class*	First Class

* The captain's first class medical with a waiver for the wearing of contact lenses had expired and automatically reverted to second class on 1 September 1982. A second class medical maintains FAA certificate validity for corporate operation.

Total Time	3703 hours	4154 hours
On Type	430 hours	456 hours
Total Last 90 Days	39 hours	63 hours
On Type Last 90 Days	39 hours	63 hours
Duty Time	4 hours	4 hours
Proficiency Training	19 Nov 1982*	12 Nov 1982*
Began Flying	1972	1963

1.6

Aircraft Information

The Sabreliner 65 (NA 265-65) was manufactured by the Rockwell International Sabreliner Division. It is a derivative of the North American Rockwell Sabreliner originally designed in 1956. Since that time, a number of updated models have been manufactured including the Sabreliner 65, which incorporates Garrett turbofan engines and a supercritical** wing. Pertinent information is tabulated below:

Year of Manufacture:	1981
Serial Number:	465-64
Registered Owner:	Sun Oil Company of Pennsylvania
Operator:	Sun Refining & Marketing Company
Home Base:	Philadelphia International Airport
Certificate of Airworthiness:	Valid
Total Airframe Time:	668 hours
Total Airframe Cycles:	407

	<u>Accident Flight</u>	<u>Sabreliner 65 Limits</u>
Ramp Weight	21,346 lbs	24,000 lbs
Take-Off Weight	21,027 lbs	24,000 lbs
Landing Weight	19,027 lbs	21,755 lbs
Centre of Gravity	24.31% MAC	20.2% MAC to 33.1% MAC

Maintenance was in accordance with the FAA approved, manufacturer recommended 'Sabreliner Maintenance/Inspection Program' (SMIP). The most recent check, a 150 hour inspection, had been carried out at 598 hours, 70 flight hours before the accident flight.

All applicable airworthiness directives, service bulletins, and service letters had been complied with. There was no current or deferred maintenance unserviceability prior to departure.

The aircraft contained approximately 5,820 lbs of Jet A fuel at take-off, and consumed approximately 2,000 lbs enroute.

* The issuance of proficiency certificates satisfies FAA regulations regarding aircraft and instrument flying proficiency.

** A supercritical wing has a relatively deep, flat-topped profile, generating lift right across the upper surface, instead of concentrated close behind the leading edge.

Fuel samples drawn 12 January from the source of the last refuelling were identified as Jet A, without icing inhibitor content. The freezing point was determined as -59°C .

The aircraft was equipped with two Garrett AiResearch Model TFE-731-3R-1D engines. Pertinent information is tabulated below:

	<u>Left</u>	<u>Right</u>
Serial Number	P83233	P83234
Total Hours Since New	597	668
Total Hours Since Repair	292	Not Applicable
Total Cycles Since New	370	407
Total Cycles Since Repair	148	Not Applicable

The engines were on a Spectrometric Oil Analysis Program (SOAP), with engine oil samples routinely sent for laboratory analysis. The left engine was removed from the aircraft at 305 hours due to bearing failure. It was reinstalled at about 376 hours.

When in Philadelphia, and whenever possible while away from home base, the aircraft was hangared. During the two weeks preceding the accident, it was not subjected to any significant amounts of rainfall while on the ground, and was washed only once. There were no known water leaks and the cabin water drain valve was opened every time refuelling took place in Philadelphia, with no water ever being found.

A Toronto fixed base operator received a radio call from N99S approximately ten minutes before the accident. An unidentified crewmember stated they would be departing directly from Customs and that the aircraft required no servicing. This indicates that, just prior to levelling at 6,000 ft and entering the downwind leg, the aircraft was serviceable for the return flight to Philadelphia.

Some Sabreliner 65 pilots reported that a small amount of wing surface contamination will significantly degrade lift production. The Airplane Flight Manual contains a note to add a minimum of 20 kts to approach and touchdown speeds, when an approach is made with known or suspected ice on the wing leading edges. An analysis of the Sabreliner 65 certification icing tests is in agreement with the Airplane Flight Manual in stating that approach safety speeds be increased 15% when wing ice may be present.

The Sabreliner 65 Pilot's Manual advises that a mild rolling tendency may be observed at the stall, and that this tendency is greatest with full flaps.

A stall warning/angle of attack system incorporated in the aircraft provides the pilot with advance warning of a stall. The system consists of a control column shaker and an angle of attack indicator which provides a visual reference of angle of attack deviation from a pre-set reference. Stall warning systems generally do not compensate for increased stall speeds due to wing leading edge contamination.

Ice protection is provided for the engines and leading edge of the wing using engine bleed air. A minimum of 75% NI is necessary to ensure sufficient bleed air pressure for adequate protection. System operation is controlled from the cockpit by individual engine and wing anti-ice switches. The system is wired through main landing gear load proximity switches to prevent operation on the ground. A malfunction of one of these switches could result in the system not operating despite being selected on.

Engine and wing anti-ice failure warning lights are located on the "caution warning light panel". These illuminate when anti-ice is selected on, and either the appropriate valves remain closed, or NI is too low to ensure adequate ice protection. In addition, the wing anti-ice light will illuminate for other reasons related to system malfunctions. There would be no indication to the crew of a malfunction of a landing gear load proximity switch.

No ice protection is provided for the tail surfaces of the aircraft. The engine conical spinner is not heated.

1.7 Meteorological Information

Environment Canada and the United States National Weather Service analyses indicate there was no significant weather enroute between Philadelphia and Toronto.

The Toronto area was under the influence of a broad surface trough. The air mass was forecast to be close to saturation from the surface to over 10,000 ft ASL, and somewhat unstable below 4,000 ft ASL. Overcast to broken ceilings were forecast at 2,000 to 3,000 ft ASL, with cloud tops at 14,000 ft ASL, and scattered to broken layers between 14,000 and 18,000 ft ASL. Mixed precipitation, with some light snow, was expected. Light to moderate rime icing in cloud was predicted above the freezing level (2000 ft ASL), with moderate mixed icing expected in areas of mixed precipitation associated with cumulus clouds. Generally overcast conditions prevailed through the day, with occasional periods of very light rainshowers. Pilots interviewed reported the cloud was based about 3,000 ft ASL, and topped around 6,000 ft ASL.

A special weather report taken at Toronto International Airport nine minutes after the accident showed the cloud ceiling was a broken layer at 1,700 ft AGL with an overcast layer at 3,400 ft AGL. Visibility was 12 sm and the surface wind was from 240°T at 9 kts. Temperature was 3°C and dewpoint 0°C.

Environment Canada provided the following information regarding probable conditions (aftercast) encountered by N99S during descent:

<u>Altitude</u>	<u>Wind Velocity</u>	<u>Temperature</u>	<u>Moisture Content</u>
4000 AGL	250°T/30 kts	-5°C	Near Saturation
3000 AGL	245°T/27 kts	-3°C	Near Saturation
2000 AGL	245°T/25 kts	-1°C	Near Saturation
1000 AGL	240°T/20 kts	+1°C	Relative Humidity 90%
Surface	240°T/10 kts	+3°C	Relative Humidity 84%

Two L-1011 crews that preceded N99S on approach reported they had ice detection lights illuminate during descent, but neither noticed ice on the airframe. The first L-1011 crew also reported encountering light chop on approach. A DC-9 crew, on approach about eleven minutes after the accident, reported a brief encounter with moderate clear icing at 4,000 ft ASL. The DC-9 was in the same area where N99S descended through 4,000 ft ASL. The pilot of a Sabreliner 60 which landed on runway 24R nine minutes before the accident, reported no icing. However, this aircraft arrived from the northeast and made a straight-in approach. None of the pilots interviewed reported precipitation. The icing and light chop reports are indicative of some cumulus cloud imbedded in an otherwise layered structure, and could account for localized areas of clear ice.

1.8 Aids to Navigation

The approach in use was the runway 24R ILS with the glideslope set at 3° and a localizer track of 236°M. Flight crews who conducted ILS approaches to 24R prior to, and following the arrival of N99S, reported no difficulty with any component of the ILS system. Following the accident, a Transport Canada calibration aircraft was used to flight check the ILS; all parameters were within specified tolerances.

During the final stages, the flight was receiving radar guidance from Toronto ATC. At the time of the accident, some functions of the ATC digital radar system were operating intermittently. As a result, the data blocks which display ground speed and altitude information would periodically go into "coast"; at these times ground speed and altitude information was not displayed to the controller. This did not affect his ability to vector the aircraft to the localizer.

Toronto ATC facilities are not equipped to record radar data under normal conditions. A DART printout of radar data was obtained from Cleveland Centre for N99S's flight path. It provided tracking information until 1518:52, about three minutes before impact, when the aircraft was turning toward the localizer and descending through 4,300 ft ASL.

1.9 Communications

Communications were normal in all respects.

1.10 Aerodrome Information

Runway 24R has a landing distance available of 10,325 ft. The runway is equipped with a VASIS, which was operating at the time of the accident.

1.11 Flight Recorders

The aircraft was not equipped with either a flight data, or cockpit voice recorder. Neither the United States' FAA nor Transport Canada require corporate aircraft to carry flight recorders.

The Air Canada Lockheed L-1011 that preceded N99S on approach was equipped with a DFDR. It was removed for playback to determine atmospheric conditions and the L-1011 flight path. Information derived from the DFDR is incorporated in section 1.17.3.

1.12 Wreckage and Impact Information

The aircraft crashed approximately 7.6 nm from the threshold of runway 24R with wreckage spread along a track of 287°M. The approximate impact angle, as determined from the impact crater, was 28° from the horizontal with 135° left bank. The aircraft exploded immediately and an intense fire followed. The major portion of the wreckage slid a total of 41 ft before stopping against a row of apple trees. Total wreckage scatter covered an area approximately 230 by 360 ft. A site survey was completed on 13 January - all major components and control surfaces were accounted for.

The windshields, cabin entry door, structure from the top of the cockpit/cabin area, an emergency exit window frame, and parts from the left wing leading edge were found at the first point of impact. The vertical stabilizer complete with the rudder, separated from the aircraft after initial ground impact and was found near that point. A small portion of the aft fuselage, less the fin and rudder, was found with the main wreckage. The right stabilizer and elevator were detached, and lying nearby. The engines tore free of their mounts and were found within the main wreckage confines. The severe post-impact fire virtually consumed the forward 35 feet of lower fuselage. The wings suffered extensive fire damage. Remnants of glass fibre cloth from both wing top surfaces were found in the wreckage area. Switch positions could not be determined with any degree of certainty due to the severity of destruction.

The following paragraphs summarize the results of various examinations undertaken during the investigation.

For a more detailed description and explanation of these examinations refer to the applicable Engineering Report listed in Appendix "F". These reports form a part of the investigation.

1.12.1 Flight Controls

The flight controls, including surfaces and related control mechanisms, sustained varying degrees of impact and fire damage. All were examined and their pre-impact position and integrity were determined to be as follows.

The ailerons were attached and showed no position disparity, with no abnormality in the control system; the aileron trim was at about zero degrees. Nothing suggested a restriction in movement of the aileron system.

The rudder was attached, and there was no abnormality in the control system; the rudder trim was at about 4 degrees right rudder. Nothing suggested a restriction in movement of the rudder or rudder trim control systems.

Both elevators were attached, with no abnormality in the control system. There was no evidence to suggest an abnormal stabilizer position. (i.e. result of run-away), or restriction in movement. Nothing was found to indicate that the crew would have been prevented from selecting any desired stabilizer trim position. The trim position at impact was 10.1° nose up.

The control handle of the gust lock was in the off (unlocked) position, and the rudder lock pawl pin was unmarked. Marks should have been evident had it been engaged, considering the extensive loads imposed on the rudder system at impact. Moreover, had the gust lock been engaged at impact, a different type of damage/failure should have been evident in the rudder system.

1.12.2 Flaps

At impact, the flaps were attached, fully extended to 36°, and capable of movement in response to crew selection.

1.12.3 Spoilers

The spoilers were retracted at impact. Gravitational forces and ground fire heat affecting the hydraulic lines and actuator jacks resulted in subsequent actuator jack and panel extension.

1.12.4 Landing Gear

The landing gear was fully retracted at impact and the right wheel well door was up and locked. The position of the left and nose wheel well doors could not be determined; however, considering that the nose landing gear was fully retracted, normal system operation would cause the nose wheel well doors to be fully retracted.

1.12.5 Thrust Reversers

Examination of the left and right thrust reversers showed they were stowed and locked.

1.12.6 Electrical System

Examination of the electrical system and associated components revealed no evidence of irregularities. The destruction of individual components prevented a conclusion as to services in operation prior to

impact. Witnesses observed aircraft recognition lights, indicating the secondary DC system was powered prior to impact, implying that at least one generator was on line. It could not be determined if power was derived from both generators.

The APU was not operating at impact.

1.12.7 Hydraulic System

Examination revealed the system contained fluid at impact, and there was no evidence to indicate it could not operate as designed.

1.12.8 Fuel System

Evidence indicates that tank selections were as follows: right tank to right engine, left tank to left engine, boost pump cross-feed off, and tank cross-feed off. The operation of the boost pumps could not be determined, nor could any fuel samples be obtained. The right and left fuel shut off valves were open. These valves are actuated by the engine fire handles or the engine master switches.

1.12.9 Auto Flight (Autopilot)

Examination of the autopilot servos and mounts (aileron, elevator and rudder) revealed no irregularities.

Because the amplifier was severely damaged by impact forces, it was impossible to determine its condition prior to the crash. Examination of the system failed to determine the control selection at impact. Had it been in operation, the individual flight control systems should have been capable of being overridden by the crew. Had it been necessary for the crew to override the autopilot, there would have been evidence of clutch slippage - none was found.

1.12.10 Anti-icing Systems

The operational configuration of the wing and engine inlet anti-ice systems at impact could not be determined.

1.12.11 Engines

The engines were forwarded to the manufacturer's plant for disassembly and initial examination. This work was witnessed by Aviation Safety Bureau investigators, and representatives of the NTSB, the aircraft owner, and the manufacturer. After disassembly, the engines were returned to the Bureau's Aviation Safety Engineering Division at Ottawa where they underwent further examination.

1.12.11.1 Left Engine

Bending and damage to the blades of the low pressure compressor of the left engine was indicative of low rotation speed at impact. Many stator vanes had separated from their mounting rings, but had not

moved significantly rearward, again indicating low engine rotation speed at impact. Material had been milled from the high pressure compressor shroud, but was limited to the softer surface layer. These gouged and roughened areas were typical of a chattering effect, rather than high speed milling. The lack of aluminum spatter on hot section components was indicative of a "flamed out" condition at the time of engine break up. No fault was found in the mechanical components of the engine fuel system. However, the fuel control unit was too badly burned to yield any useful information.

1.12.11.2 Right Engine

The compressor of the right engine suffered extensive damage. The second and third stage low pressure compressor blades had broken off near the roots; most fracture faces had been smeared. The blades had all escaped from the fourth stage rotor during compressor break up. All four stages of stator vanes had separated from their mounting rings and were severely damaged. The high pressure shroud was worn and gouged resulting in the loss of about 25% of the surface material. The impeller was severely damaged with all the blades broken off close to the roots.

A metallic deposit was found evenly distributed throughout the hot section of the engine. Chemical analysis determined these deposits were comprised of materials found in the compressor components.

The blades of the high pressure compressor turbine were significantly reduced in span and chord due to erosion from high velocity impact of metallic particles originating from the compressor sections.

The extent of the metallic deposits and the erosion of the turbine blades is indicative of pre-impact damage. The extent of damage to the blades of the low pressure compressor indicates a break up of the engine may have been initiated by the failure of a second or third stage compressor blade. Considerable secondary impact damage to the fracture faces of the blades precluded any definitive findings with regard to possible pre-existing cracking.

1.13 Medical and Pathological Information

Autopsies were conducted on all five occupants. There was insufficient evidence to determine whether incapacitation was a factor in the accident.

A review of flight crew medical records revealed no pre-existing condition which might have contributed to or resulted in pilot incapacitation.

There is no indication of personal, family or business pressures which would have placed stress on either pilot.

1.14 Fire

Eyewitnesses to the final descent and impact of N99S stated there was no visible smoke or fire prior to impact.

There was no evidence of activation of the engine fire extinguishers; both fire pull handles were in the stowed position. The condition of the APU fire bottle disc suggested this bottle had not been used. There was no evidence of an oxygen-related fire from either the main oxygen system or the walkaround bottle. All fire damage to the electrical system was attributed to the post impact fire. No evidence was found to indicate a loss of pressurization or the existence of a fire in the environmental ducting or the fuselage prior to impact.

The municipal fire department was notified within one minute of the accident and arrived at the site within seven minutes of impact; using AFFF agent, they had the blaze under control within the next five minutes.

1.15 Survival Aspects

The impact was non-survivable due to the magnitude of the deceleration forces and the destruction of the fuselage.

1.16 Tests and Research

1.16.1 Flight and Engine Instruments

Thirteen flight and engine instruments were recovered from the wreckage and analysed. All were severely damaged by direct impact forces but did not appear to have been damaged by fire.

Flight testing showed some instruments installed in Sabreliners produced erratic readings when subjected to coarse in-flight pitch or roll movements. In view of the left roll and pitchdown (up) occurring at impact, and otherwise unsupportable impact readings of the instruments, three new Sabreliner instruments were analysed to determine the effects of rapid acceleration around their sensitivity axis.

The instruments examined were an inlet turbine temperature gauge, an N2 tachometer and a DC loadmeter. They were placed in a fixture, and powered to display 'mid-range' indications, then rotated 90° both clockwise and counter-clockwise at three different rotational accelerations. All this was filmed at a rate of 1,000 frames per second.

The film revealed that the pointers, on indicators like the three tested, would deflect as much as 50° either way, depending on the rate of roll. The battery temperature indicator in a Sabreliner 65, having its sensitivity axis in the transverse plane, would similarly be subject to needle deflection by rapid pitch change. If a sudden roll and/or pitch movement occurred just prior to impact, many instrument

impact indications would not be valid, and therefore cannot be used without considering additional factors.

Quantitative analysis of impact readings using a needle displacement factor for each instrument was considered, but rejected due to the subjective nature of data available on pre-impact aircraft movement. As a result, the instrument readings at impact were not considered useful.

1.16.2 "Caution Warning Light Panel"

The "caution warning light panel" was recovered and subjected to laboratory analysis. It had been severely damaged by direct impact and only fourteen of a possible fifty-two warning lights contained bulb filament that could be analysed. It was concluded that the left and right "Engine Anti-Ice Failure" warning lights were on just prior to impact, and the following twelve warning lights were off: Cabin Pressure Failure; Cabin Air Hot; Cockpit Air Hot; Door Open; Fus Hot; Wing Anti-Ice Failure; APU DC Gen Hot; LH Pitot Heat Off; RH Pitot Heat Off; OAT Heat Off; LH Fuel Pressure Low; RH Fuel Pressure Low.

1.16.3 Tail Ice and Tail Stall Phenomenon

Testing and research have proven that ice formation may be very rapid on unheated flight surfaces. A build-up of ice on a tailplane leading edge may cause partial or total loss of longitudinal stability which could result in the aircraft pitching nose down when the tailplane stalls. This phenomenon is most severe with a raised horizontal stabilizer and a moveable horizontal flight surface, and can be induced by selecting full landing flap. If altitude is sufficient, recovery may be effected by raising flaps.

1.17 Additional Information

1.17.1 Mayday Transmission

The "Mayday" transmission was given with extreme anxiety; it was made at 1521:54. The voice was identified as that of the first officer. Eleven seconds later, a police operator received a telephone call from a witness who observed the crash from a window and immediately dialed a three-digit emergency number. The ATC and police timekeeping systems use the same official observatory time signal, thus it was established the "Mayday" call was transmitted during the last second or two of flight.

1.17.2 Landing Gear Warning Horn

A landing gear warning horn provides an audible signal of a gear unsafe condition. It cannot be silenced by the landing gear warning horn cutout button when the wing flaps are extended to the 36 degree position with the landing gear up.

Recordings of normal radio transmissions from N99S contain no background tone which correlates to the landing gear warning horn. However, during the "Mayday" transmission a 635 Hz tone is present. Recordings from a subsequent test in a Sabreliner 65 determined this to be the approximate frequency of the gear warning horn.

1.17.3 Wake Turbulence

As the aircraft was cleared to descend to 3,000 ft and was turning to intercept the localizer from the south, it was being vectored approximately 6 nm behind a Lockheed L-1011. The applicable minimum separation required under ATC wake turbulence rules is 5 nm.

The L-1011 flight path, derived from its DFDR, shows it intercepted the localizer from the north, about 8 nm from the runway threshold; it did not cross to the south side. It passed over the accident site at about 3,000 ft ASL (2,350 ft AGL) 2 minutes 29 seconds before the "Mayday" call, and landed 42 seconds after the transmission. This equates to a lateral separation of about 6.4 nm, with approach speeds of 160 KIAS for N99S and 150 KIAS for the L-1011.

Research has shown that vortex life is influenced by atmospheric conditions and is time dependent. The aftercast indicates that winds at 2,500 to 3,500 ft AGL were from 245°T at 25 to 27 kts, which would tend to break up vortices within 60 to 90 seconds. The DFDR-recorded static air temperature showed a steady increase during descent, averaging 2.4°C/1000 ft from 6,000 to 1,000 ft ASL. This agrees with the aftercast, and indicates unstable air, which would hasten vortex break-up. During tests, vortices have been identified 3 minutes 54 seconds after generation, but the vortex at that time only constituted an "organised flow" and was not considered a hazard.

Vortices normally descend at about 420 fpm, levelling off about 900 ft below the height of generation.

1.17.4 Flight Path Reconstruction

The absence of aircraft flight recorder information and recorded radar data from Toronto made it necessary to estimate the flight path of N99S between the last radar plot provided by the Cleveland Centre DART radar data and the accident site. This reconstructed flight path is a composite of factual data and the best estimates of aircraft movement.

Using groundspeed and average rate of descent calculated from the DART radar data, and heading and altitude changes and further speed restrictions given by the arrival controller, the flight path was projected ahead to 1520:26 when the last normal radio transmission was received. At this time, the crew had been given a 260° heading to intercept the localizer, and had been cleared for the ILS approach. (See Appendix "A")

Information from the eyewitness statements was used to construct a plot of the aircraft's most probable flight path after it was seen descending out of cloud. (See Appendices "B" and "C")

1.17.5 Simulator Testing

Tests were conducted using a CAE Sabreliner 65 flight crew training simulator. The simulator was not capable of providing a printed record of track and altitude. Reconstruction of the profiles flown was accomplished by manual plotting. It is considered that the results obtained are reasonably accurate. The objective was to establish the configurations which would result in a flight path similar to that flown by the accident aircraft as recorded by the DART system, and the projected flight path.

Using 20° of flap during the descent to 6,000 ft, and selecting landing gear down coincident with descent clearance to 4,000 ft, resulted in the most accurate recreation of the downwind flight path while providing the required power setting to ensure adequate engine and wing ice protection. A minimum setting of 75% N1 is required to ensure adequate ice protection. Anti-ice failure lights illuminate when N1 is less than approximately 65%.

Full landing flap with the landing gear up was not used since analysis of transmissions from N99S did not reveal the presence of a landing gear warning horn. This horn would sound if full flap was selected down and the landing gear was up, and the pilot would be unable to cancel it unless he changed the configuration of the aircraft.

Spoilers were not used, as aircraft performance with spoilers deployed is similar to that achieved with 20° flap extended. Sabreliner 65 pilots involved in the simulator tests stated they would not normally select spoilers instead of 20° flap because it would result in airframe buffeting which could cause mild passenger discomfort.

During base leg, the aircraft was cleared to descend to 3,000 ft and reduce speed to 160 KIAS. In order to comply with this clearance and maintain 75% N1 RPM it was necessary to select 36° flap. Even in this configuration, the power was at times less than that required to ensure adequate ice protection. With 20° flap, power settings would be close to 65% N1, which may have illuminated the anti-ice warning lights.

In all cases, the simulator reached 4,000 ft ASL prior to the time clearance was given to 3,000 ft, and reached 3,000 ft prior to completing the turn to 260° to intercept the localizer.

In an attempt to duplicate the flight path observed by witnesses, several tests were conducted during which engine failures were simulated. During one of these, an engine failure was simulated at 3,000 ft during the turn to intercept the localizer. The crew reacted within 15 seconds and descended to 2,500 ft to achieve VMC. It was

possible to maintain altitude without difficulty using the other engine.

On subsequent simulator runs, both engines were shut down during the turn to intercept the localizer; landing gear was selected up on recognition of the failure. Power loss at this point in the flight, coupled with 36° flap and landing gear up, closely duplicated the actual final descent. During these power off descents, a distance of approximately 2.5 to 3.0 nm was covered while descending 2,500 ft. Introducing steep banking manoeuvres, similar to those described by witnesses, resulted in an increased descent rate which reduced the distance covered and resulted in an impact point which coincided more closely with the actual crash site.

1.17.6 Flight Testing

The information gathered during the simulator sessions was applied during a test flight in a Sabreliner 65. The test flight data confirmed that obtained from the simulator. With a wind at altitude similar to that on the day of the accident, the aircraft descended downwind in about the same time as the accident aircraft, with 20° flap and landing gear down.

Two descents were accomplished with power at flight idle. Residual N1 was about 40%. With 36° flap and landing gear up, the descent rate at glide speed was in excess of 4,000 fpm. With 20° flap and landing gear up, descent rate at glide speed was approximately 2,000 fpm.

Stall sequences were conducted with flap and landing gear down, as well as with the aircraft in a clean configuration. It was found that with 36° flap, the aircraft entered the beginning of a stall and commenced a series of rolling movements of increasing intensity. The pilot allowed the rolling movements to develop to 60° before effecting recovery. On subsequent runs, raising flap to 20° had a damping effect on these oscillations, while raising the landing gear and leaving the flap at 36° had little effect in reducing the severity of the oscillations.

It was determined that a 10.1° horizontal stabilizer setting was required to trim the aircraft with 36° flap at 120 KIAS. Eight degrees of rudder trim was required at 160 KIAS to trim the aircraft with one engine inoperative.

During the test flight, the wing anti-ice failure light illuminated before the engine anti-ice failure lights when power was decreased, and extinguished after the engine anti-ice lights when power was increased.

2.0

ANALYSIS

2.1

Introduction

The analysis of the accident was hampered by the severity of the post-crash fire, the absence of onboard flight data and cockpit voice recorders, and the lack of recorded air traffic control radar data for the final portion of the flight. Much emphasis was placed on the estimated flight path reconstructed from the simulator and flight tests, and eyewitness observations.

2.2

Analysis of the Reconstructed Flight Path

Analysis of the reconstructed flight path shows there was no indication of abnormalities until after the crew acknowledged their approach clearance. The crew had not advised ATC of any difficulties, and complied with all clearances and requests throughout the descent from cruise altitude, and during the initial stages of the approach. The simulator tests suggest that when the crew acknowledged their approach clearance, the aircraft was level, or levelling, at 3,000 ft ASL and turning to a localizer interception heading of 260° M. The first indication of any abnormality was the aircraft's steep descent out of cloud south of the localizer, on a heading that corresponded to the last assigned. From this point the abnormal movements continued until impact. It follows that the initial event which precipitated the accident occurred as the aircraft was turning to intercept the localizer, as or shortly after it reached 3000 ft ASL.

In attempting to determine the factors contributing to the accident, several possible explanations for the aircraft's descent and subsequent movements were identified. These explanations were then analysed for consistency with other information obtained during the investigation.

The aircraft could have descended from its assumed position intercepting the localizer at 3000 ft ASL to the point of impact, if at least one of the following occurred:

- a) the aircraft was in a fully stalled condition;
- b) the tail plane was stalled;
- c) a major structural failure occurred;
- d) aircraft control was lost because of a wake turbulence encounter; or
- e) thrust from both engines was significantly reduced or lost.

With thrust available from one or both engines, the aircraft would not have crashed from 3000 ft ASL as a result of a wing stall, unless the pilot did not, or could not, follow the stall recovery procedures in the Sabreliner 65 Pilot's Manual.

It is possible a tail stall occurred as a result of ice accretion and the pilot was unable to recover. In this case a rapid nose-down descent may have been initiated and only by retracting flaps could the

pilot recover. However, the observed rolling movements are not consistent with the characteristics of tail stall.

There apparently was no structural failure prior to impact.

Regarding wake turbulence, the time separation between the preceding L1011 and N99S was about 2.5 minutes. During this time, the atmospheric instability and wind would have probably broken up the vortices. Even if vortices had remained longer than 90 seconds, analysis of the flight path of N99S, and vortex movement, shows that the aircraft would not have flown through these vortices. The aircraft exited the cloud 1 nm south of the localizer; the L1011 did not cross to the south side and the wind would not have caused any vortices to drift appreciably southward. Moreover, any remaining vortices would have descended to approximately 2,100 ft ASL, well below the 3,000 ft AGL the aircraft was flying at on its intercept heading to the localizer.

2.3 Engine Thrust Loss

A significant reduction, or total loss of thrust in both engines could have caused the descent out of cloud and subsequent movements of the aircraft. The simulator and flight tests demonstrated that a thrust loss in both engines while flying the final intercept heading to the localizer, coupled with steep banking manoeuvres, would result in a ground impact point very near the actual accident site. Without such a loss of thrust, it would be difficult, if not impossible, to descend approximately 2,400 ft from the base of cloud to the ground in the observed 2 miles without attaining excessive speed. Excessive speed was not described by the eyewitnesses. Had a decision been made to descend clear of cloud on recognition of a single engine failure, the full thrust capability of one engine would have eliminated any requirement to continue the descent. The observed 4° right rudder trim at impact was not considered useful in determining engine thrust.

The time of the crew's last normal radio transmission coincides with the estimate of the aircraft's level off at 3,000 ft ASL. Pilot activity at this time would have centred on making power adjustments to attain level flight and possibly changing aircraft configuration. Power would have been added to achieve the level off, and any problem with the engines would have been noticed at this time. Had a significant or total thrust loss occurred while levelling, the crew would have been forced to commence descent to maintain control of the aircraft.

Consideration was given to the possibility that the observed low level movements were an attempt to carry out a forced landing. Although possible, it is unlikely that the observed movements were solely the result of direct pilot input.

The absence of any radio transmissions made by the crew between their acknowledgement of the approach clearance and the Mayday call suggests

that when the problem did develop, the crew was totally occupied identifying it and attempting corrective action. If the crew had identified a problem and committed themselves to a forced landing, it is probable that they would have advised ATC of their intentions.

The large bank angles and abrupt movements described by the eyewitnesses are also not in keeping with what would normally be associated with a controlled forced landing situation. As well, had the crew been completely in control of the aircraft while attempting a forced landing, there were other, more suitable open areas located west of the accident site which were well within range if the aircraft had been in glide configuration and at glide speed. The eyewitness accounts of the aircraft's descent from cloud make it doubtful the aircraft was fully under control or that the crew was not hampered in some way if they were attempting a forced landing.

If a significant thrust loss was recognized by the crew during the level off at 3,000 ft ASL, it is possible that their attention was diverted, they did not commence a descent, and the airspeed decreased to the point where a stall occurred. A stall would result in the observed abrupt altitude loss and steep descent from cloud. The abrupt movement which followed the descent from cloud may also have been the result of flight at or near the stall. Had the crew experienced a significant or total thrust loss in both engines, their attention would be directed to identifying the problem and attempting corrective action.

The data block observed by the arrival controller just prior to impact indicates the aircraft's speed was in fact low. The altitude readout of 1000 ft/ASL (350 ft AGL) suggests this occurred just prior to the aircraft crossing the localizer. After accounting for the aftercast wind of about 240°T at 10 kts, this groundspeed readout suggests the airspeed of the aircraft was no more than 130 kts.

The likelihood of low airspeed is further supported by the 10.1° stabilizer trim setting at impact. The test flight determined that this setting correlates to a trimmed condition at 120 KIAS with 36° of flap.

The abrupt banking movements and turns described by the eyewitnesses are similar to those observed during the full flap stall sequences conducted on the test flight. The advice offered in the Pilot's Manual regarding a rolling tendency at stall further supports a conclusion that the observed rolling movements were the result of a stall or near stall.

The probability of a significant reduction, or total loss of thrust is supported by the post-accident condition of the engines. Their examination and analysis strongly suggests that neither was operating normally at impact.

There are indications of an internal failure in the low pressure compressor of the right engine. The cause of this could not be determined. The considerable secondary damage to the fracture faces

precluded any definitive findings with regard to possible pre-existing cracking.

The apparent flame-out of the left engine may have resulted from an interruption of fuel flow to, or a large disturbance of airflow through the engine. There is no evidence of extreme aircraft attitudes which would account for such a disturbance of airflow. Fuel flow interruption is a possible cause. An interruption as a result of fuel system malfunction or inadvertent shutdown by the flight crew are possibilities. The extreme fire damage to the fuel management system precluded evaluation of the effectiveness of the fuel management computer and the fuel control unit while the lack of flight recorder information precluded assessment of crew actions in the event the right engine failed. However, the main fuel valves to both engines were found open, indicating that the crew had not completed an emergency shutdown of either engine.

During the flight path reconstruction, it was assumed that the crew utilized configuration changes during their descent to maintain engine power sufficient to provide adequate engine ice protection. However, had sufficient power not been maintained, engine ice protection would not have been effective. If so, it is possible that ice was able to accumulate on the engine intakes, had the aircraft encountered icing conditions.

While it is possible N99S encountered a similar ice shower to that experienced eleven minutes later by the DC-9, it is unknown if a short duration shower of that nature would have resulted in engine problems.

It was suggested that the marked difference in damage to the two engines was due to the fact that they were subjected to significantly different conditions during the impact of the aircraft. It was not possible to support or refute this through analysis.

2.4

Icing

An accumulation of ice on the aircraft should not have been sufficient to cause a complete loss of control, but may have been sufficient to create some stability or control problems, particularly if the crew was attempting to control the aircraft in response to a problem, such as a power reduction or power loss in both engines.

The likelihood of a loss of control as a result of a stall would be greatly increased if ice had contaminated the wings of the aircraft. The increase in approach and touchdown speeds suggested in the aerodynamicist's analysis and stated in the flight manual, implies that stall speeds increase with any ice on the wing leading edges. If such an increase in stall speed was not anticipated by the crew it possible a stall occurred at a higher speed than they would have expected. The likelihood of such a stall occurring would increase if the crew was pre-occupied attempting to identify a problem and initiate corrective action. An unrecognized increase in stall speed would also make a series of secondary stalls during any stall recovery

attempts more likely. The stall warning system may not have provided warning of a stall if the aircraft stalled at an increased airspeed as a result of ice accumulation.

The aircraft was in potential icing conditions for about seven minutes. It is possible the aircraft encountered icing conditions similar to those experienced by the DC-9 eleven minutes after the accident. Both aircraft were vectored through the same area at about the same altitude.

If the aircraft had flown through such conditions, it is possible that it experienced a build-up of ice which degraded lift and resulted in increased stall speeds or aerodynamic instability. The amount of ice on the wing would depend upon the adequacy of protection provided during the encounter.

There would have been inadequate ice protection if the wing anti-ice system was not operating, or if power had not been maintained at a sufficiently high level. The illumination of both engine anti-ice failure lights at impact without illumination of the wing anti-ice failure-light, implies wing anti-ice was not operating.

Had the wing anti-ice system been serviceable, both systems (wing and engine) selected on, and the engine anti-ice failure lights been illuminated at impact as a result of low RPM, the wing anti-ice failure light should also have been illuminated. During test flights, the wing light illuminated prior to the engine lights when power decreased, and was extinguished after the engine lights when power was increased.

If power was high enough to ensure that the wing anti-ice failure light was extinguished, it follows that the engine anti-ice failure lights would have been extinguished as well. This indicates that either:

- both anti-ice systems were selected on, power was adequate, and engine anti-ice protection was unserviceable, or
- the wing anti-ice system was not operating, engine anti-ice was on and power insufficient for engine ice protection.

The simulator tests suggest that a duplication of the final flight path could only be accomplished by reducing engine power to near idle or less on both engines. Analysis of the engines confirms their power output at impact was minimal. This reduction of engine power should have resulted in the illumination of the wing anti-ice failure light, had the system been operating. The conclusion to be drawn is that the wing anti-ice system was not operating and wing ice protection was not available.

3.0

CONCLUSIONS

3.1

Cause-Related Findings

1. The cause or causes of this accident could not be determined.

3.2

Other Findings

1. There are indications of a pre-impact internal failure in the low pressure compressor of the right engine. The cause of this could not be determined.
2. There are indications the left engine was "flamed out" and "windmilling" at impact. The cause of this could not be determined.
3. Icing conditions were present along the flight path of N99S as it descended and approached the localizer.
4. Wing anti-ice was not operating at impact. If icing had been encountered the wings would have been contaminated by ice, which would have increased stall speeds.
5. Stall warning systems generally do not compensate for an increase in stall speeds due to wing leading edge contamination.
6. The low level movements of N99S observed by eyewitnesses are consistent with those of a Sabreliner 65 in a stalled or near-stalled condition.
7. The Sabreliner 65 Pilot's Manual advises that there is a mild rolling tendency at the stall which is maximum with full flap extended (36°). It was found that if the aircraft remains in the stalled condition, this rolling movement will intensify. Investigative flight testing showed that raising the flaps from 36° to 20° while in the stall had positive effects on the pilot's ability to control the aircraft, by reducing the severity of the rolling tendency.
8. The crew was properly certified and qualified for the flight in accordance with existing regulations.
9. The aircraft was properly certified, equipped and maintained in accordance with existing regulations and approved procedures.
10. The aircraft's weight and centre of gravity were within limits.
11. There was no evidence of a pre-impact failure of the airframe.
12. The investigation was severely hampered by the absence of a flight data recorder and cockpit voice recorder.
13. The investigation was severely hampered by the lack of recorded Air Traffic Control radar data for the final portion of the flight.

4.0

RECOMMENDATIONS

4.1

Cause-Related Recommendations

NIL

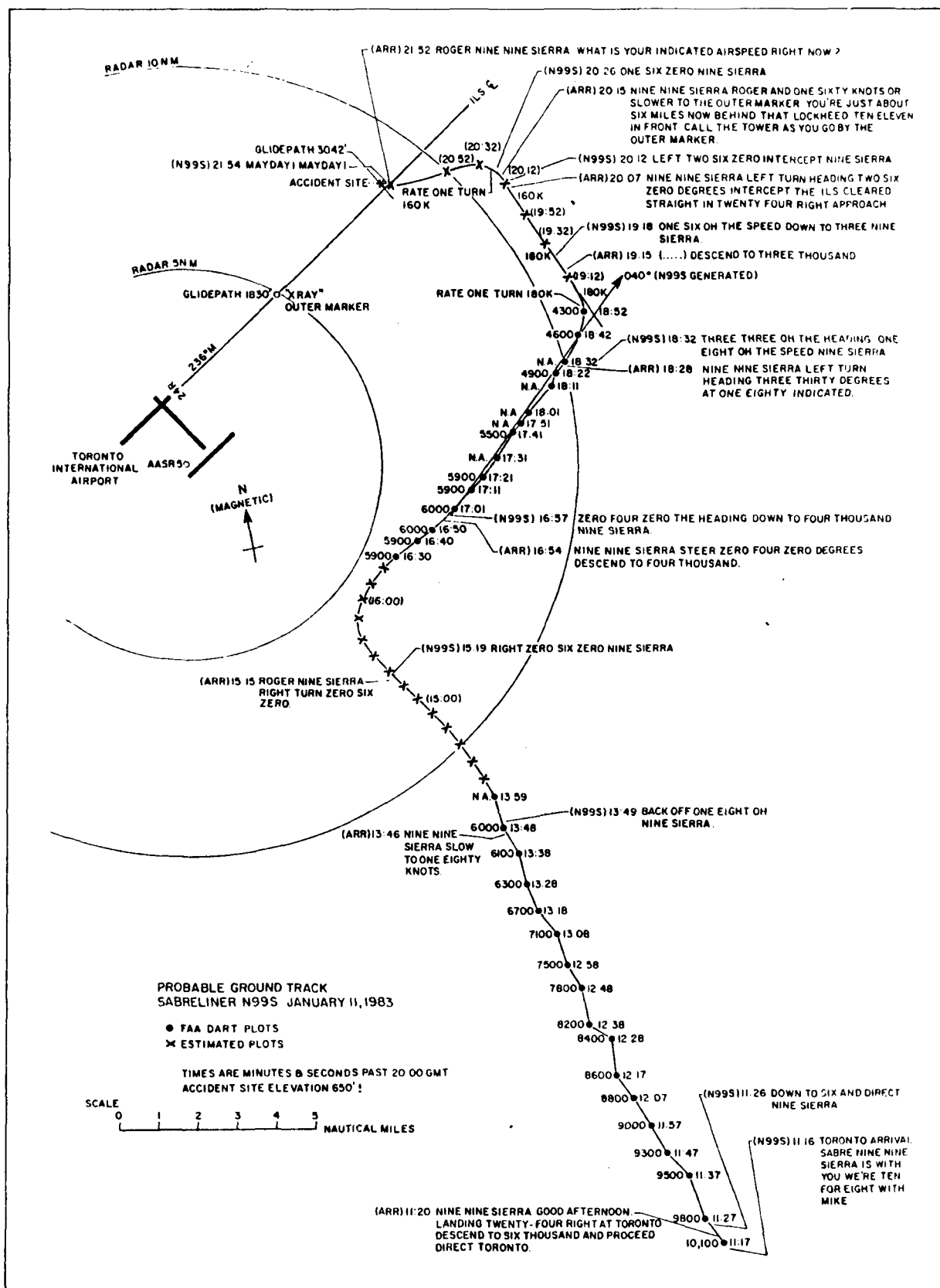
4.2

Other Recommendations

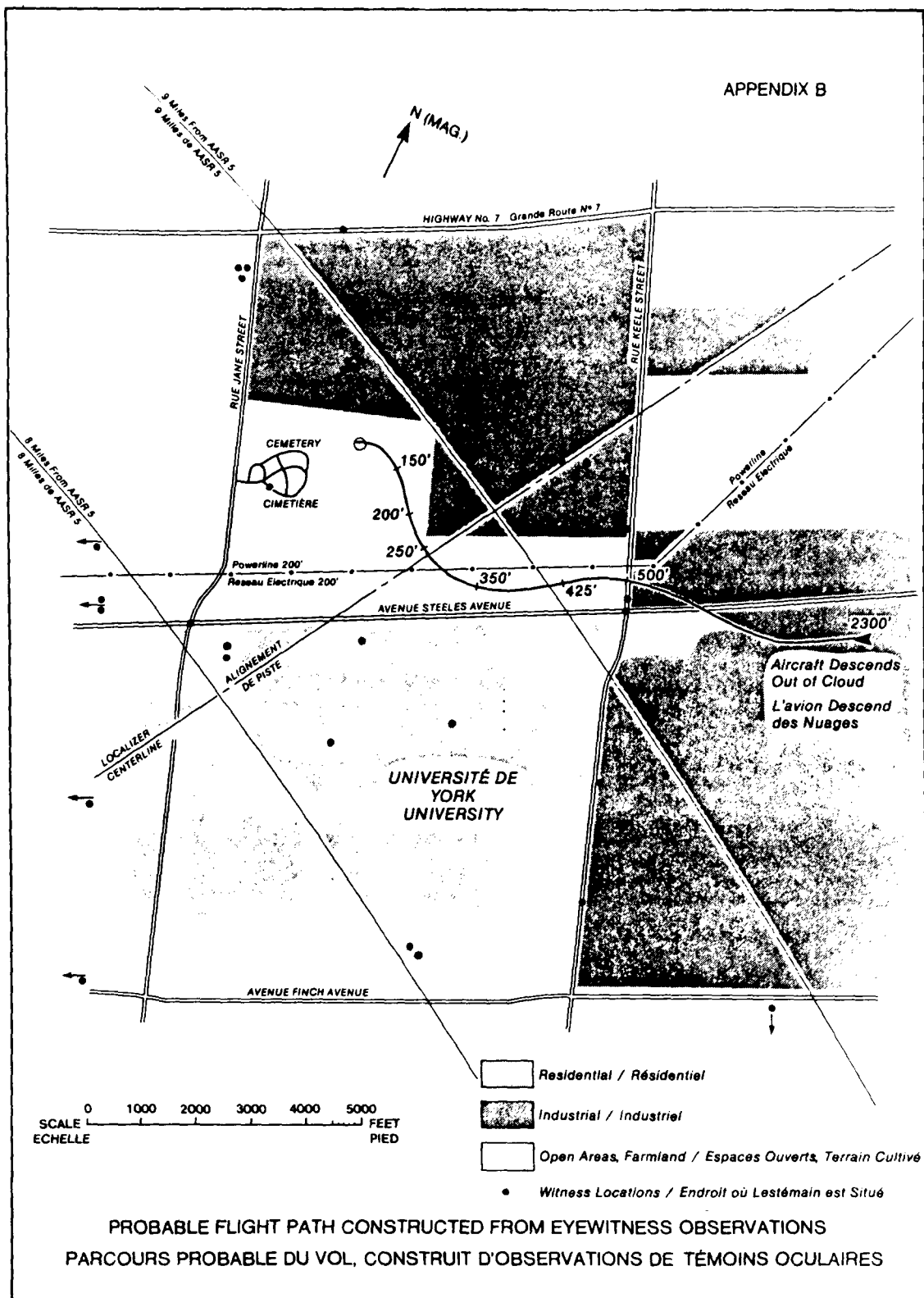
1. Manuals and crew training should stress that stall warning systems may not provide adequate warning if wings are contaminated with ice.
2. The Sabreliner 65 Pilot's Manual should reflect the aircraft's flight characteristics as outlined in 3.2.7.
3. Corporate aircraft which are used for passenger carriage should be equipped with a flight data and cockpit voice recorder.
4. Canadian Air Traffic Control facilities should be equipped to record radar data. It is realized that a new radar system which incorporates data recording is scheduled for implementation during the period 1988 to 1995. It is strongly recommended that this program be accelerated or interim measures be implemented to provide this capability.

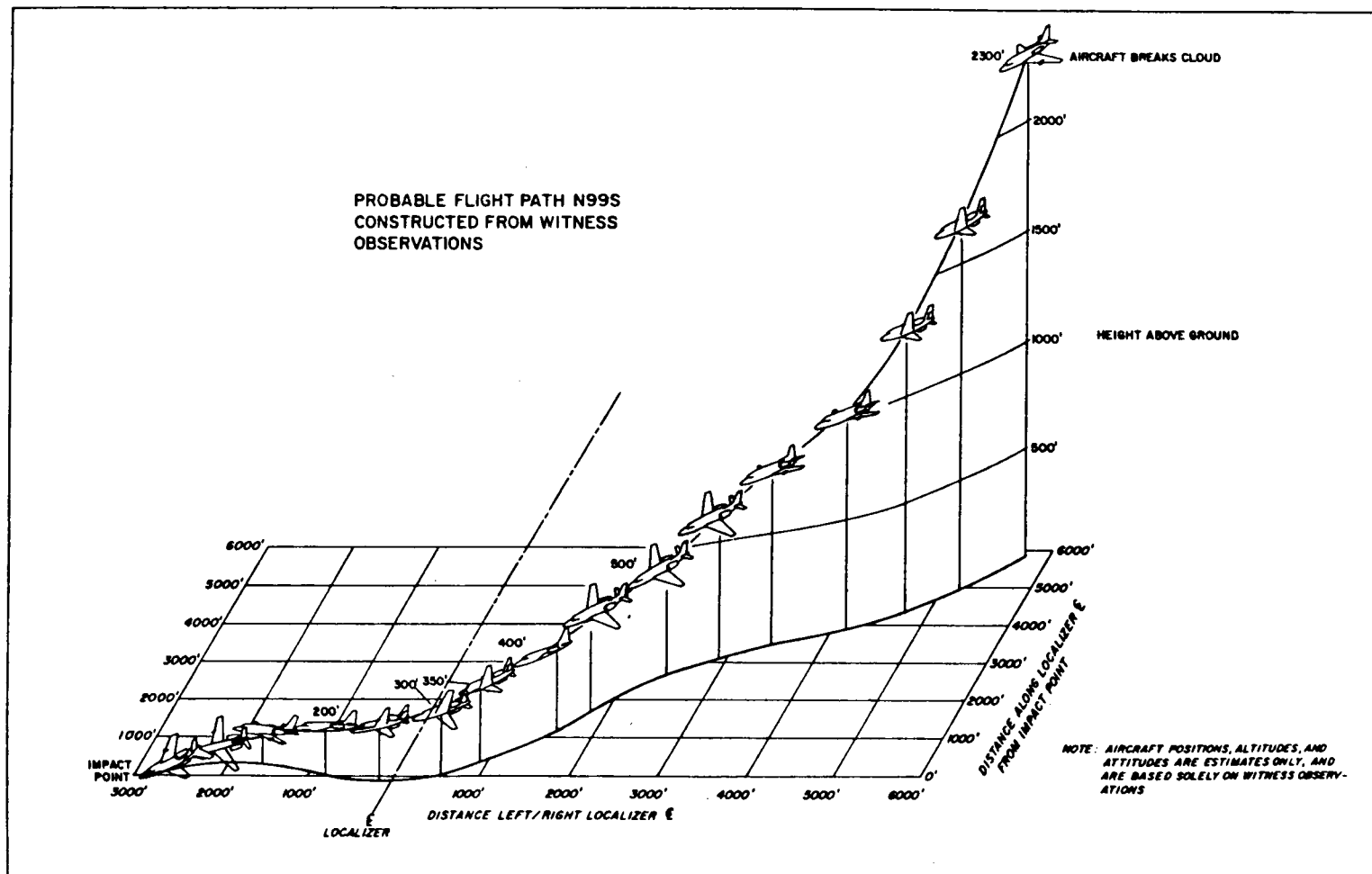
ICAO Note: Appendices D to G were not reproduced.

ICAO Ref.: 2002/83



APPENDIX A





No. 3

Cessna 310B, N6622B at Llanos del Cepo, Chile on 2 April 1983.
Report No. 07/83 released by the Accident Investigation
Department, Chile

SYNOPSIS

The pilot, flying in the capacity of a tourist from Buenos Aires, Argentine Republic, accompanied by his wife and an infant a few months of age, took off from Los Cerrillos (SCTI) in Santiago de Chile for Antofagasta airport (SCFA) also in the Republic of Chile, with a VFR flight plan and an estimated flying time of 3:40 hours.

The ultimate destination of the flight undertaken by the pilot and his wife was Los Angeles, California, USA.

Following take-off, the pilot maintained normal radio contact with air traffic control, but during the flight he failed to report his positions en route or to arrive at his destination, and as a result the Search and Rescue Service was mobilized. The aircraft was located the following day, totally destroyed and with no survivors, at an elevation of 5 300 ft in a mountain range situated 25 km north-east of the departure airport. The probable cause of the accident was identified as the operation of the flight in accordance with visual flight rules in meteorological and topographical conditions which made it advisable to operate in accordance with instrument flight rules.

1. FACTUAL INFORMATION1.1 History of the flight

On Saturday, 2 April 1983, at 1433 hours GMT (Republic of Chile time minus 4), in daylight, the twin-engined Cessna aircraft 310 B with US registration No. N6622B took off with a VFR flight plan, intended to fly at FL 45 directly from Los Cerrillos (SCTI) in Santiago de Chile to Antofagasta airport (SCFA) situated 620 NM to the north in the same country. The aircraft carried sufficient fuel for 6 hours of flying time and its occupants were the pilot, his wife and an infant child. The aircraft carried desert and jungle survival equipment.

After take-off the pilot maintained normal radio contact with ATC both in the control tower and at Santiago Control Centre. He actuated his transponder in Mode A, code 1335, and was positively identified by the control agency. The pilot reported that he was flying at FL 50 but he did not report in when leaving the control area; however, this was attributed by ATC to radio difficulties due to the many topographical obstacles present in the mountainous region within which Santiago de Chile terminal area is situated.

The prevailing meteorological conditions at the departure airport made VFR operations permissible. A pilot's meteorological report concerning that part of the route in which the aircraft commenced its flight showed that there was a cloud layer of 7 oktas cumulus with tops at 12 000 ft and base at 6 500 ft, mixed with another layer of stratocumulus having its top at 8 000 ft and base at 5 500 ft (probably lower in the mountainous area). The pilot did not report his position at any of the three stations (controlled aerodromes)

along his intended route which appeared on the flight plan, neither did he arrive at the destination airport; therefore the Search and Rescue Service was mobilized. The search was fruitless that day.

The next day, it was reported by police that an aircraft had crashed on a mountain 25 km north-east of the departure airport. The Search and Rescue Service located the remains of the Cessna 310 B, registration No. N6622B, totally destroyed and with no survivors. It had crashed at an elevation of 5 300 ft in a mountain range 6 000 - 7 000 ft in height. On the day of the accident, this mountain range was covered by cumulus-type clouds formed by orographic convection, having their base at 4 500 - 5 000 ft and their tops at 12 000 ft. Below the clouds, visibility was reduced by fog.

1.2 Injuries to persons

<u>Injuries</u>	<u>Crew</u>	<u>Passengers</u>	<u>Others</u>
Fatal	1	2	-

1.3 Damage to aircraft

The aircraft was destroyed when it collided with the mountain. There was no fire in flight or following impact.

1.4 Other damage

There was no other damage since the area was uninhabited and scarcely accessible.

1.5 Pilot information

1.5.1 American, 56 years old, holding airline transport pilot's licence No. 1369433 for single- and multi-engined landplanes, issued by the FAA on 1 February 1962.

1.5.2 Flying experience

He began his pilot training in 1947, obtaining his North American airline transport pilot's licence on the Mitchell-B25. His training was taken in the military. On 20 January 1983 he took a refresher course with an instructor. He had over 20 000 hours of flying experience on single- and multi-engined land aircraft (propeller), more than 6 000 hours of which were on instrument flights. He had flown 350 hours on the aircraft in question.

He also held an engineer/mechanic's licence (first class).

1.5.3 Medical requirement

He held a valid medical certificate first class, issued on 20 January 1983.

1.6 Aircraft information

Make: Cessna
Model: 310 B (year of manufacture 1958)
Serial No.: 35722
Registration No.: N6622B
Engines: Continental 0470M; left 52234-SM; right 52266-SM
Propellers: Unidentified
Weight and balance: Weight and balance of the aircraft had been checked on 11 December 1982, resulting in the following characteristics:

Maximum operating weight:	4 700 lbs
Weight empty:	3 188 lbs
Payload:	1 512 lbs
Centre of gravity:	34.8

It was equipped with the following avionic equipment: VHF-COM; VOR/NAV; ADF; localizer; marker beacon and automatic pilot L-2.

There is no available information to indicate that the aircraft was incorrectly loaded or exceeded the maximum take-off weight at the time of the accident.

Data obtained from the wreckage at the crash site leads to the conclusion that there were no failures prior to the accident, and that there was no outbreak of fire either before or after impact. Before take-off the aircraft's tanks had been fully loaded with 327 litres of BA 100/130, with 4 litres of oil in the right-hand engine and one litre in the left-hand engine. The pilot also purchased five litres of oil to be carried on board.

1.7 Meteorological information

The pilot filed a VFR flight plan to fly at FL 45. Prevailing meteorological conditions as regards cloud cover at the departure aerodrome, en-route, and at destination, were as follows:

1.7.1 Departure aerodrome (Los Cerrillos-SCTI) at 1300 hours GMT:

Visibility more than 10 km, 5 oktas of stratocumulus at 1 200 m, and 3 oktas of altocumulus and altostratus at 2 400 m, making VFR operations permissible.

1.7.2 En-route forecast (Serena-Santiago, first part of the flight): scattered clouds influenced by high pressure system, clear with altocumulus at 4 000 m. Winds northerly from 15 to 30 kt between 6 000 and 9 000 ft.

1.7.3 Destination aerodrome (Antofagasta-SCFA) at 1300, 1400 and 1500 hours GMT. No restrictions.

1.7.4. Pilot's report (PIREP)

A meteorological report filed by a pilot overflying the area where the crash took place, within an hour of its occurrence, indicated that the area was covered by two cloud layers, with bases at 5 000 ft and tops at 12 000 ft, and that visibility was reduced by fog.

1.8 Aids to navigation

The flight plan was for a VFR flight using the transponder in Mode A, code 1335; this was picked up by the Centre and was followed on the screen until contact was lost at a distance of 25 km from the radar station. It was believed by the controller that the signal had been lost due to topographical obstacles.

1.9 Communications

On take-off, communications functioned normally both with the control tower on the 118.5 MHz frequency, and later with Santiago Control Centre on 128.1 MHz. The pilot did not report in when leaving the control area, a fact which was also attributed by ATC to radio difficulties due to the topographical features of the terrain and the route selected by the pilot.

1.10 Aerodrome information

Not applicable, since the crash occurred 25 km north-west of the departure aerodrome.

1.11 Flight recorders

The aircraft was not equipped with flight recorders.

1.12 Wreckage and impact information

The aircraft was found totally destroyed at latitude 33° 18.5 S, longitude 70° 59W and at an elevation of 5 300 ft. The aircraft, in a general attitude of level flight, collided head-on with the east side of a mountain range 6 500 - 7 000 ft in height. Impact was sudden and occurred while at cruising speed. The left wing struck before the right wing (by a fraction of a second), and this fact, together with the configuration of the terrain at the crash site, caused the fuselage, which had been crushed and compressed by the impact, to be projected in an inverted position for a distance of 45 m. The magnetic heading of flight was 355°/005°. The left-hand engine broke away and was thrown a distance of 90 m in the direction of flight. One of the passengers was projected a distance of 80 m and the pilot was found 150 m from the collision site. All the scattered components had been thrown in the direction in which the aircraft had been flying. The location is virtually inaccessible for purposes of removing the wreckage. Appendix "A", attached, contains a sketch of the impact and wreckage. Photographs are found in Appendix "B".

1.13 Medical and pathological information

The occupants of the aircraft died from multiple skeletal and internal injuries.

1.14 Fire

There is no evidence of fire having broken out either in flight or following impact, although the aircraft's tanks were completely filled with 100/130 octane gasoline.

1.15 Survival aspects

The pilot and the two passengers died instantly as a result of the impact.

1.16 Tests and research

1.16.1 Tests

No tests were required during the flight and none could be performed at the crash site since the aircraft and all its components were totally destroyed.

1.16.2 Research

1.16.2.1 Flight planning

The pilot was 57 years old, had more than 20 000 hours of flying experience, mainly with piston-driven multi-engined landplanes. He held an airline transport pilot's licence and had over 6 000 hours of experience with VFR flight. The pilot was also qualified as engineer/mechanic.

Notwithstanding his considerable qualifications as a pilot and technician, the pilot decided to fly to the destination aerodrome at FL 45, selecting a direct route through a mountainous area where a minimum altitude of 8 500 ft was required for obstacle clearance. The pilot also decided to follow a flight plan, in accordance with visual flight rules, although the aircraft was certificated and suitably equipped to operate under instrument flight rules, and the prevailing cloud conditions as reported made the latter advisable. Furthermore, the ARO official with whom he filed his flight plan recommended that he operate in accordance with instrument flight rules, to which the pilot replied that he had flown the route more than a thousand times and that he was surprised at the altered designation of the airways in the region.

During meteorological planning, the pilot informed the forecaster that he would fly at a low level to take advantage of favourable winds.

A minute or less before the accident, the pilot reported to air traffic control that he was flying at an altitude of 5 000 ft, in spite of having specified FL 45 on his flight plan. The crash site is located at an altitude of 5 300 ft. When the accident occurred the aircraft was flying on a northerly magnetic heading, i.e. that of the direct route from Santiago to Antofagasta.

1.16.2.2 Study of IFR operations carried out by the pilot on this tourist flight.

The occasions on which the pilot flew in accordance with instrument flight rules during this tourist flight were researched as far as possible, and it was determined that over his entire route from Los Angeles, California to Buenos Aires (Argentine Republic), this was the case only in Central America from Nicaragua to Panama, and later from Lima to Tacna and Salta. He was able to fly the latter segment at FL 150 since the aircraft was equipped with a portable oxygen system.

Later on, when flying Buenos Aires - Bariloche - Puerto Montt - Santiago, he operated exclusively in accordance with visual flight rules.

1.16.2.3 Meteorological study of the crash area.

At the time of the accident, the geographical area where it occurred was covered by stratocumulus clouds, particularly in the vicinity of the Lampa hills, with cloud base at 4 500-5 000 ft. Visibility was reduced by fog.

1.17 Additional information

The pilot took off at 1432 hours GMT from runway 21 at Los Cerrillos aerodrome which has an elevation of 1 680 ft. He climbed straight ahead to an altitude of approximately 2 500-3 000 ft then made a right turn and continued climbing to 5 000 ft, at which altitude he continued on a northerly heading. At 1436 hours he established contact with Santiago Control Centre and was positively identified on secondary radar on code 1335. He maintained contact with the control unit and reported an altitude of 5 000 ft.

2. ANALYSIS

2.1 On 2 April 1983, while continuing a tourist flight originating in Los Angeles, California, USA, the pilot, who had travelled from the Argentine Republic accompanied by his wife and an infant, took off from Los Cerrillos airport in Santiago de Chile with a flight plan in accordance with visual flight rules intending to fly a distance of 620 NM to Antofagasta airport. The aeroplane, a Cessna twin-engined 310 B, registration No. N6622B, had been refuelled in preparation for 6 hours of flight. Between ten and twelve minutes after take-off, during which time normal radio contact with air traffic services had been maintained, the aircraft crashed at an elevation of 5 300 ft. The downed aircraft was not located until the second day of the search.

2.2 The pilot, an American 57 years of age, held a valid airline transport pilot's licence with instrument rating. He had over 20 000 hours of flying experience and had flown enough hours to maintain his training over the previous 30 days. He had undergone a physical and psychological examination in January 1983.

The pilot was also an engineer/mechanic.

2.3 The aircraft had a valid Certificate of Airworthiness and was suitably equipped for flying in accordance with instrument flight rules. Load and trim at the time of the accident were within normal operational limits.

2.4 The aircraft was completely destroyed and was rendered totally unserviceable as a result of the impact.

The crash site is an uninhabited spot accessible only with difficulty. The pilot and both passengers lost their lives. No injury to other persons or property damage resulted from the accident.

2.5 There was a high pressure system along the route, but the airport take-off area and the first segment of the flight (200 NM) were partially covered by stratocumulus and cumulus clouds. In this area visibility was reduced by fog.

A pilot's report indicated that at the time of the accident, the crash sector was covered by two cloud layers, particularly in the vicinity of the mountains. The cloud base was at 4 500-5 000 ft and the tops were at 8 000-12 000 ft.

2.6 The aircraft collided with the mountain virtually head-on, apparently while flying at cruising speed (150 mph), and the wreckage was scattered for a distance of 200 m in the general direction of the aircraft's magnetic heading (355°/005°).

2.7 The investigation showed that when the pilot filed his flight plan and received the meteorological data required to fly the route:

- A. He planned the flight improperly, since he intended to fly direct from Los Cerrillos to Antofagasta at FL 45 although under the prevailing circumstances FL 85 would have been the minimum safe level for such a flight.
- B. On receiving the available data for meteorological planning from the MET office, the pilot stated that "he would fly at a low level since the wind was in his favour". The cloudy conditions in the take-off area made it advisable to operate with an IFR flight plan.
- C. When the flight plan was filed, the ARO official suggested to the pilot that an IFR plan should be prepared, but the latter replied that he was thoroughly conversant with the route.

3. CONCLUSIONS

3.1 Findings

- A. The pilot held a valid pilot's licence, which included an instrument rating. His physical and psychological requirement was valid.
- B. The pilot's flying experience and training over the previous 30 days were sufficient to carry out the intended flight plan, which was in accordance with visual flight rules.
- C. The aircraft had a valid Certificate of Airworthiness and was suitably equipped for flying in accordance with instrument flight rules.
- D. The pilot and both passengers lost their lives in the crash.
- E. The geographical area where the accident occurred was covered by stratocumulus clouds with a base at 4 500-5 000 ft, and below this, visibility was reduced on account of fog.
- F. While flying at cruising speed, the aircraft struck the hillside head-on at an elevation of 5 300 ft. It was completely destroyed and crushed on impact and the wreckage was scattered for a distance of 200 m in a northerly magnetic direction. There was no fire on impact.
- G. The pilot planned the flight improperly since he intended to fly by visual flight rules at FL 45, although under the circumstances FL 85 was the minimum safe level.
- H. The weather information with which the pilot was provided during meteorological planning was such that he should have taken precautionary measures in the light of his experience, particularly since the flight took place in a mountainous area.

3.2 Probable cause

The probable cause of this accident is the fact that the pilot continued to perform the flight in accordance with visual flight rules under the circumstances which made it advisable to operate in accordance with instrument flight rules due to prevailing reported weather conditions. The problem was compounded by improper planning of the flight, which took place in an area with significant topographical obstacles.

4. RECOMMENDATIONS

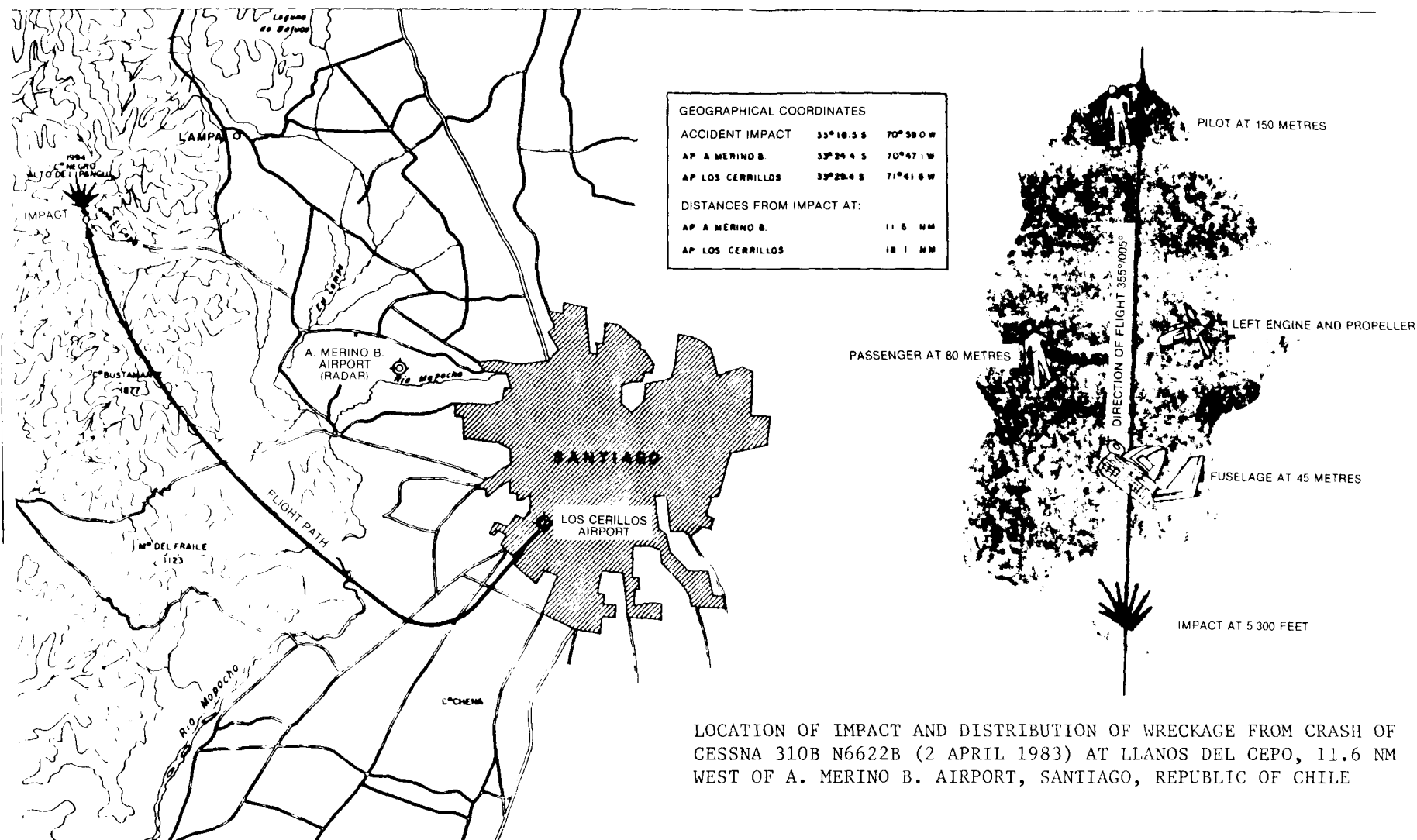
4.1 To issue a Safety Bulletin describing the circumstances under which this accident occurred, and stressing the safety advantages of IFR operations.

4.2 To insert in AIP-Chile a recommendation that foreign pilots should operate in accordance with instrument flight rules provided they hold the required rating and their aircraft is suitably equipped.

ICAO Note: Names of personnel were deleted. Appendix B was not reproduced.

ICAO Ref.: 123/83

APPENDIX A



No. 4

Sikorsky S-61N, G-BEON, near Isles of Scilly, United Kingdom,
on 16 July 1983. Report No. 8/84 released by the Accidents
Investigation Branch, United Kingdom

Synopsis

The accident was reported to the Accidents Investigation Branch (AIB) by the British Airways Air Safety Branch at 1245 hrs on 16 July 1983, and the investigation commenced the same day.

G-BEON was on a scheduled service from Penzance to the Isles of Scilly, and was being operated in accordance with the Visual Flight Rules (VFR). Whilst it was on the approach to St Mary's aerodrome the helicopter gradually descended from its intended height of 250 feet without either pilot being aware of this, and flew into the water.

Nineteen of the 23 passengers, and 1 of the 3 crew members lost their lives. St Mary's lifeboat attended the scene and picked up the 6 survivors.

The report concludes that the accident was caused by the commander not observing and correcting an unintentional descent before the helicopter collided with the surface, whilst he was attempting to fly at 250 feet by external visual reference only in conditions of poor and deceptive visibility over a calm sea. Contributory factors were: inadequate flight instrument monitoring; a combination of VFR weather minima which were unsuited to visual flight and insufficiently detailed company operating procedures; and the lack of an audio height warning equipment.

Eight safety recommendations are made.

1. Factual Information

1.1 History of the flight

G-BEON (ON) was operating a scheduled passenger flight from Penzance Heliport to St Mary's aerodrome, Isles of Scilly, when the accident occurred (see map at appendix 1). ON had been scheduled to depart at 0815 hrs, and the crew of two pilots and a cabin attendant reported for briefing at about 0730 hrs. Both pilots were qualified S-61 captains, and one of them was nominated as the commander and handling pilot. Two aircraft had been due to fly to the Isles of Scilly on the morning of 16 July – ON and another S-61, G-BDDA (DA), which had been originally scheduled to take-off at 0750 hrs.

Poor visibility prevented either aircraft from departing until DA took off at 1046 hrs on a VFR flight to St Mary's; it landed without incident at 1106 hrs. Since there was a possibility of the weather deteriorating, the commander of ON decided that he would conduct the flight either wholly VFR or not at all. He therefore awaited confirmation that DA had landed at St Mary's. By then the weather being reported by St Mary's was 1,200 metres visibility and a cloud cover of 3/8 at 500 feet. This was better than the laid down minima for day VFR operations, which were 900 metres and 200 feet cloud ceiling. ON took off at approximately 1110 hrs, carrying 23 passengers and sufficient fuel to allow a diversion to Royal Air Force St Mawgan should a deterioration of the weather make that necessary.

Following the normal procedure, ON climbed en-route to an altitude of 2,000 feet on the Scillies regional pressure setting (regional QNH) of 1014, and cruised at an indicated airspeed (IAS) of 110 kt along a prescribed track which was marked on the Decca flight log. In the vicinity of the Longships lighthouse visibility was assessed as well in excess of half to three quarters of a mile in haze, and the crew saw DA passing below at 1,500 feet on its way back to Penzance. The crew stated that around this time DA passed them a report of the weather conditions at St Mary's as half to three quarters of a mile visibility at 300 feet. However, the crew of DA do not recall speaking to ON at any time, and the source of this message remains unidentified. The commander believed that the term "300 feet" referred to the cloud base but did not discuss the report with the co-pilot, who understood that it referred to the height at which the visibility had been observed. With a 300 foot cloud base over St Mary's aerodrome in mind, the commander decided to descend to 500 feet so as to be better able to assess the prospects of making a satisfactory approach and landing.

At 1126:30 hrs ON reported being at 18 miles range from St Mary's, and that a descent to 500 feet was being carried out. During the descent the crew carried out successively the descent checks, the initial approach checks, and the landing checks – except that the radar was left on to provide mapping information, and the cabin attendant had yet to make his report. The landing gear was down (resulting in the 'gear up below 250 feet' warning horn circuit being disarmed). Both pressure altimeters were set to the St Mary's aerodrome surface pressure (QFE) of 1010, thus displaying the height above the aerodrome.

ON levelled off at a height of 500 feet on the radio altimeter (radio height) on a track of 259°M, which was maintained for the rest of the flight. The co-pilot then cross-checked the barometric and radio altimeters and, at 1130 hrs, reported to St Mary's that ON had passed the mid-point and was level at 500 feet. The crew stated that they

continued to have visual contact with the surface, that they saw no cloud or fog (at or below their level), but that thick haze resulted in restricted forward visibility with no discernable horizon, and that there was a flat calm sea. Relying on their experience, the weather forecast, and the report by DA, they were confident that the forward visibility was in excess of the company's prescribed minimum of 900 metres.

Approximately 6nm from the coast the commander commenced a descent to 250 feet radio height in anticipation of low cloud at St Mary's, and to provide himself with a better sight of the texture of the sea surface. 250 feet was the minimum en-route height permitted by the BAH Operations Manual for flight over the sea in daylight 'contact' conditions, provided that the forward visibility was no less than 900 metres.

During the descent the commander continued to fly primarily by external visual reference, but also monitoring the flight instruments. The co-pilot, who was monitoring his own flight instruments, had set the altitude warning bug on his radio altimeter at 300 feet and at that height he warned the commander that the aircraft was nearing the desired 250 feet. Both pilots stated that having levelled at that height they cross-checked that both radio altimeter indicators showed a height of 250 feet, that the two pressure altimeters showed about 134 feet, and that the helicopter was stabilised in level flight at about 110 knots. The commander stated that his radio altimeter bug was set at 200 feet, but the co-pilot was unsure of the height at which his bug was then positioned.

The commander stated that whilst at 250 feet he was "principally looking outside" the helicopter but was at the same time monitoring his flight instruments, concentrating on the attitude indicator, the radio altimeter and the airspeed indicator.

The co-pilot, being satisfied that there was adequate visual reference and having assured himself that the commander was flying visually, concentrated his attention on the radar and the Decca to ensure accurate navigation. From the moment when ON was 3 to 3½ nm from the land ahead (54 to 72 seconds before impact at an average ground speed of 100 kt) the co-pilot was entirely engaged in operating the radar set so that he could call out ranges to the commander every half mile, and so he was no longer monitoring the flight instruments. The co-pilot stated that because of the position of the radar display he had to bend to his right, put his face within one foot of it, and shield the tube with one hand from sunlight, in order to see the picture satisfactorily. He added that the set when selected to the 5 mile range setting, as was the case, provided no range markers to assist judgement of distance and needed constant adjustment. Apart from measuring distance ahead he also had to keep a watch for ships, as these had to be avoided by at least 500 feet.

At 1132:00 hrs ON reported "ABOUT SIX MILES TO RUN TO ST MARY'S"; and at 1133:15 hrs "JUST UNDER FIVE MILES", and was told by St Mary's to report approaching 2 miles. At 1134:45 hrs ON reported, "COMING DOWN TO 2 MILES" and was told by St Mary's "CONTINUE THE APPROACH RUNWAY 28, SURFACE WINDS 300 DEGREES AT 5 KNOTS QFE 1010". At 1135:00 hrs St Mary's transmitted "OSCAR NOVEMBER IS CLEAR TO LAND 300 DEGREES AT 5 KNOTS". This message was not acknowledged by ON, and no further transmission was received from the helicopter.

At some undetermined point in this sequence of events the commander told the co-pilot that he was going to reduce speed to about 90 knots. The commander stated that he then lowered the collective pitch lever and used the beeper trim to trim nose-up to reduce speed at constant height. He did not refer to the torque meter, but

from experience judged that torque was reduced from the cruise setting of about 60% to about 48%. The commander stated that while he was checking the radio altimeter, which was reading about 250 feet with no warning light evident, his attention was drawn to the vertical gyro indicator (VGI) by the momentary appearance of its attitude failure (ATT) orange coloured flag. The indications appeared normal and the commander, believing that the weather would be much better from this point onwards, reverted to external visual reference in an attempt to establish a horizon and to sight the islands ahead. However, he was unable to discern either a horizon or a landfall. He has stated that if he had not seen the land by the time the helicopter was 1 nm from the coast he would have prepared to overshoot.

The commander also stated that during the period he was looking outside he was still slowing the helicopter down by further lowering the collective pitch lever and trimming nose-up. The helicopter then unexpectedly struck the water in a straight and level attitude. The commander could not recall the airspeed at impact but considered that it might have been below 90 kt. The co-pilot stated that when ON was 1½ nm from the coast he told the commander (who also recalled this). He then decided to look up, expecting to see the coastline and with a view to cross checking with the Decca flight log. As he moved his head to do so the helicopter struck the sea.

The co-pilot stated that the impact position was on the Decca track of 259° M to St Mary's airfield and approximately on Decca lane Green 38, ie about 2 nm from the airfield and 1½ nm from the coast (see appendix 2). It is estimated that the accident occurred at about 1135 hrs. Neither the commander nor the co-pilot had been aware of any descent below 250 feet.

The crew reported that, apart from the momentary appearance of the VGI 'ATT' flag noticed only by the commander, the aircraft had appeared to be completely serviceable throughout the flight.

A passenger stated that towards the end of the flight the cabin attendant had walked forward to the flight deck and then returned to a position near the airstair door where his folding seat was positioned, but might not have had time to sit down and fasten his seat belt before the impact occurred. This passenger, and another, reported that the cabin attendant told them separately that the helicopter was flying at 100 feet as he passed them. Neither the commander nor the co-pilot could recall the cabin attendant approaching the flight deck at this stage of the flight.

During the impact both sponsons broke off together with the inflatable flotation gear, water entered the cockpit forcibly, and the aircraft's hull was disrupted in such a way as to cause water to burst open the two freight-bay hatches in the floor. The fuselage rolled over, filled with water, and quickly sank. Only four of the passengers and the two pilots survived. Nineteen passengers and the cabin attendant lost their lives. The six survivors were picked up by the St Mary's lifeboat at approximately 1225 hrs.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	19	—
Serious	1	1	—
Minor/none	1	3	

1.3 Damage to aircraft

The helicopter was destroyed as a result of the impact.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 *Commander:* Male, aged 37 years

Operational experience:

In 1975-6, whilst in the United States, the commander gained FAA commercial licences for both rotary and fixed wing aircraft. In May 1977 he was granted a Commercial Pilot's Licence (Helicopters), and in August joined British Airways Helicopters (BAH) as a co-pilot on S-61N helicopters at Sumburgh in the Shetland Islands. In November 1979 he was promoted to Captain and remained at Sumburgh until November 1982 when he was posted to Aberdeen. He was based at Aberdeen at the time of the accident, although he had been detached at various times to Bergen, Beccles and Penzance. His experience of the Penzance-Isles of Scilly schedule was 2 detachments and on the second, which began on 9 July 1983, he had flown 28 sectors prior to the accident, having flown approximately 35 sectors on the first.

Licence:	Airline Transport Pilot's Licence (Helicopters). Valid until 22 May 1988 and endorsed for Bell 206 and Sikorsky S-61N as pilot in command. Private Pilot's Licence for Group A Land Planes and Self Launching Motor Gliders; permanent validity.
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Instrument Rating:	Renewed 30 November 1982
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Competency checks:	Last base check: 5 May 1983
	Last line check: 8 February 1983
	Last survival check: 8 February 1983
	Last dinghy drill: 23 October 1981

Medical certificate:	Last medical: 14 February 1983, Class I, no limitations
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Total pilot hours:	3,970
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Total helicopter hours:	3,506
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Total S-61N hours:	2,820
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Total in last 28 days:	69 hours 25 minutes
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Total in last 7 days: 15 hours 05 minutes

Rest period prior to reporting for duty: 14 hours 30 minutes

1.5.2 *Co-Pilot:* Male, aged 30 years

Operational experience:

In 1974 the co-pilot graduated from the College of Air Training, Hamble, with a Commercial Pilot's Licence (Aeroplanes) and, in the absence of pilot vacancies, was seconded to temporary ground duties with British Airways. In 1976 he attended the Oxford Air Training School on a helicopter course, and gained a CPL (Helicopters) in August 1976. In September 1976 he was posted to Sumburgh, Shetland Islands, as a co-pilot on S-61N helicopters. In October 1977 he was posted to Beccles, Suffolk, as an aircraft commander on the Sikorsky S-58T. In January 1979 he returned to Sumburgh as a co-pilot on the S-61N. In July 1979 he was promoted to Captain and remained at Sumburgh as an aircraft commander until January 1982. He then returned to Beccles, initially on Sikorsky S-76 helicopters and then, from June 1983 until the time of the accident, on the S-61N. During these postings he had been detached on duty to Teesside, Aberdeen, Gatwick and Penzance. His experience of the Penzance-Isles of Scilly schedule was 2 detachments; on the first he flew 42 sectors and on the second, which began on 5 July 1983, he had flown 68 sectors prior to the accident.

Licence: Airline Transport Pilot's Licence (Helicopters). Valid until 13 December 1988 and endorsed for Eastrom F28A, Sikorsky S-61N, S-58T, and S-76A, as pilot in command.

Commercial Pilot's Licence (Aeroplanes) Groups A and B.

Instrument rating: Renewed 24 June 1983

Competency checks: Last base check: 24 June 1983

Last line check: 24 June 1983

Last survival check: 24 June 1983

Last dinghy drill: 27 November 1981

Medical certificate: Last medical: 2 March 1983, Class 1, no limitations.

Total pilot hours: 3,737

Total helicopter hours: 3,350

Hours on S-61N: 2,280

Total in last 28 days: 31 hours

Total in last 7 days: 18 hours 25 minutes

Rest period prior to reporting for duty: 14 hours

1.5.3 Of the 63 Penzance–Scilly sectors flown by the commander and the 110 by the co-pilot, they had flown 10 together as a crew. They had also flown as a crew on 6 other occasions.

1.5.4 Cabin attendant: Male, aged 22 years

Competency checks: Last training: 28 March 1983

Last survival check: 28 March 1983

Last dinghy drill: 15 March 1983

Rest period prior to reporting for duty: 14 hours 15 minutes

1.6 Aircraft information

1.6.1 Sikorsky S–61N G–BEON had been in service with British Airways Helicopters since 1977. It was normally based at Aberdeen and was configured for offshore oil support operations, fitted with 24 passenger seats. ON had been positioned at Penzance since 24 June 1983 and at the time of the accident was being employed to back-up the 32 seat Sikorsky S–61NM dedicated to the Penzance–Isles of Scilly service.

1.6.2 Main particulars

Manufacturer: The Sikorsky Division of United Technologies, USA

Aircraft type: S–61N

Date of manufacture: 1977

Manufacturer's Serial No: 61770

Registered Owner: British Airways Board

Certificate of Airworthiness: UK Transport Category (Passenger) renewed by the Civil Aviation Authority (CAA) on 3 July 1983 and valid until 2 July 1984

Total airframe hours: 7,904 hours, of which 49 had been flown since the issue of the last C of A

Engines: Two General Electric CT58-140-1

Total engine hours since overhaul: No 1 engine 896 hours, No 2 engine 1,647 hours

1.6.3 *Weight and balance data*

Maximum permitted take-off weight:	19,650 lb
Actual take-off weight:	19,627 lb
Estimated weight at accident:	19,177 lb
Permitted centre of gravity range:	258 inches to 276 inches aft of datum
Estimated C of G at accident:	265 inches aft of datum
Type of fuel:	Jet A-1 (Avtur)
Total fuel at take-off:	2,000 lb
Fuel at impact (estimated)	1,550 lb

1.6.4 *Flying controls*

The S-61N has conventional dual flying controls incorporating two hydraulic systems. The aircraft was equipped with a three axis automatic flight control system (AFCS) able to maintain a selected attitude and heading, but not a height or an airspeed. In this system the No 1 (co-pilot's) vertical gyro is the attitude sensor for the pitch and roll channels, and the compass system for the yaw channel. A four-way switch on each cyclic stick permits trimming at a controlled rate in both pitch and roll (beeper 'trim'), and a trim release switch on each cyclic stick allows rapid manual re-positioning of the stick. The authority of the AFCS system is 10% in roll, 7½% in pitch, and 5% in yaw. The system can be over-ridden by normal forces applied to the controls by the pilot, and it can be switched off by operating a switch on either cyclic stick.

1.6.5 *Vertical Gyro Indicators and Standby Horizon Indicator (see appendix 3)*

G-BEON was equipped with two Sperry HZ444 Flight Director Indicators, in this installation referred to as Vertical Gyro Indicators (VGI). One of these instruments was mounted centrally in each pilot's instrument panel. Each instrument was supplied with pitch and roll signals from the vertical gyro on the corresponding side of the aircraft, the indicator in the No 1 (co-pilot's) position using the same gyro as supplied the signals to the AFCS system. No flight director signals are available in the BAH S-61 installation, so the instruments simply supply pitch and roll attitude information to the crew. During normal operation the flight director command bars, and the failure flag (marked FD), disappear from the faces of the instruments and only reappear when power supplies are interrupted.

Each VGI also has an orange coloured attitude (marked ATT) mode failure warning flag which, when pertinent, appears on the periphery of the instrument face. Failure of the attitude mode in either indicator will produce an 'ATT' flag, which is discrete to the instrument displaying it and indicates one of the following:

- (a) Power failure to its vertical gyro
- (b) Power failure or lack of attitude information to the instrument
- (c) Lack of co-ordination between the signal from the vertical gyro and the visual horizon information being displayed on the instrument.

It has, however, been observed by S-61 pilots that the 'ATT' flag can also momentarily appear during flight.

An R C Allen Standby Horizon Indicator was fitted on the centre instrument panel between the two pilots. This instrument works independently of either of the VGIs or vertical gyros, and therefore can provide attitude reference in the event of failure of either or both of those instrument systems.

1.6.6 *The radio altimeter*

G-BEON was equipped with a Sperry AA-200 series Radio Altimeter System. This comprised one RT-220 transmit/receive unit of the short pulse modulation type working on a nominal frequency of 4300 MHz, and two RA-215 indicator instruments. The transmitter/receiver was mounted in the electronics compartment under the cockpit floor and one instrument was on each pilot's instrument panel. The RA-215 instrument has a circular scale from 0 to 2,500 feet which is expanded below 500 feet. A pointer indicates absolute height within this range to a stated displayed accuracy of ± 5 feet between 0 and 100 feet, ± 3 per cent between 100 and 500 feet, and ± 7 per cent between 500 and 2,500 feet. Altitude trip points are provided at 50, 250, 400 and 1,200 feet; only the 250 feet point was employed in the BAH fleet – to supply the undercarriage audio warning system.

Each RA-215 indicator has its own moveable decision height bug. Whenever the actual height is at or below the height set a small amber light on the top right of the instrument is illuminated. There is no associated audio warning. By setting the decision height bug below zero height the pilot can prevent nuisance lighting of the warning lamp. A warning flag appears if a system failure is detected. Pressing a test button on the instrument causes the pointer to show 100 feet, illuminates the decision height light and brings the warning flag into view. The BAH Operations Manual contained no instructions on the use of the decision height warning system and there was no standard practice in use by pilots.

The possibility was considered of the effects of a failure occurring in the radio altimeter system such that during a descent the instrument needle is caused to remain stationary while simultaneously the decision height warning light is prevented from operating as decision height is passed. Error in the pointer indication due to simple mechanical sticking within either instrument will not prevent the operation of the corresponding warning light during descent when the aircraft passes the decision height selected on the individual instrument. This feature results from the use of circuitry within each instrument to drive the pointer which is independent of the circuitry which triggers the warning light.

The single transmit/receive unit supplies signals to both instrument pointers and both warning light circuits. An erroneous signal output from the unit could therefore produce inaccurate operation of both pointers and both decision height warning lights. Such inaccuracy would not be detectable by cross-referencing between the warning light and the corresponding pointer, or indeed by cross-referencing between No 1 and No 2 radio altimeter instruments. However, a failure which causes the output signal to remain at a fixed figure comparable with that occurring shortly before the failure is very rare. Such a failure would be necessary to produce the effect of a sticking pointer combined with a failure of the warning light to function. Failures within the transmit-receive unit or in the antennae connections almost invariably cause a sudden and considerable change in output signal and hence in pointer indication.

ON's commander gave evidence that in his selected seat position the radio altimeter indicator was partially obscured by the top of the cyclic stick. This caused him to move his head each time he wanted to see the right hand side of the indicator, which included the height scale below 500 feet and the decision height warning light. Tests were carried out, and it was established that the seats have sufficient range of adjustment to enable a pilot to ensure a clear view of the instrument. However, it was evident that some pilots selected a different seat position because of other factors.

1.6.7 Warning light system

The S-61N has three warning light panels, positioned on the console between the pilots. Each panel contains warning captions which separately illuminate to warn of a failure, unsafe condition, or operating state of its associated component or system. A master caution light, located on the glare shield above the instrument panel, lights up concurrently with the captions. The crew did not observe any warning caption illuminate during the flight.

1.6.8 Undercarriage audio warning system

ON was equipped with an undercarriage audio warning system which uses the radio altimeter as a sensor, taking a feed from the 250 feet trip point. It sounds a pulsating note if the aircraft descends below 250 feet with the wheels up with the system operative. A Test/On/Off switch allows the system to be tested on the ground and to be switched off for low level flight. The switch is normally kept on throughout the flight.

1.6.9 Underwater acoustic beacon

ON was equipped with a Dukane model B15F 210 B underwater acoustic beacon, with an operating frequency of 37.5 KHz and a pulse rate of 1 per second. It was mounted on the main gearbox support frame on the starboard side of the helicopter.

1.6.10 Maintenance information

1.6.10.1 Recent maintenance history

Separate Certificates of Maintenance (C of M) were issued for different maintenance procedures. A C of M for Electrics, Instruments and AFCS was issued on 6 July 1983; a C of M for Airframe and Engines was issued following completion of a check 1 on 8 July 1983; a Radio C of M was issued on 26 May 1983; and a Compass C of M was issued on 6 July 1983. All were valid at the time of the accident.

1.6.10.2 Technical Log

No carried forward defects were recorded in the Technical Log. The only significant entries were as follows:

- (1) On 12 May 1983 at 7,898:05 hours: "Rad altimeter suddenly went to zero and undercarriage warning sounded whilst aircraft was still at 1,200 feet AGL. Switching it on/off put it right." and "Rad alt incorrect self-test operation". These were followed by: "Rad alt T/R changed and test satisfactory".

A check was carried out to establish the status of the transmit/receive unit removed on that date. It has been confirmed by the overhaul agents that the unit was found to be defective and was repaired. There are no further technical log entries relating to radio altimeter problems on the aircraft between then and the time of the accident.

- (2) On 21 June 1983 at 7,867:35 hours: "AFCS occasionally drops out (X3 today) however it will engage again," and "Co-pilot's vertical gyro replaced P/No 121672-01-17 S/No off 287 S/No 0000627 HEL 02202S".

The vertical gyro replaced in this position was undamaged by the accident and was found to perform within specification when tested.

- (3) On 8 June 1983 at 7,819:00 hours: "Pilot's and co-pilot's ASI's replaced, found time expired".

1.7 Meteorological information

- 1.7.1 A verbal forecast was passed over the telephone to the operations centre at Penzance by the Plymouth Meteorological Office. This was then written out in longhand and photo-copied for the crew. It was as follows:

"Valid 0700 – 1230 hrs:

Moist slack air mass becoming more unstable

Wind: Surface – 5,000 ft. Variable 10 Knots

Cloud: 8/8 Stratus, surface to 200 feet

Visibility: 1-4 Km. Below 500 metres in fog and less than 100 metres locally. Fogbanks dense at times with outbreaks of thundery rain.

Fog warning: Valid 0700-1700 hrs: Sea fog is expected in our area today and tonight, reducing visibility to less than 200 metres at times".

- 1.7.2 Actual meteorological conditions recorded at St Mary's aerodrome and passed to Penzance were:

Time (hrs)	Wind	Visibility	Cloud Cover	QNH
0930	300°/2 kt	1,200 metres, mist	3/8 at 500 ft, 7/8 at 1,200 ft	1014
1030	300°/2 kt	1,200 metres, mist	3/8 at 500 ft, 7/8 at 1,200 ft	1014
1130	300°/5 kt	2,200 metres, mist	3/8 at 500 ft, 7/8 at 1,200 ft	1014
1230	310°/5 kt	2,200 metres, mist	3/8 at 500 ft, 7/8 at 1,200 ft	1014

1.7.3 *Conditions observed by DA*

- 11.04 hrs: At 400 feet on the approach to St Mary's DA was in visual contact with the sea surface and sighted the coast at $\frac{1}{2}$ to $\frac{3}{4}$ miles range. The weather was basically as had been reported by St Mary's, but patches of sea fog were sighted approximately $\frac{1}{2}$ mile south of the aerodrome.
- 11.16 hrs: Whilst climbing out of St Mary's on the return flight, DA entered cloud between 400 and 500 feet before passing over the coastline.
- 11.55 hrs: Returning to St Mary's on its second flight at a range of 3 miles from St Mary's and at 400 feet. DA found the weather to be: no cloud, hazy, estimated visibility 1 mile above extensive sea fog. The aerodrome was sighted over the top of the fog which ended at the coastline but seemed to surround the island.
- 12.06 hrs: During a low level radar search for ON, DA established the height of fog as 150 to 200 feet. There was then extensive fog to the east, north-east and south of the islands.

At 1107 hrs, when DA was on the ground at St Mary's, an inbound Twin Otter requested the weather encountered by DA during its approach and this was given as "300 feet and $\frac{1}{2}$ mile". This conversation was recorded on the St Mary's ATC tape. The commander of DA does not recall having later passed this information to ON when they passed at the Longships (or at any other time), nor do the recordings of the St Mary's ATC tape show it. However, the crew of ON clearly remember receiving this meteorological report although the source remains unidentified. It is possible that this information was passed on the (unrecorded) Penzance frequency of 118.1 MHz either by DA to Penzance or by Penzance and received by ON, but the discrepancy in this evidence could not be resolved.

1.7.4 The sun's position at St Mary's at 1135 hrs was: elevation 59.6°, azimuth 155.0°.

The sea temperature was 18°C.

1.8 Aids to navigation

The route Penzance to St Mary's was served by two independent radio aids. These were a Decca chain, and the Land's End co-located VHF omni-directional radio range (VOR) and distance measuring equipment (DME). These were all operating and serviceable throughout the flight.

The aircraft was equipped with a Decca Mk 19 navigator, providing a flight display head situated at the top of the centre instrument panel. A VOR indicator was positioned on each pilot's instrument panel, and an automatic direction finding system (ADF) and DME were also fitted.

The Decca equipment may be used in one of two ways on the route between Penzance and St Mary's. Firstly, it may be used as a general navigational aid without having been precisely checked by flying over a fixed datum. Secondly, it may be used to carry out a Decca approach cloud break procedure, but only if it has been checked while flying directly overhead the fixed datum of the Land's End

VOR (LND). The Decca flight log chart had three procedural tracks marked for the route. The northernmost of the three tracks passed directly over LND, and only if this track was selected could the Decca equipment be used for the approach cloud break procedure. G-BEON's flight was a VFR one along the middle of the three tracks marked on the Decca flight log chart, and so the Decca equipment could only be used as a navigational aid.

The BAH Operations Manual contained details of the Decca approach cloud break procedure for St Mary's aerodrome. The procedure commenced at 2,000 feet on the regional QNH overhead LND. The procedural track of 249°M was marked on the Decca flight log chart, and in the vicinity of the accident was nearly co-incident with the marked Decca track of 259° flown by ON. The procedure called for a descent to be commenced 20 nm from LND to an obstacle clearance limit (OCL) of 200 feet on the Scilly QFE (316 feet above mean sea level) at a range of 25 nm from LND (3.6 nm from St Mary's aerodrome). The associated minimum visibility was 900 metres, reducing to 600 metres if the mapping radar was serviceable. While this procedure was not relevant to ON's flight, the minimum visibility permitted is the subject of comment in para 2.7.2.

The aircraft was also equipped with an Ekco E290M weather/mapping radar, the display and the control unit being positioned on the centre console.

1.9 Communications

The Penzance Heliport frequency 118.1 MHz was not recorded. It was used by ON from departure until 1114 hrs when contact was made with St Mary's aerodrome Air Traffic Control (ATC) on the tower frequency of 123.15 MHz, which is used along the route between the Longships lighthouse and St Mary's. This frequency was recorded and a transcript is at appendix 4. G-BEON's co-pilot carried out the air-ground communications throughout the flight. The air traffic control officer (ATCO) on duty at St Mary's at the time of the accident stated that the time injection unit is accurate to ± 1 minute only.

1.10 Aerodrome information

St Mary's aerodrome, Isles of Scilly, is situated on the south east coast of the island at latitude 49° 54.8' North and longitude 006° 17.5' West, and is 116 ft above sea level. There are three available runways, 10/28, 15/33 and 18/36. Runway 28 was in use at the time of the accident. There were no radio beacons or radar at St Mary's aerodrome.

1.11 Flight recorders

G-BEON was not equipped with either a flight data recorder or a cockpit voice recorder, nor were these required to be fitted.

1.12 Wreckage and impact information

1.12.1 Wreckage recovery

The MV Seaforth Clansman sailed from Falmouth for the crash area at 1704 hrs on 16 July 1983. She was fully manned with a Royal Navy saturation diving team and her lifting capacity was more than adequate for the task. She arrived on station at 2210 hrs and began searching the location in which the survivors had been rescued and which had been marked by two 'dan-buoys'.

AIB Inspectors joined the ship at sea by helicopter as soon as the fog cleared on the morning of 17 July, taking Dukane acoustic detectors with them. The ship was at that time searching the area using sonar and underwater television. By 1000 hrs a search was started using the acoustic detector. Weak signals were detected almost immediately 500 metres south of the ship, but they faded after about 30 minutes and during this time no logical or high confidence bearings could be obtained.

The search team then decided that the signals received were either the result of unusual acoustic propagation conditions, or that the helicopter still retained some bouyancy and the strong tide was moving it along the sea bottom. As two acoustic detectors were available, one was deployed by a diver at a depth of 20 metres and the other from the more normal position just below the surface. By this method it was hoped to overcome the reduction in detection range if a surface thermal layer existed. No detections were obtained in the area where previous signals had been received so the four quadrants within half a mile from the ship were searched, again without success. The search area was then expanded to the north of the ship and contact was gained at 1800 hrs. By 1830 hrs an accurate fix on the acoustic beacon had been obtained and the ship was established in a 'four point moor' over the datum by 0130 hrs on 18 July. The strength of the tide did not allow diving until 0500 hrs.

The fuselage of the S-61 was found by a diver at 2110 hrs and the ship was moved into a position to raise the wreckage, which was lifted onto the deck at 1200 hrs on 19 July. (See photograph at appendix 5.)

1.12.2 Examination of the wreckage

An extensive and detailed examination of the wreckage was carried out at the AIB facility at Farnborough. Particular attention was paid to the power plants, flying controls, and flight instruments.

All the evidence indicated that the aircraft was structurally and mechanically complete at the time of the impact, that the engines were capable of delivering power to the rotor system, and that the flying control system was capable of controlling the aircraft.

The general state of the electrical components and many of the instruments, however, prevented any positive conclusion from being drawn as to their pre-crash serviceability. Nonetheless no evidence of pre-impact failure was found in any of these components.

There was little doubt from the wreckage examination that the aircraft struck the water in a nearly level attitude, at a low rate of descent, and on a heading of about 265°M.

1.13 Medical and pathological information

1.13.1 Post-mortem examinations

Seventeen bodies were found in the fuselage and a post-mortem examination was carried out on each. The bodies of the cabin attendant and two adult passengers were not recovered.

The post-mortem examinations revealed that all the passengers died from drowning, and that although no fractures or incapacitating injuries had been sustained during the impact it was possible that a number could have been concussed or at least dazed. It was the opinion of the pathologist that no pre-existing disease restricted the ability of any of the passengers to escape. Only three of the 17 bodies examined showed evidence of lap strap bruising or abrasions.

1.13.2 The pilots

As part of the accident investigation each of the pilots underwent an examination by a consultant in neurology, carried out under the auspices of the CAA Medical Department. These examinations included an electro-encephalogram. The consultant reported that nothing abnormal was found. Following a review of their medical histories the CAA Medical Department reported that in their opinion both pilots were fully fit at the time of the accident, and that nothing had been discovered that would appear to have any medical bearing on the cause of the accident.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 The impact, evacuation, and survival in the water

Details of ON's emergency exits, liferafts, and seat positions are shown at appendices 6 and 7. At the moment of its initial impact with the water the helicopter appears to have been slightly nose-down and banked slightly to port, flying at an airspeed probably between 80 and 100 knots, and at a low rate of descent. Both the pilots and all the passengers were seated and strapped in, but it could not be established whether the cabin attendant was seated or was standing near his seat. Seat positions were not allocated to passengers, and it was not possible to establish the position of most of the passengers. However it was established that the two adult surviving passengers had been in the double seat in row 6, and the child survivors in the single seats in rows 2 and 5 respectively.

The impact forces caused the sponsons to detach, and destroyed the aircraft hull below floor level for most of its length. The two access hatches from the cabin to the underfloor freight bays were displaced, leaving the cabin open to the sea at these points. Six of the helicopter's eight double passenger seats became detached from the airframe. The helicopter quickly rolled over, filled with water, and sank before all but four passengers (two women and two children) and the two pilots could escape. Only one of the survivors managed to take a lifejacket out of the aircraft, but lost it before it could be removed from its case and inflated.

The evidence of the survivors indicated that each escaped as follows: the commander through his emergency exit window, the co-pilot and one child out of the forward freight bay hatch and hole in the fuselage floor, another child out of the rear freight bay hatch and hole, and the remaining two passengers out of the airstairs door on the starboard side. Having seen the helicopter sink, the two pilots collected the other four survivors together and, using suitcases as flotation aids,

kept themselves and two of the four passengers afloat until rescued by the St Mary's lifeboat at approximately 1225 hrs. The surviving passengers highly commended the actions of the two pilots in sustaining them in the water until rescue could be effected.

1.15.2 The rescue

As nearly as could be established, the accident occurred at 1135 hrs. At 1144 hrs after making several attempts to contact G-BEON, the ATCO at St Mary's aerodrome alerted the Rescue Co-ordination Centre (RCC) at Plymouth. At 1144 hrs London Air Traffic Control Centre (LATCC) were notified, and shortly afterwards the Police, the Fire Service and BAH helicopter 'DA' were informed. At 1145 hrs the RCC requested that the St Mary's lifeboat be launched, and by 1206 hrs it was making all possible speed (18 knots) towards the suspected crash area.

At 1146 hrs, the RCC informed Royal Naval Air Station Culdrose that the S-61 was overdue and asked them to "Bring helos to immediate readiness". Two helicopters were available for search and rescue (SAR) tasks at Culdrose, a Wessex (callsign 'Rescue 77') and a Sea King (callsign 'Rescue 80'). The Wessex was already preparing to take off to carry out an exercise at St Michael's Mount, and was airborne at 1155 hrs. At about 1158 hrs, following the receipt of a scramble and tasking message for the Wessex, Culdrose diverted it to attend the accident. The Sea King, on 90 minute readiness for such emergencies, was alerted at 1200 hrs and took off from RNAS Culdrose at 1240 hrs.

Rescue 77 set course for St Mary's at 1,000 feet amsl and descended en-route to 500 feet to remain visual with the surface. On nearing the Isles of Scilly, fog banks were seen below and visibility was 1 to 2 km. Having received no precise information about the position or nature of the accident, the captain landed at St Mary's at 1223 hrs for a briefing. On the ground ATC provided all the available details, and Rescue 77 took off at 1230 hrs to search the north and east sectors of the coast at 200 feet. At approximately 1235 hrs the crew, having heard the lifeboat say they were picking up survivors, returned to St Mary's aerodrome. Having acquired a definite datum position for the accident from the lifeboat, Rescue 77 then flew at 100 feet to the area. Arriving at the specified position, it performed a 180° turn during which the pilot became disorientated due to poor visibility in fog. He therefore levelled the aircraft, climbed above the fog and returned to land again at St Mary's aerodrome. Rescue 77 then acted as a radio relay station between Culdrose and Rescue 80, which had an unserviceable high frequency radio.

Meanwhile, at approximately 1225 hrs, the St Mary's lifeboat arrived in the area of the accident, which was initially identified by the smell of aviation kerosene. With the assistance of its inflatable tender, the crew picked up six survivors and began the search for others. At 1300 hrs, Rescue 80 arrived overhead the datum area but the lifeboat was in a patch of dense fog which necessitated the use of flares and radio to guide the helicopter to the exact spot. The two sponsons from the S-61 were then sighted by Rescue 80 and a diver was dropped between them. A medical attendant and a crewman were then winched down to the lifeboat to give assistance, and Rescue 80 took control of the air operation.

At 1327 hrs, the lifeboat set course for St Mary's harbour with the six survivors. The vessel 'Flying Cloud' remained with the Deputy Lifeboat Launching Authority aboard as the 'on scene commander' of the small vessels which arrived in the area in response to a 'Mayday Relay' message broadcast by Lands End Radio on all maritime distress frequencies.

A short time later, at 1335 hrs, Rescue 80 requested that Rescue 77 should position his diver on board one of the fishing vessels and thence return to St Mary's to pick up one of the survivors and take her to hospital at Truro, before returning to base. At 1525 hrs Rescue 80, which was getting low on fuel, winched up the divers and left the scene. It subsequently also returned to base, arriving there at 1620 hrs.

1.15.3 Co-ordination and control of the rescue operation

Examination of the various logs at RCC Plymouth, the Maritime Rescue Co-ordination Centre (MRCC) Falmouth, and RNAS Culdrose revealed that, although the physical and electronic means of communication were readily available, there were times during the incident when understanding broke down between the RCC and Culdrose. When the RCC asked Culdrose to "Bring helos to immediate readiness" at 1146 hrs, the RCC meant that the readiness of both the Wessex and the Sea King helicopters should be reduced to the minimum possible without actually getting airborne. Culdrose did not recognise reductions in readiness from the standard 15 mins for the Wessex and 90 mins for the Sea King, and so the Sea King was not brought to a higher state of readiness. Culdrose did not interpret the message from the RCC to mean that there was a high probability of an aircraft accident involving 26 persons and that both Wessex and Sea King helicopters were likely to be required for a rescue operation. Their understanding of the message was that the S-61 was overdue at St Mary's and that the Wessex might possibly be required. Since the Wessex was already starting up to exercise with the Penlee lifeboat and no scramble message had yet been passed by the RCC, the Wessex crew were not told of the possibility of an SAR operation but were allowed to continue with their exercise. In the event this resulted in little or no delay as the Wessex was airborne at 1155 hrs and was diverted to the Scillies at about 1158 hrs.

When the Wessex scramble and tasking messages were received at Culdrose operations they realized that the lack of navigation equipment in the Wessex would make it extremely difficult for the crew to carry out a search in the very poor visibility obtaining, and so at 1200 hrs they called out the Sea King crew. The Sea King is superior in SAR capability compared with the Wessex in that it has an area navigation equipment, radar, an automatic flight control system with a hover capability, and can carry many more survivors. The Sea King became airborne at 1240 hrs, a fast reaction by the crew, and well within the 90 mins readiness stipulated. However, some 14 minutes had been lost because of the misunderstanding between the RCC and RNAS Culdrose.

By 1255 hrs another Sea King was available although there was no formal requirement to provide a second such aircraft.

1.15.4 Safety equipment

The aircraft carried the following safety equipment:

2 x 19 seat liferafts (RFD 18U MK 1)

1 lifejacket at each of the 24 seats (RFD 102 MK 2BA)

1 lifejacket per crew member (3), equipped with personal locator beacons (PLB). (RFD 5DC with BE375 PLB's)

1 emergency position indicating radio beacon (EPIRB) (BE 369 stowed alongside the emergency rear door).

G-BEON was on temporary detachment to Penzance from its usual base at Aberdeen and was equipped for operation in the offshore oil support role. Because of this the passenger lifejackets were of the constant wear type which are designed so that they can be tied around the waist before take-off, if desired. On the Penzance-Scillies service this was judged impractical and so one lifejacket was placed at each passenger seat for donning if an emergency arose, as is normal practice on ordinary passenger flights.

1.15.5 Homing capability

The lifejackets provided for the commander and the cabin attendant each contained a PLB set to the civil distress frequency of 121.5 MHz; the co-pilot's lifejacket contained a beacon set to the military distress frequency of 243 MHz; the EPIRB was capable of operation on both 121.5 and 243 MHz. In the event none of these survival radio beacons was available to the survivors because the pilots were unable to lay their hands on their lifejackets (which were stowed under their respective seats) or on the EPIRB.

The RN Wessex and Sea King helicopters used in the SAR operation carried homing equipment operating on 243 MHz but not on 121.5 MHz. Thus even if all members of ON's crew had been wearing their lifejackets it was only the co-pilot's beacon that could have provided a homing capability, and he might well not have escaped. Whilst all UK dedicated SAR aircraft are capable of homing on 243 MHz, the only ones that can home on 121.5 MHz are RAF Sea Kings, none of which were deployed during this operation.

The St Mary's lifeboat carried no equipment capable of homing onto transmissions on either 121.5 or 243 MHz, but the Royal National Lifeboat Institution (RNLI) are equipping lifeboats with equipment to home on 121.5 MHz.

1.15.6 Cabin seats

ON was equipped with seats for 24 passengers, and one fold-up seat for the cabin attendant. Those along the port wall were all single seats, those along the starboard wall double seats. Thus an aisle was formed on the left of the cabin centreline. All the seats were recovered with the exception of the cabin attendant's seat. Unlike some other public transport helicopters and most fixed-wing airliners whose seats are anchored only to the floor, these seats were mounted at their inboard ends to the floor, their outboard ends being fastened to the fuselage wall. This arrangement defined the position of each seat row, as the floor and wall fittings were not of the continuous rail type.

All seat belt buckles on the passenger seats were fitted to the left hand seat belt, with the exception of the single seat at row 9 which was fitted on the right. AIB report 10/82, on an accident to a Bell 212 helicopter, recommended that the handing of seat safety belts be standardised to avoid the possibility of confusion as to the opening direction of the buckle.

The cabin attendant's seat was not recovered but examination of its mounting showed that it had failed in a forward direction, all but one of its attachment screws remaining in the floor structure. Fragments of the structure had remained around the screw heads, indicating that the seat had pivoted about its forward feet as the screw heads tore through the material of the rear structure. Tests carried out on a deceleration track at the RAF Institute of Aviation Medicine resulted in a similar failure mode at a longitudinal deceleration of 6.5g when an identical seat was tested carrying a 170 lb dummy. Details were passed to the CAA, with the suggestion that the strength of this seat be reviewed.

Examination of the passenger seats revealed that whereas none of the single seats had become completely detached, six double seats had separated from the fuselage as a result of the impact. The separated seats contained examples of both types of seat fitted to the helicopter (the Burns Aero Seat Co Inc Type 650-2-39 and the Aerosmith HC 25C/D-1). Appendices 8 and 9 refer.

These separations were associated with the seat foot and the wall fittings, and were not a function of the type of seat. Seat rows 3, 5 and 6 had characteristics consistent with having initially suffered release of their floor attachments, and seat rows 9 and 10 appeared to have suffered initial release of their attachments to the fuselage walls. Seat row 4 had suffered a complex failure leaving both the forward and the aft legs still attached to the floor.

Examination of the seat floor attachments in the aircraft showed that the starboard double rows at positions 3, 5 and 6 had floor attachment stud fittings (part number unknown) on their rear legs which relied on a locking collar alone to hold the moving tongues in engagement with the corresponding floor mounted fittings. The rear legs of seat rows 4, 9 and 10 had a different, though compatible, design of floor attachment fitting (part number 33115). This incorporated a positive locking plunger to secure the collar, and hence the locking tongues, in the fully closed position. Examination of the locking fittings of the first type, both in this aircraft and in others, showed that disengagement could occur if the locking collars were moved upwards, which could be done with minimal force. Those of the second type, however, could not be released without first disengaging the locking plungers.

Examination of the fuselage side attachments of the seats indicated that those securing double rows 3, 5 and 6 had the single protruding bolt tails on the wall fittings positioned forward of the seat attachment spigots. These bolt tails appear to have prevented the seat fittings on double rows 3, 5 and 6 from sliding forward out of engagement with the fixed rails. Seat rows 9 and 10 had such bolt tails positioned aft of the spigots. This appears to have permitted forward sliding disengagements to take place from the rails once the attachment spigot locating plates had released from their engagement position in the rails.

During the accident investigation deceleration tests were also conducted on several S-61 passenger dual seats of the two types with which ON was equipped, carrying two 170 lb dummies. The results indicated that the seat structures, when securely

attached to the test vehicle, could withstand longitudinal decelerations of about 12g before failure occurred. Details of the results of the investigation and tests were passed to the CAA.

As BCAR's only require helicopter passenger seats to be able to withstand the loads generated by a longitudinal deceleration of only 4g in crash landing conditions, it is considered that these requirements should be reviewed.

1.15.7 *Emergency exits*

All the exits on the helicopter were examined during the investigation. The designated emergency exits were: a jettisonable window at each of the pilot's positions, a removable window at seat row 5 port and starboard, the forward starboard side sliding cargo door, the port rear emergency door, and the normal airstair door. All the exits were found to be marked in accordance with the relevant requirements.

Both crew emergency windows became detached during or subsequent to the accident, due to structural deformation of the cockpit structure. Neither jettison handle had apparently been operated.

The two escape hatches at row 5 position were fitted with frangible plastic panels covering the operating mechanism. Neither had been broken. The top of the starboard hatch was found to be displaced outwards by approximately 25 mm, but this did not prevent a satisfactory test jettison of the hatch. Subsequent examination revealed distortion to its top engagement tongues, a distortion that would have occurred if a relatively low pressure had been applied across the inside face of the hatch. The port hatch also operated satisfactorily when tested.

Some difficulty was experienced in opening the cargo door when checking its operation. However, deformation of the fuselage structure along its lower edge had affected part of the mechanism which allows the door to move outboard before sliding rearwards. This damage was entirely attributable to impact forces.

The port rear emergency door was found to be securely locked to the airframe, both inside and outside manual operation handles being in the 'door locked' position. The external handle wire locking was intact. When tested by operation of the interior handle the door functioned satisfactorily. The liferaft lanyard was correctly attached to the airframe. This door can be electrically unlocked by operation of a switch to the side of the pilot's overhead panel, but the system had not been actuated. Electrical power for the system is taken from the emergency battery (essential DC Bus) which is mounted in the nose bay, but this area of structure had suffered gross disruption during the impact which would have precluded electrical actuation of the door. The violence of the in-rushing water had, in fact, prevented the co-pilot operating the actuating switch.

The normal entry/exit airstair door was found closed. Operation of the door, which is hinged about its lower edge, was found to be satisfactory when tested. Some evidence of wear was evident in the latching mechanism, but this was judged to be typical of an in-service door when compared with several other helicopters examined.

1.15.8 *Passenger briefing*

On the Penzance – Scilly Islands route the passenger briefing was normally given by the cabin attendant over the cabin address system shortly before take-off. Passengers were asked to read the safety leaflet provided, and to note the emergency procedures and the position of the emergency exits. No demonstration or briefing on the use of lifejackets was normally given. It was not possible to establish exactly what briefing was given on the accident flight but there was no reason to believe that it was other than the standard briefing.

Following the accident a number of passengers who use this service regularly wrote to say that they had experienced great difficulty in understanding the cabin attendant's safety briefing owing to the poor audibility of the cabin address system when the helicopter's engines and rotors were turning. This was brought to the notice of the CAA.

1.16 Tests and research

1.16.1 *S-61 performance*

Computer simulations were carried out by Sikorsky Aircraft and at the Royal Aircraft Establishment, Farnborough (RAE) into various aspects of the performance of the S-61. Based on this work a summary of the approximate performance of an S-61 under the loading and atmospheric conditions of the accident flight is as follows:

Power required for level flight at 110 kt:	58% torque Associated pitch attitude -2.2°
Power required for level flight at 90 kt:	50% torque Associated pitch attitude -1.0°
Minimum power speed:	72 knots. 47.5% torque

When torque was decreased from a level flight condition at 90 kt but with pitch attitude being maintained at -1.0° the following results were obtained:

Torque (%)	Time to lose 250 feet (secs)	Final rate of descent (fpm)
44	113	210
40	66	231
37	33	397

When pitch attitude was decreased from the 90 knot level flight condition but with torque being maintained at 50% the following results were obtained:

Pitch Attitude ($^{\circ}$)	Time to lose 250 feet (secs)	Final rate of descent (fpm)
-2	74	234
-2.5	51	335

Finally, tests were carried out to explore the effect of small reductions in both pitch attitude and power below that required to maintain level flight. The simulations were again commenced with the aircraft in level flight at 250 feet and 90 knots, and the results were as follows:

Pitch Attitude (°)	Torque (%)	Time to lose 250 feet (secs)	Final rate of descent (fpm)
-2	44	46	342
-2	40	35	457
-2.5	44	40	404
-2.5	40	33	477

1.16.2 *Effect of cabin attendant's movement*

Sikorsky Aircraft carried out a computer simulation to determine the effect on fuselage pitch attitude and helicopter rate of climb or descent that would be produced if a weight of 170 lbs (representing a cabin attendant) was moved between the airstair door and the cockpit entrance, assuming no pilot intervention. The start condition was that the helicopter was in trim at an airspeed of 90 knots under the loading and atmospheric conditions of the accident flight. Two cases were considered and the results were reported as follows:

"Case 1 represents the S-61N aircraft response when a 170 lb load is moved from the rear passenger door to the entrance of the cockpit. This distance is approximately 19.2 feet. The net impact on the aircraft CG for this change in loading is a 2 inch forward shift and is assumed to occur over a 10 second period. Equivalent translation rate of the load is 2 ft/sec. The automatic stabilization equipment (ASE) is on, and represents the only corrective action, ie, no retrimming of the cockpit controls.

The aircraft simulation model response initially consists of a nose-down pitch attitude change of approximately 1.5 degrees. This results in a shallow descent of approximately 150 ft/minute. If the load remains at the forward location, the aircraft pitch attitude stabilizes about 1.0 degrees below its initial trim. Altitude loss after 60 seconds from the initial movement of the load is approximately 135 feet with a concurrent descent rate of 120 ft/minute.

In Case 2, the load is returned to the passenger door immediately after reaching the cockpit entrance. The response for this case is initially the same as Case 1, but in the long term, the aircraft returns to a level flight condition with a net loss in altitude of approximately 20 feet."

1.17 **Additional information**

1.17.1 *The Visual Flight Rules and company operating minima*

Pilots of helicopters making VFR flights outside controlled airspace in visual contact with the surface must conform with Rule of the Air 23 (a) (iii) which reads as follows:

"A helicopter flying outside controlled airspace at or below 3,000 feet above mean sea level shall remain clear of cloud and in sight of the surface, or at least 1 nautical mile horizontally and 1,000 feet vertically away from cloud and in a flight visibility of at least 3 nautical miles."

The BAH Operations Manual, drawn up within this rule, permitted VFR flight over sea by day down to a minimum height of 250 feet, in a minimum cloud ceiling of 300 feet, and a forward visibility of not less than 900 metres. Other UK helicopter operators had similar limits for S-61 aircraft.

In November 1981 the British Airline Pilots Association (BALPA) to which most BAH pilots including the commander and co-pilot of ON belonged, wrote to the CAA concerning Rule 23 (a) (iii). The letter expressed BALPA's serious doubts as to whether it was possible to guarantee adequate visual reference for a helicopter flight without reliance on instruments in a visibility of less than one nautical mile, especially over an unbroken surface with no reference points such as snow or a smooth expanse of water. BALPA proposed that changes be made to Rule 23 to bring helicopters in line with fixed wing aircraft, so that the minimum visibility permitted in VFR flight would be one nautical mile. Following discussions between the CAA, BALPA, and other interested parties, the CAA, although not accepting that the appropriate minimum visibility was one nautical mile, decided to review the minima for helicopters. The CAA were also of the opinion that whilst an amendment to Rule 23 was not an appropriate method of implementing any change considered necessary, action could be effected by amending the operating minima in company operations manuals.

By March 1983 proposals had been drawn up for CAA internal discussion. These were to the effect that for flights up to 50 nautical miles present minima should be allowed to stand, but be reinforced by provisions that operating indicated airspeed should allow a forward visibility of 60 seconds to a single-pilot crew and 30 seconds to a two-pilot crew. The pilot should also be able to assess attitude by external reference. The proposals for longer flights were more restrictive, requiring a 600 feet ceiling and 10 km visibility by day, and a 1,200 feet ceiling and 10 km visibility by night. These proposals were being considered when the accident to G-BEON occurred.

1.17.2 The Operations Manual

Relevant extracts from the BAH Operations Manual are at appendix 10.

1.17.3 Visual flight in poor visibility

Both pilots were interviewed by the Head of Flight Skills Section of the Royal Air Force Institute of Aviation Medicine. He provided an assessment of the problems pilots face when flying by external visual reference in poor visibility over the sea, with particular reference to this accident. Extracts from his report are as follows:

"The pilot who is attempting to fly reasonably close to the surface of the earth by visual reference to that surface, must control both height and attitude. The visual cues which a pilot may use to accomplish these goals are several. To maintain control of attitude it is clear that use may be made of the horizon if it is visible. In more restricted visibility, it is possible that information derived from the visual range of the haze can be used to provide the same type of information as the horizon, but such information almost certainly provides a weak and potentially illusory cue. A more powerful cue to attitude perception is provided by the gradients and movement of surface texture on the retina. As long as a surface is textured in a reasonably uniform way, judgements may be made of the angle at which the surface is being observed even if the texture

is unfamiliar and of unknown element size. Thus, the absence of surface texture (ie the glassy sea) at the time of this accident would effectively have presented the visual perception of orientation, and the vestibular system cannot be relied upon to detect rates of attitude change (ie small angle accelerations) or to detect the resultant, perhaps quite large, changes of attitude.

There can be no doubt that this pilot (ON's commander) would have been placed extremely poorly to perceive the attitude of the aircraft, and it is quite conceivable that large attitude changes could have occurred which would, to him have been undetectable both from a visual and vestibular point of view. Even if this pilot had failed to appreciate an attitude change, one might suppose that he should have detected the reduction in height as he approached the surface of the sea. In this respect, the horizon is of little consequence as no height information may be derived from it, visual height judgements predominantly being influenced by two factors. The first and more important is the retinal size (or visual angle) of objects and texture of known actual size on the surface. The second is the rate at which objects and texture on the surface pass the observer (their relative angular velocity) and this variable is affected by both height and speed."

"... It is recognised that the analysis above of the cues used in height judgement is simplified and it is quite possible that the use of surface texture will interact in a complex manner with visual range in the judgement of height and descent rate. Furthermore, even if texture is present, illusory phenomena can occur leading to erroneous judgements if the real element size in the texture is unknown to the observer.

To summarize though, it can be said that the perception of attitude may be achieved using the horizon and surface texture as cues. Height perception however, does not depend on the horizon, does require surface texture and what is more, requires the observer to be aware of the real size of the texture . . . Because of this, the pilot flying by limited external cues would ideally be provided with information from the radio altimeter as close to the forward cockpit transparency as possible. Regrettably, the radio altimeter in this aircraft is located in a far from ideal location, requiring not only a large head and eye movement to transfer the gaze from it to the outside world, but it is also partially obscured behind the control column."

1.18 New investigation techniques

None.

2. Analysis

2.1 The nature of the accident

Neither of the pilots was able to describe how the accident occurred because up to the moment of impact each was under the impression that the helicopter was at 250 feet. However, their evidence as to the serviceable condition of the helicopter at the start of the flight and its behaviour during it, taken together with the evidence derived from the engineering investigation, leads to the conclusion that G-BEON was mechanically serviceable, with both engines operating, and was fully controllable up to the moment that it struck the sea in a substantially straight and level attitude on its intended track and heading. This accident therefore falls into the category of a collision with the water in controlled flight. It was not in any sense a ditching.

2.2 The VGI

Various conceivable subtle failures or malfunctions which might have led directly or indirectly to an unnoticed loss of height were examined, but the only one for which there was any evidence at all was the possibility of an error in the No 2 VGI system. The only evidence for this was the commander's report of a momentary appearance of his VGI 'ATT' flag whilst he was checking the height on his radio altimeter. The commander noticed nothing else unusual about the VGI, but did not then compare it with the standby horizon or the co-pilot's indicator. In fact his reaction was to look outside the cockpit to seek a reference on the approaching coastline, and he did not again refer to his VGI (or any other instruments) during the rest of the flight. Thus any VGI malfunction at this time could not have misled him. The reason why the helicopter lost 250 feet unnoticed by the pilots must, therefore, be sought in the areas of their performance and in operational factors.

2.3 The weather encountered

Before ON took off the commander had received a satisfactory weather report from St Mary's, and he knew that DA had landed after a VFR flight. He was therefore justified in his decision that the weather was suitable for his own flight to be a VFR one.

During the course of the flight both pilots were in no doubt that VFR conditions prevailed. Although the identity of the station which transmitted the report of the weather at St Mary's received by ON when near the Longships could not be established, the report was in fact the weather that DA had encountered – a visibility of $\frac{1}{2}$ to $\frac{3}{4}$ nm when at 300 feet radio height.

ON's crew stated that towards the end of the flight they were flying at 250 feet radio height, in visual contact with a flat calm sea, with no horizon discernable, in haze but with a forward visibility they were confident exceeded the minimum permissible of 900 metres. They were supported in this assessment by the report they believe came from DA. The best independent evidence of the weather in the accident area at the time of the accident is that of the crew of DA. Although it is apparent that patches of shallow sea fog appeared in the area soon after the accident, it is concluded that during the last stages of ON's flight the crew were in visual contact with the sea and in a flight visibility of over 900 metres, and possibly as much as $\frac{3}{4}$ nm (1,200 metres). ON was, therefore, being operated in conformity with the instructions in the BAH Operations Manual on weather minima for daytime VFR flight over the sea.

The evidence concerning the weather encountered towards the end of the flight indicates that not only were conditions such as to make the assessment of attitude and height by external visual reference difficult, but that nonetheless they were also capable of causing a pilot to be deceived into believing that adequate cues were available for the safe control of a helicopter's flight path – at least for short periods of time.

2.4 Operating height

The apparent conflict of evidence between the statements of the two pilots that the final stage of the flight was being conducted at 250 feet radio height, and that of the two passengers who stated that shortly before the impact the cabin attendant had said the helicopter was flying at 100 feet deserves examination. Several explanations were considered, namely: the helicopter was being flown level at 100 feet and not at 250 feet; the passengers misheard what the cabin attendant said; the cabin attendant misread the radio altimeter; the cabin attendant read the height from one of the barometric altimeters which are much more obvious than the radio altimeters to a person standing at the cockpit entrance, and at 250 feet radio height would have indicated about 134 feet QFE; finally that the cabin attendant had in fact seen a height of about 100 feet indicated on the radio altimeter as the helicopter was descending without realising that it was not level. In view of the fact that the crew's evidence is direct and that of the passengers' hearsay, and as there would have been no advantage to be gained by intentionally flying lower than 250 feet but rather the opposite, it is concluded that immediately prior to the final loss of height which resulted in the impact the crew intended to fly at 250 feet radio height, ie in accordance with the minimum en-route height for daytime VFR flight over the sea laid down in the BAH Operations Manual.

2.5 The cause of the unintentional descent

The effect of the cabin attendant's movement forwards to the cockpit entrance and then rearwards to his seat was examined as a possible cause of an undemanded rate of descent. It was discounted because of the small effect it would have had on the helicopter's performance, even in the absence of pilot intervention.

On the other hand the evidence is that just before the commander directed his attention from his radio altimeter to his VGI, and thence outside the cockpit, he had reduced power to decrease airspeed. He had made a further power reduction later whilst looking ahead, and had also been adjusting the helicopter's attitude by trimming nose-up with a view to maintaining height as airspeed decreased. There is no firm evidence regarding the time that elapsed from the start of the descent from 250 feet to the impact. However the loss of height must have been gradual because the pilots' non-visual senses were not alerted. It is likely, therefore, that the commander made neither large changes in power nor large changes in attitude, and this accords with his evidence.

The computer simulation of the S-61's performance indicates that for variation of torque or pitch attitude alone, a relatively large error from the figure appropriate to level flight at 90 knots would be required to produce a loss of 250 feet in a credible time scale, but that a relatively small error of both together could do so in about 40 seconds. Decelerating a helicopter at constant height demands close co-ordination of power and attitude. The accurate control required would be difficult to achieve in the external visual conditions that pertained without reference to the flight instruments.

Once the commander had transferred his attention from the VGI to continue flying by external visual reference he was expecting to sight land shortly and to find improved weather in the vicinity of the airfield. He clearly did not realise that the external visual cues were insufficient for what he was attempting without any further check of the flight instruments. If the helicopter had been in stabilised level flight when the commander last looked out and power had remained unaltered, it is likely that little height change would have taken place. But in fact power and attitude were being altered to decrease airspeed, and unless control was perfectly co-ordinated an unwanted change of height was likely. Thus it seems probable that whilst looking out ahead the commander had insufficient visual cues to realise that an imperfect co-ordination of the cyclic and collective pitch controls had resulted in a power and attitude combination which had given rise to a gradual but continuous loss of height.

2.6 Contributory factors

2.6.1 *Flight instrument monitoring*

One of the principal reasons for having a co-pilot in public transport aircraft over 12,500 lbs weight is so that safety may be enhanced by the non-handling pilot being able to monitor the flight path, especially when the aircraft is at low level. As a general principle of good airmanship, the co-pilot should monitor the instruments throughout the flight and the commander should ensure that this is done.

The BAH Operations Manual (Vol 5 para 4.1.3.1, Allocation of Duties S-61N, Normal Operations) specifically required the co-pilot to monitor the instruments during the 'final approach' phase of flight, but monitoring of the instruments was not mentioned under the 'descent and initial approach' phase. These instructions were applicable to both VFR and IFR approaches; for a VFR approach such as that conducted by ON, there was no clear definition of the point at which the initial approach ended and the final approach began. Whereas the commander considered the helicopter was on the initial approach at the time of the accident, the co-pilot believed that it had been on the final approach.

As the helicopter approached land at 250 feet the co-pilot, being satisfied that there was adequate visual reference and having confirmed with the commander that he was flying visually, concentrated on his navigation and radio communication duties. He considered that the range from the coast was of particular importance because, if the helicopter were to reach a point one mile from land without it being visible, he would have to warn the commander to prepare to carry out an overshoot procedure. Because of this, and because he was constantly adjusting the radar set and had to shield the screen from glare, the co-pilot concentrated solely on obtaining radar ranges and on radio communication to the exclusion of flight instrument monitoring for about the last minute of the flight – a period which probably included the entire time of the helicopter's descent from 250 feet to the water.

Nevertheless, monitoring of the flight instruments was of vital importance in the potentially deceptive meteorological conditions obtaining, the Decca flight log was operating satisfactorily, the helicopter was on track, and the range to the land ahead was closing at a known rate. Because of these factors, and notwithstanding his navigational and communications duties, the co-pilot could and should have paid some attention to the flight instruments during the last minute or so of the flight.

2.6.2 *The weather minima*

The flight was conducted in accordance with the rules for VFR flight and the BAH Operations Manual minima and procedures. The BALPA argument (first put to the

CAA 20 months before the accident) that the weather minima relevant to VFR 'contact' flight were unsatisfactory led to a review by the CAA, but proposed changes were still under consideration when the accident occurred. Although the flight was conducted in accordance with the minima contained in the Operations Manual the poor external visual cues during the approach phase meant that adequate control of the helicopter's flight path could not be maintained purely through external visual reference, although such reference was essential for collision avoidance and to make a safe landfall.

The weather minima applicable to this flight are most appropriately considered in the context of the BAH operating procedures, and in the light of the lessons long learned from the operation of fixed wing aircraft concerning the value of continuous (as opposed to intermittent) instrument monitoring during the visual phase of landing approaches in poor visibility. It is considered that the operating procedures left too much to the individual commander's and co-pilot's discretion as regards flight instrument monitoring when flying VFR at low level in poor visibility, as compared with a formally structured method of arranging the crew duties such that the flight instruments would be continuously monitored by one pilot in such conditions e.g. the concept of the monitored approach. The practice of operating the S-61 (a helicopter which had neither an auto-pilot, nor a height hold facility on its AFCS system) in VFR flight over water, at 250 feet in visibilities down to 900 metres, without a company operating procedure capable of ensuring that the flight instruments would be continuously monitored, was one which eroded safety margins to the extent that it allowed catastrophe to be the consequence of human error of a kind already well known in aviation. This practice was thus a major contributory factor.

As a result of a review of operating procedures undertaken after the accident BAH introduced revised operating procedures concerning two-pilot operations. They included the statement that "if, overwater, the cloud base is less than 550 feet or there is no discernable horizon the handling pilot is to fly the aircraft by reference to instruments only, whilst the non-handling pilot maintains the look-out and monitors the instruments paying particular attention to altitude and airspeed".

2.6.3 *The radio altimeter*

Thirdly there is the question of the adequacy of the height alert system incorporated in ON's radio altimeter. At the time of the accident the BAH Operations Manual contained no instructions on the use of the radio altimeter height alert system, but one was issued after the accident. However, the commander had set his radio altimeter bug at 200 feet after levelling at 250 feet, although it is not known to what position the bug on the co-pilot's instrument was set.

Nevertheless the height alert system is unlikely to attract the attention of a pilot not looking at the instrument panel, because the radio altimeters are mounted low on the panel and the warning light is small. It is surprising that following the action taken a decade ago to require the larger public transport aircraft to be equipped with a ground proximity warning system, no action had been taken to apply this important safety lesson to helicopters. Had even the simplest audio alert system, such as one operated simultaneously with a radio altimeter decision height warning light, been in use in ON it could have alerted the crew in ample time for them to arrest the helicopter's descent safely. Such systems are reliable and have been available for many years. The lack of an audio height alert system capable of warning pilots even if they are not looking at their flight instruments is therefore judged to have been a contributory factor in this accident.

It is ironic that ON was equipped with an audio alert system which would operate at 250 feet if the landing gear was still up. If the landing gear had been left up until the aerodrome was in sight, and the final approach made, say, at 300 feet, then the crew would have had an audio height alert system. But the equipment was not intended to be used in this manner and pilots were not trained or instructed to do so, although in the past some Penzance based pilots had so used it when circumstances warranted.

At the time of the accident radio altimeters were not mandatory equipment for helicopters operating offshore. A recommendation that radio altimeters incorporating audio as well as visual decision height warning be fitted to all such helicopters was made in AIB reports 4/83 and 2/84, and to the CAA in the early stage of this investigation. Although such equipment is considered a vital contribution to the prevention of further accidents following an inadvertent loss of height and should therefore be introduced quickly, in the longer term a more elaborate system should be considered. The report of the Helicopter Airworthiness Review Panel (HARP) of the Airworthiness Requirements Board, published in March 1984, stated that "ground proximity warning systems (GPWS) suitable for helicopters seem highly desirable and should be developed and used". This view is supported.

Given the importance of the radio altimeter in offshore helicopter operations it is suggested that consideration be given to re-locating the S-61N's radio altimeter indicators to significantly reduce the head and eye movement needed to transfer the gaze between them and the outside world, and to ensure that they are fully visible to a pilot whatever his seat position. In the longer term the solution to the problem of assessing height when flying VFR at low level over water probably resides in providing a display of height in the pilot's head-up visual field.

2.7 Other operational matters

2.7.1 *Crew workload*

The circumstances of this accident contain indications of an unsatisfactory workload on both the commander and the co-pilot. Although it is one which has long been carried by helicopter crews it is now being alleviated in new types of machine by the introduction of autopilots, and by improvements in navigation and radar equipment. Such developments should be encouraged for reasons of safety. Moreover retrospective modification of older helicopter types such as the S61N should also be encouraged, perhaps by applying higher operating minima to helicopters with inferior equipment.

2.7.2 *Landing minima at St Mary's airfield*

During the investigation it was noted that whereas the BAH minimum visibility for overwater flight was 900 metres, the day time landing minimum runway visual range (RVR) at St Mary's was 600 metres for S-61's whose mapping radar was serviceable. There were no instructions concerning at what point the 900 metres minima ended and the 600 metres limit began. It is thus conceivable, even likely, that a crew being passed an RVR that was anywhere between 600 and 900 metres might continue an approach over the sea in a visibility less than 900 metres as the assessment of visibility over water in such conditions is extremely difficult. As there is no instrument approach procedure to St Mary's airfield it is suggested that the CAA consider whether the minimum RVR for day landings should be not less than that laid down for overwater VFR flight at low level.

2.7.3 *Altimeter pressure settings*

The crew acted normally in carrying out the landing checks when they did, and in setting both barometric altimeters to the St Mary's QFE at that time. In the case of this level approach over the sea to an airfield above sea level such an action produces the condition whereby the helicopter's height is supposed to be controlled at 250 feet above the sea but the barometric altimeters indicate 134 feet. In such circumstances it would not be surprising if pilots gave the radio altimeter their prime attention, even to the extent of ignoring the barometric altimeters during the final approach. One danger of this practice is that a failure of the radio altimeter which resulted in a credible but incorrect indication might not be detected. It should be considered whether safety would be enhanced if one or both barometric altimeters were to be set to QNH until the coast was crossed or the airfield was in sight.

2.7.4 *Flight data recorders*

This accident serves to underline the continued need for large transport helicopters to be fitted with flight data recorders (FDR). Whilst such helicopters are now required to have a cockpit voice recorder the urgent requirement for the introduction of a helicopter FDR is in no way diminished.

2.8 **Survival aspects**

2.8.1 *Lifejackets and liferafts*

The bodies of the cabin attendant and two adult passengers were not recovered, and the possibility remains that they managed to escape from the aircraft. The six persons that were rescued were extremely fortunate to survive, and credit is due to the two pilots who helped to keep their passengers afloat and maintained their will to survive.

ON, being an Aberdeen based helicopter on temporary detachment to Penzance, was equipped with constant wear type lifejackets. However, in accordance with standard practice on the Penzance – Isles of Scilly service, these were not tied around the waists of the passengers as is the practice on flights to offshore oil installations. Similarly none of the crew was wearing a lifejacket. The fact that no flotation aid was available to the six survivors emphasises the value to both crew and passengers of having a lifejacket on in the event of a helicopter flooding quickly after an accident on water.

As a result of previous accidents the automatic deployment of at least one of a helicopter's liferafts has been considered in the past, and a design exists for modifying the S-61's rear door accordingly. Whilst there could be objections to a simple inertia operated system which might release the liferaft before the fuselage and rotors had come to rest, it might be possible to incorporate an appropriate delay in such a mechanism. Alternatively it might be feasible to employ a switch activated by water pressure so that as a last resort the raft would be released if the helicopter sinks. Had an automatic system capable of operating despite the disruption of the aircraft's electrical supplies been fitted to ON it is probable that the liferaft, which was found fully serviceable during the accident investigation, would have been available to the survivors.

2.8.2 *Search and rescue*

Apart from flotation aspects another severe handicap incurred by the survivors in the water was that the helicopter sank together with the dual frequency BE369 beacon

and the BE375 PLB's carried in the lifejackets of the three crew members. This accident again illustrates the value of equipping helicopters which operate offshore with a survival radio beacon which is automatically deployed by immersion in water or by impact forces. Recommendations to this effect were made in AIB reports 10/82, 4/83, and 2/84.

This accident also illustrates the value to be gained following an accident in which a helicopter fills rapidly with water after impact if crew members wore their PLB equipped lifejackets on every flight. If this had been standard practice at the time of this accident a radio location device would have been available despite the loss of the BE369 beacon, and this should normally have ensured a speedy rescue even in the very poor visibility pertaining on the day. In the event, had the crew been wearing their lifejackets, the two rescue helicopters deployed could have homed onto only the co-pilots PLB as neither had the capability to home on the civil distress frequency of 121.5 MHz, on which the PLB's of the captain and cabin attendant were designed to operate. This is a severe limitation on the capability of the SAR organisation to effect a speedy location of survivors and subsequent rescue. A recommendation that all SAR helicopters should have the capability of homing onto emergency beacon transmissions was made in AIB report 8/78. Additionally the St Mary's lifeboat was not equipped with a homing capability on either 121.5 MHz or 243 MHz. The RNLI are presently fitting their lifeboats with equipment capable of homing on 121.5 MHz.

A further shortcoming in the rescue operation was due to the misunderstanding between the RCC and RNAS Culdrose which resulted in Culdrose not interpreting the earlier information from the RCC as meaning that there was a high probability of an S-61 accident involving 26 persons. This resulted in an inadequate response to the accident in that, although the Wessex was despatched, the Sea King was initially not brought to a higher state of readiness. Furthermore, the Wessex was not equipped with any form of fixing aid and, although the crew demonstrated considerable skill in navigating their machine by dead reckoning, the effectiveness of their search was considerably limited by navigational inaccuracy. This coupled with the poor visibility made it unlikely that the Wessex was in any position to effect a rescue even if the precise location of the survivors had been known. On the other hand the Sea King is capable of hovering automatically and this, together with its radar and superior load carrying capability, would have made it an effective SAR vehicle had it arrived at an early stage. In the event, it had not taken off by the time the survivors had been rescued by the St Mary's lifeboat, whose crew had with great skill located them in fog.

Although co-ordination between the RCC and RNAS Culdrose left much to be desired on this occasion the lack of location devices available to the few survivors made it doubtful whether this had any effect on the rescue operation. When the shortcomings became apparent during the AIB investigation both the RCC and RNAS Culdrose took immediate steps to ensure that there would be no recurrence of the problem.

Representations have been made by the AIB to the Department of Transport, who are responsible for SAR involving civil aircraft, to review the capability, equipment and response times of the SAR helicopters in the South West, and to examine the overall UK SAR capability with regard to civil air accidents.

3. Conclusions

(a) Findings

- (i) G-BEON had been maintained in accordance with an approved maintenance schedule, its Certificate of Airworthiness was valid, and it was fully serviceable throughout the flight.
- (ii) The crew were properly licensed and sufficiently experienced.
- (iii) The helicopter was correctly loaded and carried ample fuel.
- (iv) The commander was justified in planning a VFR flight and the weather throughout the flight was above the minima laid down in the BAH Operations Manual, which were similar to those of other operators.
- (v) When the helicopter was nearing land on its approach to St Mary's aerodrome it was initially flying at 250 feet in a flight visibility in excess of 900 metres. With no natural horizon discernable, but believing he had adequate visual reference, the commander was alternating his scan between the flight instruments and the external scene.
- (vi) At about the time that the commander reduced power so as to decrease air-speed he altered his scan pattern, and thereafter flew entirely by external visual reference.
- (vii) The helicopter's loss of height probably occurred because the commander did not correctly co-ordinate power and attitude to maintain level flight as speed decreased.
- (viii) Because of the inadequate external visual cues and his lack of reference to the flight instruments the commander did not notice that the helicopter was descending before it struck the water.
- (ix) The co-pilot did not notice the loss of height because his attention was fully directed to operating the radar and in communicating with St Mary's for about the last minute of the flight.
- (x) The helicopter's radio altimeter decision height alert system was incapable of warning a pilot who was not looking at the flight instruments, and there was no procedure in the Operations Manual for use of the system.
- (xi) The BAH operating procedures did not require the flight instruments to be continuously monitored by one pilot when flying over water at low level in poor visual conditions.
- (xii) Following the evacuation of the helicopter, the commander and co-pilot acted with courage and determination in assisting the passengers to survive until rescue arrived.
- (xiii) Untoward features of the search and rescue operation were an initial lack of co-ordination between the Rescue Co-ordination Centre and RNAS Culdrose, and the original despatch of a rescue helicopter which did not have the capability to operate in fog.

- (xiv) Although the helicopters and lifeboat deployed did not have the capability of homing onto emergency radio beacons transmitting on the civil aeronautical distress frequency of 121.5 MHz, this had no effect on the rescue operation because ON's crew were unable to take any beacons with them on evacuation.
- (xv) The timely despatch of the St Mary's lifeboat and the skill exhibited by its crew were crucial factors in the rescue of the six survivors, who were floating without lifejackets and in fog.

(b) *Cause*

The accident was caused by the commander not observing and correcting an unintentional descent before the helicopter collided with the surface, whilst he was attempting to fly at 250 feet by external visual reference only in conditions of poor and deceptive visibility over a calm sea. Contributory factors were: inadequate flight instrument monitoring; a combination of VFR weather minima which were unsuited to visual flight and insufficiently detailed company operating procedures; and the lack of an audio height warning equipment.

4. Safety Recommendations

It is recommended that:

- 4.1 The weather minima for helicopter VFR 'contact' flight, and the associated crew instrument monitoring procedures, should be reviewed.
- 4.2 Radio altimeters incorporating audio as well as visual decision height warning be fitted to all helicopters operating offshore as a matter of urgency.
- 4.3 In the longer term, consideration be given to the development of a ground proximity warning system for helicopter use.
- 4.4 The practicability of moving the S-61N's radio altimeter indicators to a position clear of the cyclic stick, and nearer the pilot's head-up field of vision, should be examined.
- 4.5 Public transport helicopters be fitted with a survival radio beacon which is automatically deployed on immersion in water or by impact forces.
- 4.6 Consideration be given to requiring pilots of public transport helicopters operating offshore to wear lifejackets incorporating dual frequency (121.5 and 243 MHz) personal locator beacons.
- 4.7 The use of QFE by BAH helicopters on low level approaches to St Mary's aerodrome prior to crossing the coast, and the minimum RVR of 600 metres, be reviewed.
- 4.8 The requirements concerning the strength of helicopter passenger and cabin attendant seats be reviewed.

ICAO Note: The Appendices were not reproduced

ICAO Ref.: 156/83

No. 5

Boeing 747-249F, N806FT, at Frankfurt/Main, Federal Republic of Germany on 11 October 1983. Report No. A X 0002/83 released by the Accident Investigation Branch, Federal Republic of Germany

SUMMARY

After an intermediate stop in Frankfurt on October 11, 1983, the Boeing 747 having arrived from New York taxied to runway 25R to depart to Amsterdam. Three crew members, three passengers, and two pallets with the cargo which had not been unloaded but was to be flown to its destination airport Amsterdam, were on board the cargo airplane of the air carrier Flying Tiger. When starting the take-off run the pallet on the right side detached and slid backwards causing substantial damage to the airplane. Due to the centre-of-gravity shift, the Boeing rotated into a nose-up attitude. The pilot-in-command rejected the take-off run at a speed of about 70 kt.

The airplane exited the runway to the left and came to rest between the runways.

1. FACTUAL INFORMATION1.1 History of the flight

On October 10, 1983 at 2230 GMT, the almost fully loaded Flying Tiger cargo airplane Flight No. 4006/08 took off for a scheduled flight from New York (JFK) to Frankfurt and Amsterdam. Besides the cargo and three crew members, 15 passengers were aboard the airplane.

On October 11 at 0535 Z, the airplane landed in Frankfurt with a delay of one hour and was parked on the cargo terminal near the basis of Flying Tiger.

Unloading was commenced by appropriately trained staff members of the air carrier. The workers were foreigners, who were directed and supervised by German staff members. As a matter of routine, all pallets were released, since also the pallets which were to remain on board had to be moved in order to take the pallets to be unloaded through the cargo doors. Immediately afterwards there was a change of shifts and two Italian staff members continued to unload the cargo.

At that time, the responsible shift supervisor as a representative of the staff council was attending a hearing at the Labour Court. His deputy was for most of the time also otherwise occupied and left the unloading to the two Italians.

The working instruction was a telex, in which the pieces to be unloaded were identified by the handwritten words: "raus" (unload) - "bleibt" (keep) - "hinten raus" (unload through aft cargo door). The OFFLOAD CONTROL SHEET prescribed in the Terminals Operating Manual had not been used.

As intended two pallets with extra long cargo (steel tubes) were finally left in the upper cargo compartment. The pallet on the right side was to remain in its original position and in fact was not moved. The pallet on the left side was to be shifted backwards from its original position 21/22 to position 23/24 in order to obtain a favourable centre-of-gravity position. A so-called ONLOAD CONTROL SHEET had been established in the Flying Tiger office but was left there.

Since the departure from Frankfurt to Amsterdam (Flight No. FT 9014/11) was already delayed an effort was made to rapidly finish the loading works. The flight engineer directed the two workers, who did not speak English, to hurry, and the deputy of the shift supervisor reported that the airplane was ready.

At 0745 GMT, 45 minutes after the scheduled departure time, the airplane left the parking area and taxied to runway 25R. Aboard the aircraft were the flight crew, who also had performed the preceding flight, three passengers and the two pallets with cargo.

After the clearance to taxi onto the runway, the check lists were read. The co-pilot took the controls whereas the pilot-in-command actuated the thrust levers. At 0804 GMT, the airplane received the take-off clearance and was accelerated. Shortly afterwards the pallet on the right side detached and slid backwards; the Boeing 747 rotated in a nose-up attitude. The pilot-in-command rejected the take-off run at about 60 kt. Thrust revers, which was immediately initiated, caused the airplane nose to suddenly lower. In order to avoid damage to the nose wheel, the crew stopped thrust revers and tried to stop the airplane by using main wheel brakes only.

When the braking action did not show any effect and the airplane began to yaw to the right in the direction of the parking areas, the pilot-in-command steered the airplane to the left off the runway by shortly increasing thrust on the right engines. The airplane veered off the runway with the nose up and came to rest in the grass at HtO junction after having passed taxiway C.

The airport fire brigade was informed by the air traffic controller as soon as he had recognized the situation, and arrived at the airplane shortly after it had come to rest.

Meanwhile, the crew had cut off the engines and then after having read the check lists left the airplane together with the passengers through the aft exit on the left.

1.2 Injuries to persons

There were no injuries to persons.

1.3 Damage to aircraft

The aircraft was substantially damaged. Due to the shift of the pallet, parts of the rear cargo compartment were penetrated. The outer skin on the right side showed a tear ca. 5 m in length, from which the pallet partly protruded. Parts of the fairings and the side rails of the loading system were found at the beginning of runway 25R.

The rear pressure bulkhead was penetrated. Hydraulic circuits and control cables located behind the bulkhead were torn off. Additional damage was caused by the repeated impacts of the fuselage belly on the runway and the grass.

1.4 Other damage

Airport facilities were only slightly damaged.

1.5 Crew

The crew was appropriately qualified and licensed to conduct the flight. The licences and ratings were valid at the time of the accident.

Pilot-in-command:

41 years old
AIRLINE TRANSPORT PILOT LICENCE

type ratings:
airplane multi-engine land
B747 DC-8
Commercial privileges
flight hours: more than 8000
as a pilot-in-command B747 - 1500 hours
B747 total - 3500 hours

Co-pilot:

37 years old
AIRLINE TRANSPORT PILOT LICENCE

type ratings:
airplane single and multi-engine land
DC-8 B747
commercial privileges
flight hours: 5500 hours
second-in-command B747: 350 hours
check flight engineer: 1000 hours

Flight engineer:

55 years old
FLIGHT ENGINEER LICENCE

type ratings:
reciprocating engine powered
turbopropeller powered
turbojet powered airplane
flight hours: 21000 hours
second-in-command: 3000 hours

1.6 Aircraft

At the time of the occurrence the aircraft was duly certificated. All maintenance work required had been performed.

type:	Boeing 747-249F
manufacturer:	Boeing
year of manufacture/serial number:	1979 - 21827
certificate of airworthiness:	issued by the FAA on October 31, 1979
airplane category:	transport
total operating time:	13810 hours
operator:	Flying Tiger Line Inc. 7401 World Way West Los Angeles CA 90009

1.6.1 Weight and balance

At the time of take-off, the weight and centre of gravity of the aircraft were within the operational limits.

Maximum take-off weight:	820 000 lbs
Actual take-off weight:	447 300 lbs
Maximum zero-fuel weight:	590 000 lbs
Actual zero-fuel weight:	403 880 lbs

1.7 Meteorological information

The accident occurred in daylight. Weather has had no influence on the accident.

Weather at the site of occurrence:

Wind:	220°/9 kt
Ground visibility:	20 km
Clouds:	1/8 cumulus at 2000 ft GND 6/8 altocumulus at 10 000 ft GND
Temperature:	11°C
Dew point:	9°C
Atmospheric pressure:	1015 hPa (mb)

1.8 Aids to navigation (on ground)

Frankfurt airport was fully operational. Navigation and ground facilities had no influence on the accident.

1.9 Communications

At the time of the occurrence, the aircraft was in contact with the control tower (frequency 119.9). Radio communication between the pilot and the ground stations was perfect. A transcription of the registered radio communication was made by the Bundesanstalt für Flugsicherung.

1.10 Airport facilities

Airport facilities were slightly damaged.

1.11 Flight data recorder (DFDR), cockpit voice recorder (CVR)

Before the arrival of the official flight accident investigators, both data recorders had been removed from the aircraft. Both recorders were taken into custody by the FAA and given to the investigators for the purpose of evaluation.

1.11.1 Flight data recorder

The airplane was equipped with a digital flight data recorder (DFDR) manufactured by Sundstrand (USA), P/N 981-6009-011, S/N 2085.

Immediate reading of the registered data was not possible since the recorder was found to be defective and the recording medium advanced only by jerks. Only after repair was an evaluation possible.

1.11.2 Cockpit voice recorder

Since an evaluation of the eight-track CVR - AV 557 B - manufactured by Sundstrand (USA), P/N 980-6005-055, S/N 7122, was not possible at the FUS (aircraft accident investigation office), the recorder was given to the NTSB. As a result the FUS received a cassette copy.

1.12 Findings at the site of occurrence and the wreckage

Parts of the torn-out outer skin of the aircraft as well as parts of the packaging of the cargo and the loading system were found at the beginning of runway 25R and taxiway D. The parts were distributed over a length of ca. 200 m. After about 1000 m, obvious markings on the left of the centre line started, shifting to the right after about 1900 m, afterwards turning again to the left and finally leaving the runway near taxiway HtO. Deep marks of the aircraft tail section in the grass extended beyond taxiway C. The airplane came to rest in a grass field near taxiway HtO and at a distance of ca. 160 m from the southern runway.

The pallet with the cargo packaged in four wooden boxes must have been detached from its position immediately after the take-off run had been started. It slid unhindered on the freely rotating rollers of the loading system to the end of the cargo compartment. Parts of the side rails were torn out of their attachments and forced out through the skin on the right side. The cargo projecting beyond the pallet penetrated the rear pressure bulkhead and damaged hydraulic circuits and control cables. The leaking hydraulic fluid was found on the runway and in the grass. All normal brake systems of the Boeing were depressurized. The stand-by brake switch was not actuated.

The airplane itself rested on the main landing gear and the tail section. The pallet had penetrated the skin on the right side in the area of the registration mark over a length of approximately 2.70 m and partly projected outside.

Besides two completely broken tie-down straps, only slight damage to the centre roller row was found in the area of the main cargo compartment where the pallet concerned had been stowed. All locks to attach the pallet were found in the open position.

Due to the contact of the tail section with the runway surface, the skin in the aft area of the fuselage belly was partly abraded to the frames.

1.13 Medical information

The medical certificates of the crew members were valid at the time of the accident and gave no cause for complaints.

1.14 Fire

There was no fire.

1.15 Survival aspects

The accident was survivable.

1.16 Special investigations

Since all the locks of the pallet on the right side were found in the open position, it had to be examined whether the locks could change position by themselves if not completely engaged. For this purpose, several tests with the original pallet on the B747, N 806 FT of Flying Tiger in co-operation with Lufthansa experts and further tests on a corresponding airplane of Lufthansa in the presence of representatives of Flying Tiger and the Luftfahrt-Bundesamt were conducted.

All tests showed that by lateral shifting of the pallets, the locks, if not completely engaged, could move independently of each other to the open or closed position. Due to the simple design, the side guide restraint assembly keeps any position over a large range. A definite open or closed position is achieved only for the extreme ends of travel range.

2. ASSESSMENT

The flight from New York to Frankfurt was normal. However, the landing at Frankfurt was with a delay of 50 minutes, at 0535 GMT. At 0546 GMT, the airplane was parked on the cargo terminal near the Flying Tiger station. After the passengers and the crew had left the airplane, unloading of the incoming cargo was immediately started.

For these works, Flying Tiger employ a number of foreign staff members, who work as RSM (ramp service man). The two workers who were in charge first in the cargo compartment prepared unloading. As a matter of routine, they opened all locks of the pallets so that it was possible to shift the pallets to the cargo doors.

Since there was a change of shifts, two Italians continued to unload the cargo. The shift supervisor, who was to supervise these RSM, attended that morning a hearing at the Labour Court as a representative of the staff council. He was substituted by another German staff member who, however, was also otherwise occupied for most of the time and therefore left the unloading work to the experienced RSM.

The working instruction for the RSM was a telex, in which the pallets were identified in German by the words "unload" or "keep".

The form OFFLOAD CONTROL SHEET prescribed in the Terminals Operating Manual of the air carrier was not used. According to the statement of the station director, this procedure was always used since it had proved to be more practical.

Both remaining pallets were loaded with four wooden boxes each, with a total length of ca. 13.25 m and with a total weight of 31 878 lbs (ca. 14.5 t). The pallet on the right side was to remain in its position. In accordance with an orally given instruction, the RSM shifted the pallet on the left side from position 21/22 to 23/24 and again tied it down. The ONLOAD CONTROL SHEET designated for this purpose had been prepared in the office the evening before but had been left there. The responsibility for loading and securing of the cargo had not been assigned to any one of the two RSM. The inspection of the cargo established in the Terminals Operating Manual under no. 500.4B-1 as well as the entries on the form had not been confirmed by signature.

Meanwhile, the scheduled departure time (0700 GMT) had been exceeded. According to his own statement, the flight engineer checked the cargo compartment and ordered the RMS, who did not speak English, to finish the work and leave the airplane. The two RSM followed this order even though they actually wanted to secure the pallet on the right side additionally with straps (without a special instruction). The deputy of the shift supervisor reported to the crew in the cockpit that everything was all right and delivered the documents. The inspection of the main cargo compartment by the flight engineer was performed in a hurry.

During engine start and taxiing, the airplane did not show any abnormal characteristics. The way in which the cargo moved from its position during the take-off run and the fact that all locks on the right hand side were found in the open position leads to the assumption that the pallet had not been locked. This pallet was the only one which had not been moved from its position during the whole off-load and on-load procedure. As a result of the special investigations, however, the possibility that the locks had only partially engaged cannot be completely excluded.

The rejected take-off was conducted by the crew in accordance with the operating procedures of the air carrier. Due to the loss of hydraulic fluid, the main landing gear brakes failed. The crew did not try to switch over to the stand-by system of the second hydraulic circuit. Since the nose wheel during the whole occurrence had no ground contact, steering of the airplane on the runway by the primary controls was not possible. The airplane was steered to the left off the runway by a thrust increase on the right side.

3. CONCLUSIONS

a) Findings

1. The crew possessed the licences and ratings necessary to conduct the flight.
2. The rest periods prior to the beginning of the flight in New York were sufficient. The flight duty periods had not been exceeded.
3. The airplane was duly certificated and maintained.
4. Until the occurrence took place, loading and the centre of gravity were within the admissible limits.
5. The flight was concluded in Frankfurt with a delay. The departure therefore was delayed correspondingly.
6. The procedures established in the Operating Manuals of the air carrier had not been applied. The required checks during loading had not been performed consistently.
7. The RSM (ramp service men) were not supervised by the shift supervisor or his deputy.
8. Besides their language, the RSM only spoke German. There were communication difficulties with the American airplane crew.
9. The reaction of the airplane crew during the rejected take-off complied with the procedures established by the air carrier.
10. Due to the loss of hydraulic fluid, the main gear brakes failed.
11. The crew did not try to switch over to the stand-by system.

12. The accident occurred in daylight.
13. Weather had no influence on the accident.
14. The ground facilities of the airport had no influence on the accident.

b) Probable causes

Even though it has been shown by tests that the side locks, if not correctly engaged, may open when the pallet is pushed sideways, it must be assumed that the shifted pallet had not been secured. The simple design of the locks to restrain the pallets requires thorough visual inspection since the locks do not automatically take a definite open or locked position.

Pressure of time, lack of supervision and non-adherence to operational procedures together with communication difficulties between the crew and the ramp service men led to a chain of unfortunate conditions. The necessary final checks concerning loading, in the end, were omitted or were conducted only superficially.

4. RECOMMENDATIONS

It is recommended to the air carrier to enforce and to strictly supervise the application of operational procedures also at the external stations.

The operational procedures in the Terminals Operating Manual - Aircraft Loading, 500.4 B-1 - should be formulated clearly so that it is obvious who is responsible for the final loading check.

The attention of the airplane crews, and especially that of flight engineers, must be drawn to the consistent application of the procedures of the 747 Operating Manual, Second Officer Pre-flight Inspection, IV Main Deck Inspection.

The ONLOAD CONTROL SHEET for loading in New York found in the airplane had not been signed for the most important positions either.

ICAO Note: The appendices are not reproduced.

ICAO Ref.: 235/83

No. 6

Boeing 747-283B, HK-2910, near Madrid, Spain,
on 27 November 1983. Report No. 1/85 released
by the Accident Investigation Board, Spain.

Synopsis:

The Spanish Accident Investigation Board was notified of the accident at 0400 h on 27 November 1983. The accident occurred in a deserted area of low hills 20 km SE of the airport of Madrid/Barajas.

In accordance with Annex 13 of the International Civil Aviation Organization the accident was reported to the States of registry and manufacture, respectively Colombia and USA.

The accident took place during a scheduled flight from Paris to Madrid performed under instrument flight rules, with instructions to land on runway 33 at Madrid/Barajas Airport.

The aircraft collided with three hills successively and was destroyed by the third impact and subsequent fire, in which 181 of the 192 persons on board lost their lives.

1. Factual information

1.1 History of the flight

Boeing 747, HK-2910, was engaged in a scheduled flight, No. AV-011. It took off from Charles-de-Gaulle Airport (Paris) at 2225:35 on 26 November 1983 for Madrid/Barajas Airport, carrying 169 passengers, a crew of 19 and 4 additional air crew who were off duty.

At take-off the aircraft carried 66 500 lb of fuel and its take-off gross weight was 514 156 lb.

The crew had rested three days in Paris before undertaking the flight.

The normal pre-flight operations were performed and the meteorological information for the flight was requested and supplied.

Take-off was delayed 1 hour 20 minutes to wait for 55 passengers from Frankfurt (Germany) on Lufthansa flight 116 due to cancellation of the segment Paris-Frankfurt-Paris by Avianca for operational reasons.

The flight was scheduled to proceed via Sid Vason, Limoges, Pamplona, Barahona and Castejón. The final contact with French ATC took place at 2331:30 at FL 370:

CRNA/SO France Avianca 11.

AV011 France Avianca 11 Go ahead.

CRNA/SO Avianca 11 France contact Madrid 133.95 Bonsoir.

AV011 Avianca 11 133.95 Roger au revoir.

The first contact with Spanish ATC took place at 2331:50 h:

AV011 Madrid Avianca zero eleven, good morning.
ACC Avianca 011 cleared to Madrid VOR via Pamplona, Barahona, Castejón, reply four one one one.
AV011 Four one one one, cleared to Charlie, Papa, Lima via Castejón aah ..., Barahona Castejón.
ACC Pamplona, Barahona Castejón.

Later on, at 2346:34 h, the aircraft again contacted control to request let-down and was cleared to FL 190:

AV011 Madrid Avianca eleven.
ACC Avianca 011 Madrid.
AV011 Requesting descent.
ACC Avianca 011, Roger, descend and maintain FL 190, over.
AV011 Zero eleven, to 190.
ACC Roger.
AV011 Leaving 37 now.
ACC Avianca 011 Roger.

At 2352:43 ACC transferred the aircraft to Madrid APP, informing it that the flight had passed Barahona and enquiring whether it could be sent direct to Charlie Papa Lima (CPL). APP replied accepting.

Immediately thereafter, starting at 2352:55, the following communications took place:

ACC Avianca 011 passing Barahona. Proceed directly to Charlie Papa Lima and continue descent to level 90, over.
AV011 Nine zero, to Charlie Papa Lima direct.

After this communication the aircraft altered heading to CPL.

At 2356:32 the following exchange took place between ACC and the aircraft:

ACC Avianca 011, contact Madrid APP now one hundred and twenty point nine, over.
AV011 Twenty-nine, Roger, good morning.
ACC Good-bye.

At 2356:44 the aircraft contacted APP:

AV011 Madrid approach, good evening Avianca eleven.

APP Avianca eleven you are still in radar contact and are cleared to approach Barajas runway 33 altimeter one zero two five point seven.

AV011 One zero two five point seven and cleared approach to Madrid.

Later on, at 0000:07 on 27 November, the aircraft again contacted APP:

AV011 Approaching 9 000 ft Avianca ...

APP Roger, you are cleared to approach, continue descent.

AV011 Will do, sir.

At 0001:25 APP coordinated the transfer of the aircraft with Madrid/Barajas TWR.

A final exchange between the aircraft and APP took place at 0003:29:

APP Avianca 011 approaching CPL, continue approach Barajas 33 and tower 1815.

AV011 Good night, thanks.

Immediately following this communication, which took place when the aircraft was approximately 7 NM from the CPL VOR/DME, the aircraft began turning towards the outer marker.

At 0003:56 the aircraft contacted Madrid/Barajas TWR:

AV011 Barajas, good evening, Avianca eleven.

Barajas Avianca zero one one, good evening, cleared to land runway 33, wind 180, 05.

AV011 180, 05 ... Over.

This was the last contact with the aircraft.

The aircraft continued on heading MA, descending until it collided with the ground at an altitude of 2 242 ft.

Site of the accident

The accident took place at 40 deg 24 min 12 sec N and 03 deg 26 min 57 sec W, in the township of Mejorada del Campo (Madrid), approximately 12 km SE of Madrid/Barajas Airport.

Time of the accident

The accident occurred at approximately 0006:24 h on 27 November 1983.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	19	158	4*
Serious	0	11	0
Minor/none	0	0	0

* Additional crew travelling with outflight duties.

1.3 Damage to aircraft

The aircraft was completely destroyed by the impacts and ensuing fire.

1.4 Other damage

N/A

1.5 Personnel information1.5.1 Pilot-in-command

Name:

Nationality: Colombian

Date and place of birth: 02/03/25, Viani, Cundinamarca (Colombia)

Licence

Airline transport pilot: in August 1954. Number: PTL-322

Medical certificate

No. 76977, First Class, valid until 29 February 1984.

Last renewed in August 1983, endorsed "Fit for flight duties, must wear correcting lenses".

B-747 pilot-in-command rating

Issued by the FAA on 7 July 1979.

Last refresher course

Conducted by Avianca at Bogotá on 31 August 1983.

Last flight proficiency check

Done by Avianca on PAA simulator in Miami, USA, on 3 and 4 September 1983.

Types flown for Avianca

DC-3	Co-pilot	Since 31-08-51
C-46	"	" 04-01-52
DC-4	"	" 09-09-52
DC-3	Pilot-in-command	" 02-02-54
DC-4	"	" 22-07-63
B-747	Co-pilot	" 19-09-66
B-727	Pilot-in-command	" 21-10-67
B-707	"	" 21-03-71
B-747	"	" 26-05-79

Hours of flight

Total:	23 215 h 23 min
On B-747:	2 432 h 32 min
In the preceding 30 days:	39 h 39 min
In the preceding 24 hours:	1 h 39 min

Route and airport experience

Between 27 November 1982 and 26 November 1983 he made 25 landings and 23 take-offs at Madrid/Barajas Airport.

Between 1979 and 1983 he flew the Paris-Madrid route 33 times, including 8 times in 1983.

Rest time before the flight

Stay of 72 hours in Paris.

Duty time up to the moment of the accident

3 hours 40 minutes. He had reported for duty at Paris Airport two hours before the flight started.

1.5.2 Co-pilot

Name:

Nationality: Colombian

Date and place of birth: 27-06-47 in Bogotá (Colombia)

Licence

Commercial pilot, dated 15 May 1970. No. PC-1557.

Medical certificate

No. 17185241, First Class, valid until 31 July 1984.

Last renewed on 19 July 1983. Fit without restrictions.

B-747 co-pilot rating

Issued by the Colombian Aeronautical Authority on 22 July 1981 after a course conducted for Avianca by PAA in Bogotá and New York.

Last refresher course

Given by Avianca in Bogotá between 14 and 16 March 1983.

Last flight check

Made by Avianca on the PAA simulator in Miami on 19 and 20 July 1983 with satisfactory results.

Aeroplanes flown for Avianca

DC-3	Co-pilot	since 19-07-73
Avro 748	"	" 25-11-74
B-727	"	" 14-04-77
B-707	"	" 30-08-79
B-747	"	" 22-07-81

Hours of flight

Total:	4 384 h 13 min
On B-747:	875 h 29 min
In the preceding 30 days:	32 h 54 min
In the preceding 24 hours:	1 h 39 min

Route and airport experience

Between 27 November 1982 and 26 November 1983 he made 18 landings and 18 take-offs at Madrid/Barajas Airport.

Between 1981 and 1983 he flew the Paris-Madrid route 16 times, including 8 times in 1983.

Rest time prior to the flight

Stay of 72 hours in Paris.

Duty time up to the moment of accident

3 h 40 min. He had reported for duty at Paris Airport two hours before the flight started.

1.5.3 Flight engineer

Name:

Nationality: Colombian

Date and place of birth: 05-07-26 at Cali (Colombia)

Licence

Flight engineer dated 17 July 1962. No. IDV-024.

Medical certificate

No. 811204, Second Class, valid until 31 January 1984. Required to wear glasses for close work during the performance of his duties.

B-747 flight engineer rating

Issued by the FAA on 23 June 1977.

Last refresher course

Given by Avianca in Bogotá between 23 and 25 May 1983.

Proficiency rating

Performed by Avianca on PAA simulator in Miami on 3 and 4 September 1983.

Aeroplanes flown for Avianca

L-749/1049	Flight engineer	since 06-06-58
B-720/707	"	" 18-10-61
B-747	"	" 30-04-78

Hours of flight

Total:	15 942 h 57 min
On B-747:	3 676 h 20 min
In the preceding 30 days:	33 h 40 min
In the preceding 24 hours:	1 h 39 min

Route and airport experience

Between 27 November 1982 and 26 November 1983 he made 24 landings and 22 take-offs at Madrid/Barajas Airport.

Between 1980 and 1983 he flew the Paris-Madrid route 27 times, including 6 times in 1983.

Rest time prior to the flight

Stay of 72 hours in Paris.

Duty time up to the moment of the accident

3 h 40 min. He had reported for duty at Paris Airport two hours before the start of the flight.

1.5.4 Route controller (ACC)

Name:

Nationality: Spanish

Date and place of birth: 24-01-32 in Seville

Licence No.: A01TC000193

Ratings: Approach radar controller. Dated 01-10-71

Date of entry into ATC: 01-10-62

Last medical check: 30 June 1983. Certified fit for duty.

Rest period prior to duty shift: 24 hours

Duty period up to the moment of the accident: 3 hours

1.5.5 Approach controller (APP)

Name:

Nationality: Spanish

Date and place of birth: 05-01-34 at Aguilar de Campoo (Palencia)

Licence No.: A01TC000359

Ratings: Area control, dated 03-06-75. Approach radar control dated 30-01-80

Date of entry into ATC: 01-11-72

Last medical check: 10 November 1983. Certified fit for service.

Rest time prior to service shift: 24 hours

Duty time up to the moment of the accident: 3 hours

1.5.6 Tower controller (TWR)

Name:

Nationality: Spanish

Date and place of birth: 27-01-38 At Blesa (Teruel)

Licence No.: A01TC000178

Rating: Aerodrome control, dated 20-07-81

Date of entry into ATC: 09-03-67

Last medical check: 3 February 1983. Certified fit for duty.

Rest time prior to start of service shift: 24 hours

Duty time up to the moment of the accident: 4 hours

1.5.7 Tower controller (TWR)

Name:

Nationality: Spanish

Date and place of birth: 23-06-41, Madrid.

Licence No.: A01TC000505

Rating: Aerodrome control, dated 24-04-74

Current rating: dated 21-04-82

Date of entry into ATC: 24-04-74

Last medical examination: 19 October 1983. Certified fit for duty.

Rest time prior to duty shift: 24 hours

Duty time up to the moment of the accident: 4 hours

1.6 Aircraft information

Aircraft type: Boeing 747-283B

Description: Low-wing monoplane, metal structure and skin, powered by four Pratt and Whitney JT9D-70A engines located under the wings. Retractable tricycle undercarriage. The aircraft is pressurized.

Manufacturer: The Boeing Company, USA.

Serial No.: S/N 21381

Date of manufacture: October 1977

Category: Passenger transport

Operator: Avianca since 03-08-82

Registration letters: HK-2910

Owner: Scandinavian Airlines System

Previous registration letters: LN-RNA

Management: Copenhagen Airport, Kastrup, P.O. Box 150 DK2770 Kastrup Denmark

Validity of Certificate of Registration: Unlimited

Certificate of Airworthiness: No. 2789, issued on 22-07-83, valid until 31-05-84

Engines

Make and model: Pratt and Whitney JT9D-70A

POSITION	SERIAL NO.	HOURS SINCE LAST OVERHAUL	TOTAL HOURS
1	689182	4.004:24	12.982:24
2	689183	3.943:46	10.813:46
3	689168	3.595:24	15.577:24
4	688852	4.929:24	14.065:24

Aircraft maintenance record

Total hours: 20 811 h 24 min

Total cycles: 5 800

Hours since last overhaul: 1 476 h 12 min

Cycles since last overhaul: 494

Hours since last A7 service inspection: 285 h

Electronic equipment carried by HK-2910

Description	Type/model	P/N	Manufacturer
H.F. TRANSCEIVER	618T2	522-1501-041	Collins
VHF TRANSCEIVER	618M3A	522-4088-203	Collins
P/A AMPLIFIER	346D-1B		Collins
SELCAL	NA 135		Motorola
TAPE REPRODUCER	108002-04		Sunstrand
VOICE RECORDER	AV 557A	980-6005-056	Sunstrand

Description	Type/Model	P/N	Manufacturer
HF CONTROL PANEL	71 4E-3		Collins
VHF CONTROL PANEL	G2751		Gables
AUDIO SELECTION PANEL	G2750		Gables
COULING TUN. UNIT HF		777-1329-001	Collins
DME INTERROGATOR	860-5/-3	522-4209-001	Collins
ADF RECEIVER	51Y-7	777-1492-001	Collins
ATC TRANSPONDER	621A-6	622-2224-001	Collins
VOR RECEIVER	RNA 26C	2067593-2660	Bendix
MARKER 1	----		-----
WEATHER RADAR	PTI1N		Bendix
ATC PANEL	G2752		Gables
GP.W.COMP.X		965-0476-088	Sunstrand
ALTIMETER	9802-07-05		Clifton
ADI	AV 350		Sperry
HSI	RD 350		Sperry
RMI		259-4661-801	Sperry
ALTITUDE ALERTING		965-0184-001	Sunstrand
FLIGHT RECORDER	ED74 3830-3	981-6009-014	Hamilton
INS SYSTEM		788-3450-041	Delco
LOW RANGE RADIO ALT.	860F1	522-3698-014	Collins
MACH AIRSPEED IND.	A43217100007		Kollsman
STAND BY HORIZONT	705-7V4		Sfena
PICH COMPT		259-0622-929	Sperry
ROLL COMPT		259-0623-908	Sperry
A/P PANEL		259-0624-929	Sperry
YAM DAMPER COMP.	1964212-2		Bendix
CENTRAL AIR DATA C.	3757183-2		Bendix
FLIGHT CONTROLLER	60B00013-402		Sperry

Modifications made to comply with FAA Airworthiness Directives

<u>AD. NO.</u>	<u>TITLE</u>	<u>ACFTTT/TC</u>	<u>DATE</u>
77-25-06	Cabin press, out-flow valve	774/298	27 JAN 78
78-07-09	Cargo Compt. Lining	2043/681	23 MAY 78
78-08-04	Cabin press, out-flow valve	3561/1004	19 SEP 78
78-09-08 RI	Floors beam lower chords and web etc.		
78-16-05	No. 4 bearing compt.		
78-25-06	Wing trailing edge flap	4760/1269	19 DEC 78
		7748/1970	03 SEP 79
79-06-02	Main fuel tank pump wiring	6373/1655	15 MAY 79
79-09-03	Aural warning switch	5970/1569	08 APR 79
79-18-02	Slide/raft firing and pack board lanyards	12187/2922	15 OCT 80
79-20-11	Outboard wing fuel compo- nents el. bonding	12059/2906 13068/3045	01 OCT 80 13 JAN 81
80-01-05 RI	Crew seat belt	10381/2613	21 MAY 80
80-19-05	Leading edge flap control circuit	16371/3584	17 JAN 82
80-20-01	Fuselage. Addition of radius fillers	13068/3045	13 JAN 81
80-20-02	Replacement of defect flapper valve.	16355/3581	31 DEC 81
81-06-02	Emergency descent devices	16182/3559	05 DEC 80
81-06-02	Off-wing scape slide firing cable. Rigging.	16232/3565	11 DEC 81

Defects recorded by the crew

According to the flight log book, the following repair jobs were still outstanding:

- No. 117: "Autothrottle only works T/O and cruise, in Mach in climb and cruise speed retard the throttles".
- No. 201: "Eng. Reverser. Eng. No. 1 reverser amber light stuck blinking from T/O".

No. 203: "Engines thrust lever engine No. 4 is spring load and in the heat in idle position".

According to MEL items 22-4 and 78-1, the aircraft was airworthy.

1.7 Meteorological information

The following is a transcript of the meteorological information available at Barajas as supplied by the Spanish Meteorological Service:

26 November 1983 at 2300 h

Wind direction: 140°, windspeed: 4 kt

Visibility: 8 km

Cloud cover: 1 000 ft mist

3/8 stratus at 1 000 ft

5/8 stratocumulus at 1 800 ft

Temperatures: Ambient: 11°C

Dewpoint: 10°C

Barometric pressure: 1 025 mb equivalent to 30.28 inches.

27 November 1983 at 0000 h

Wind: Calm

Visibility: 8 km

Clouds: 1 000 ft mist, 3/8 stratus at 1 000 ft, 5/8 stratocumulus at 1 800 ft.

Temperature: Ambient: 11°C

Dewpoint: 10°C.

Barometric pressure: 1 025 mb equivalent to 30.28 inches.

27 November 1983 at 0100 h

Wind direction: 150°, windspeed: 5 kt

Visibility: 8 km

Cloud cover: 1 000 ft mist, 3/8 stratus at 1 000 ft, 5/8 stratocumulus at 1 800 ft.

Temperatures: Ambient: 11°C

Dewpoint: 10°C

Barometric pressure: 1 024 mb equivalent to 30.25 inches.

27 November 1983 at 0200 h

Wind direction: 140°, windspeed: 5 kt

Visibility: 8 km

Cloud cover: 1 000 ft mist, 3/8 stratus at 1 000 ft, 5/8 stratocumulus at 1 800 ft.

Temperature: Ambient: 11°C

Dewpoint: 10°C

Barometric pressure: 1 023 mb equivalent to 30.22 inches.

In the above-mentioned period meteorological conditions at Barajas were very stable.

About 20 minutes prior to the impact the aircraft obtained meteorological information on Barajas on the Avianca Company frequency as follows (transcribed from the CVR):

"Roger, Captain. Confirm present weather Madrid: wind 140°, 8 kt; visibility 8 km; mist; 3 stratus at 1 000 ft; 5 stratocumulus at 1 800 ft; temperature one one; dewpoint one zero; altimeter one zero two five; runway in service three three; parking sixty-two; six two..."

1.8 Aids to navigation

Castejón NDB

Call sign: CJN

EM: NON A2A

Transmits on: 362 KHz

Hours of operation: 24 hours

Coordinates: 40 deg 22 min 56 sec N; 02 deg 31 min 26 sec W

Observations: Coverage 40 NM 0.06 Kw

Castejón VOR/DME

Call sign: CJN

EM: A9W/PON

Transmits on: 115.6 MHz

Hours of operation: 24 hours

Coordinates: 40 deg 22 min 15 sec N; 02 deg 32 min 50 sec W.

Observations: Range:
069°/7 500 ft 70 NM
002°/5 500 ft 27 NM
143°/5 500 ft 35 NM
0.2 Kw. DME, Ch 103 X
Elev. 1 060 m

The instrument approach aids to runway 33 at Madrid/Barajas Airport are the following:

Campo Real VOR/DME

Call sign: CPL
EM: A9W/PON
Transmits on: 114.5 MHz
Hours of operation: 24 hours
Coordinates: 40 deg 19 min 28 sec N; 03 deg 22 min 15 sec W.
Location: 141° 11.1 NM from threshold RWY 33, 0.1 Kw. Ch 92 x
 elev. 783 m.

ILS/LLZ

Call sign: MAA
EM: A8W
Transmits on: 109.9 MHz
Hours of operation: 24 hours
Coordinates: 40 deg 29 min 19 sec N; 03 deg 34 min 44 sec W
Location: 330 deg 0.29 NM from threshold RWY 15, 0.025 Kw,
 coverage 25 NM
 Height ILS datum 16.6 m

GP

EM: A8W
Transmits on: 333.8 MHz
Hours of operation: 24 hours
Coordinates: 40 deg 27 min 35 sec N; 03 deg 32 min 45 sec W.
Observations: Located 300 m from threshold runway 33 and 120 m to
 the right of the runway centre line in the approach
 direction.
 Angle 3 deg.

OM

EM: A2A
Transmits on: 75 MHz
Hours of operation: 24 hours
Coordinates: 40 deg 24 min 03 sec N; 03 deg 29 min 29 sec W
Location: 150 deg 4.15 NM from the threshold of runway 33

LO

Call sign: MA
EM: A2A
Transmits on: 390 kHz
Hours of operation: 24 hours
Coordinates: 40 deg 24 min 03 sec N; 03 deg 29 min 29 sec W
Location: 150 deg, 4.15 from threshold RWY 33, 0.05 Kw
Observations: Coverage 30 NM

MM

EM: A2A
Transmits on: 75 MHz
Hours of operation: 24 hours
Coordinates: 40 deg 26 min 54 sec N; 03 deg 32 min 21 sec W
Location: 150 deg, 0.56 NM from the threshold of runway 33

LM

Call sign: AA
EM: A2A
Transmits on: 355 kHz
Hours of operation: 24 hours
Coordinates: 40 deg 26 min 54 sec N; 03 deg 32 min 21 sec W.
Location: 150 deg, 0.56 NM from the threshold of runway 33,
0.05 Kw
Observations: Coverage 30 NM

Performance characteristics of Madrid radarsSite ASR 4/5

Primary radar	TX frequency	Peak power	Range
ASR 4/5	Channel A: 2850 MHz Channel B: 2840 MHz	425 Kw	60 NM
Secondary radar	Frequency	Peak power	Range
ANTPX-42/A	TX: 1030 MHz RX: 1090 MHz	2 Kw	150 NM

Site SELENIA

Primary radar	TX frequency	Peak power	Range
ATCR 44	Channel A: 1330 MHz Channel B: 1280 MHz	500 Kw	80 NM
Secondary radar	Frequency	Peak power	Range
IRS-10	TX: 1030 MHz RX: 1090 MHz	2 Kw	200 NM

1.9

CommunicationsRoute-ACC

Service: UIS/FIR/RSR/ACC

Call sign: Madrid Control

EM: A3E

Transmits on: Bilbao sector: 127.1 MHz; 134.45 MHz
 Zaragoza sector: 133.95 MHz
 Castejón sector: 128.7 MHz; 133.85 MHz
 Emergency: 121.5 MHz

Hours of operation: 24 hours

Approach-APP

Service: APCH/ASR

Call sign: Madrid APCH

EM: A3E

Transmits on: 120.9 MHz/119.9 MHz; 121.5 MHz in emergency;
 120.9 MHz on standby

Hours of operation: 24 hours

Take-off-DEP

Service: DEP/ASR
Call sign: Madrid Despegues
EM: A3E
Transmits on: 118.4 MHz; 121.5 MHz in emergency
Hours of operation: 24 hours

Tower-TWR

Service: TWR
Call sign: Barajas
EM: A3E
Transmits on: 118.15 MHz; 121.7 MHz in rotation;
121.5 MHz in emergency
Hours of operation: 24 hours

Each and every one of these aids receives on the same frequency on which it transmits and is fitted with recording devices, so that all the communications were recorded.

1.10 Aerodrome information

The elevation of Madrid/Barajas Airport, referenced to the approach end of Runway 15, is 609 m (1 998 ft) AMSL.

The geographical coordinates of the airport reference point (REFP) are: 40 deg 28 min 24 sec N; 03 deg 33 min 49 sec W.

There are two take-off and landing runways: runway 01/19 and runway 15/33, both paved with asphalt.

Runway 01/19 is 3 700 m long and 45 m wide and its true bearings are 001 and 181 deg. The elevation of the 01 end is 594 m (1 948 ft), and the elevation of the 19 end is 590 m (1 936 ft).

Runway 15/33 is 4 100 m long and 45 m wide, and the true bearings are 143 deg and 323 deg. The elevation of the approach end of runway 15 is 609 m (1 998 ft), and that of the approach end of runway 33 is 581 m (1 906 ft).

Madrid/Barajas Airport is equipped with the necessary light markers for night-time operations.

1.11 Flight recorders

The aircraft was equipped with a digital flight data recorder and a cockpit voice recorder, both of which were recovered on the day of the accident in acceptable condition.

The DFDR yielded the flight path from approximately 5 min prior to impact up to the moment of impact.

Two master copies and various other copies were made of the CVR for the purposes of the Board and for transcription.

Digital flight data recorder

Manufacturer: Sunstrand

Type and model: ED 743830-3

P/N: 981-6009-014

S/N: 2578

This model records a total of 64 parameters.

Cockpit voice recorder

Manufacturer: Sunstrand

Type and model: AV 557A

P/N: 980-6005-056

This model carried four recording channels.

These channels were connected as follows:

One of the channels recorded what the pilot-in-command heard over his headset.

Another channel recorded conversations between the pilot-in-command, co-pilot and flight engineer picked up by their microphones.

The remaining channel recorded the voices in the cockpit environment.

Only the last-named channel could be used, as the crew did not use their headsets or microphones for internal communications.

1.12 Wreckage and impact information

The debris of the aeroplane were scattered as a consequence of the three impacts.

FIRST IMPACT

At 0006:19, the moment of first impact, the aircraft's configuration was 20 degrees flaps, gear down, speed 142 kt IAS, altitude 2 247 ft MSL, heading 284 degrees, turbines on idle power, 5 degrees nose-up, 6 units of trim nose-up and G + on impact, rate of descent 1 016 ft/min.

This impact was made by the main gear, except the left wing gear, on a hill. Turbine No. 4 also impacted the hill, leaving the lower fairing and part of the engine accessories box at the scene. The right wing tip collided with a tree about 4 to 5 m high, slicing off approximately the top third. Part of the right outside aileron and the wing tip were fractured.

SECOND IMPACT

This occurred on a second hill approximately 240 m from the first impact. According to the DFDR a momentary application of power took place between the first and second impact. The second hill has roughly the same elevation as the first.

On second impact the speed of the aeroplane was 135 kt IAS, heading 290 degrees, 4.9 degrees nose-up, 3 units of trim nose-up, 3 G +.

Traces were found there of two wheels, apparently belonging to the main gear.

Immediately after the first impact, two whistle blasts can be heard on the CVR which in this case, according to the aeroplane manual, signify that the spoiler control lever was in the extended position and that the No. 3 engine accelerator lever had been pushed forward through more than 50% of its travel.

The time that elapsed between the first and second impacts was 3 seconds.

THIRD IMPACT

This took place approximately 6 seconds after the preceding impact against a hill of similar elevation to the two previous ones and approximately 320 m away from the second.

The probable speed of the aircraft was 126 kt. On this third hill the aircraft struck the ground with its right wing, which broke off and, with engine No. 3 attached, followed a different trajectory to the rest of the aircraft.

The upper right portion of the fuselage struck the ground and broke into five pieces which slid over the surface on different trajectories, although they could all be said to have the same component, leaving debris scattered over a wide area.

Between the second and third impacts, due to the reduced lift of the right wing, its degradation and the loss of No. 4 engine, the aircraft began cartwheeling in a clockwise direction and came to rest upside down.

1.13 Medical and pathological information

As a consequence of the third impact and the inverted position in which the aircraft collided with the ground, the possibilities of survival were very small.

This fact, combined with the immediate outbreak of fire, militated against the possibility of many of the occupants surviving.

When the positions occupied by the surviving passengers were studied, it transpired that nine were ejected out of the aeroplane - a few of them with their seats still attached - and two of them claimed to have exited the aircraft by their own efforts. They were all suffering from serious injuries, mainly involving cranial-encephalic trauma, and a few - although they had been projected outside the aircraft by their own inertia - suffered burns of varying degrees.

All the survivors were seated in or near areas where structural fractures occurred as a consequence of impact.

From the studies performed it was ascertained that 35% of the victims died from the effects of fire, 30% from multiple injuries and the remainder from the combined effects of physical injuries and inhalation of toxic gases generated by the fire.

Autopsies and toxicological tests were performed on the flight crew with negative results as far as the pilot-in-command and co-pilot were concerned.

The toxicological tests performed on the body of the flight engineer revealed the presence of medozepan, which was found to be a component of some mild tranquilizing drug, which suggests that he was either treating himself with drugs or was being treated by a doctor not specialized in aviation medicine.

1.14 Fire

The fires were caused by combustion of the aircraft fuel consequent upon impact with the terrain and there is no evidence of any other contributory factor independent of the accident.

The principal outbreaks occurred in the main area of the debris and immediately engulfed every part of the fuselage.

The first information concerning the approximate whereabouts of the fire reached a fire station about 20 minutes after the accident. As the locality was an agricultural one that could only be reached by cart tracks, rapid access to the scene of the accident was difficult.

The first fire-fighting vehicles and personnel arrived at approximately 0058:00 h from fire stations in the nearby municipalities.

The fire was considered to be fully extinguished approximately two hours after it had broken out.

1.15 Survival aspects

It was noted that the passengers had their seatbelts fastened and that the latter withstood the forces generated by the impact. The injuries sustained by most of the victims indicate that they were caused by the top and sides of the passenger cabin, due to the upside-down position in which the aircraft struck the ground on final impact.

The immediate outbreak of fire and subsequent generation of toxic vapours may well have prevented the survival of some of the passengers located in the central part of the fuselage.

All the survivors except two, who apparently extricated themselves by their own efforts, were projected out of the aircraft. These survivors were evacuated immediately by police vehicles, which were the first to reach the accident site.

Heavy cranes had to be used to recover the corpses trapped under the debris of the fuselage.

1.16 Test and research

The checks run on the radio aids show that they were all operating correctly.

An aerial survey of the accident area did not turn up anything that could have been relevant to the cause of the accident, and the meteorological information rules out the possibility of turbulence, downdraughts or mountain waves in the vicinity of the site.

The investigations conducted on the aircraft and its crew at the site did not produce any evidence that could be significant in the accident.

1.17 Additional information

1.17.1 Ground proximity warning system

The ground proximity warning system (GPWS) operates automatically and continually between 50 and 2 450 feet on the radio altimeter and emits audio and visual alarms whenever the flight path of the aeroplane leads to a condition (MODE) involving a ground collision hazard. The system is not capable of detecting vertical obstacles unless they are preceded by a certain slope in the terrain, and would not give warning of ground proximity where there is no runway if the aeroplane configuration is the normal one for landing as regards flaps, landing gear and rate of descent.

The GPWS uses the following inputs in its calculations:

- Height (radio altimeter)
- Vertical speed (air data calculator)
- Mach number (air data calculator)
- Deviation from glide path (ILS receiver)
- Flap setting
- Position of landing gear.

These establish the 6 Modes or types of hazardous situations, each of which is identified and brought to the attention of the crew by a common warning light and a specific audio message transmitted over the cockpit speakers. The warning light is a red light labelled "GPWS" or "PULL UP" for Modes 1 to 4 and an amber light labelled "BELOW G/S" for Mode 5. No warning light appears for Mode 6.

The acoustic warnings are described hereunder in the general description of the computer modes of the GPWS fitted to the subject aircraft - a Sundstrand MARK II Data Control P/N 965-0476-088.

MODE 1: EXCESSIVE RATE OF DESCENT

Is activated when the GPWS detects that the vertical speed is exceeding a predetermined threshold value for a given radio altimeter height. The acoustic alert begins with the message "SINK RATE" repeated until the aircraft returns below the threshold determined by the Mode. If excessive rate of descent continues, the message changes to "WHOOOP-WHOOOP PULL UP" repeated continually until a height of 50 feet is attained, when all alerts are terminated on all Modes. Mode 1 operates independently of the flap and landing gear configuration.

MODE 2: EXCESSIVE RATE OF TERRAIN APPROXIMATION (CLOSURE RATE)

Is activated when the distance between the aircraft and the ground diminishes at a rate in excess of a preset threshold value, determined either in relation to the elevation of the terrain alone, or a combination of ground elevation and rate of descent (the rate of descent case by itself is taken care of by Mode 1).

The various sub-modes are differentiated according to flap settings:

- 2A) Flaps extended beyond landing settings: the alerts may begin at 1 650 feet for maximum closure rates and Mach number 0.35 or below. The point of initiation is delayed in proportion as the Mach number increases (to allow for greater response time) up to 2 450 feet at Mach 0.45 or above. The acoustic alert consists of the message "TERRAIN TERRAIN" followed by "WHOOOP-WHOOOP PULL UP" repeated as long as the conditions of mode activation persist. When these are lifted by corrective action by the crew or levelling of the relief, the signals do not cease but change to "TERRAIN" repeated until the aircraft climbs to a (barometric) altitude of at least 300 feet above that which existed at the last "PULL UP". Otherwise they cease when 50 feet above ground level is reached.
- 2B) Flaps in landing positions: The mode begins at 790 feet and, unlike all the others, does not conclude at 50 feet but, in order to avoid unwanted activations in normal landings, is adjusted to finish between 200 and 600 feet depending on the vertical velocity. The messages are the same as for 2A except that they cease as soon as the aircraft leaves the trigger threshold of the sub-mode without it being necessary to climb the extra 300 feet. Moreover, if the landing gear is extended, the "TERRAIN" signal sounds instead of "WHOOOP-WHOOOP PULL UP" below 700 feet.

MODE 3: DESCENT FOLLOWING TAKE-OFF

An alert is sounded for losses of altitude following take-off prior to attainment of 700 feet. A "DON'T SINK" message is heard if the aircraft loses barometric altitude equivalent to approximately 10% of the radio altimeter altitude at which the loss of altitude commenced. The alert is cancelled when the aircraft levels out or re-initiates climb.

MODE 4: INADVERTENT PROXIMITY TO THE GROUND

Provides protection against excessive ground proximity when the aeroplane is not in landing configuration and the rate of descent or the ground elevation is small.

- 4A) Landing gear retracted: Below 500 feet and at Mach 0.35 or less, the message "TOO LOW GEAR" is repeated until the gear is extended or altitude is gained. Above Mach 0.35 and at heights below 1 000 feet the warning is "TOO LOW TERRAIN", which is cancelled when the conditions of entry no longer obtain.
- 4B) Flaps extended beyond landing settings: below 200 feet and Mach 0.29 or less, the signal "TOO LOW FLAPS" is repeated until the flaps are set for landing or height is gained. Above Mach 0.29 and for heights below 1 000 feet the signal is "TOO LOW TERRAIN", which is cancelled when the conditions of entry no longer obtain.

MODE 5: DESCENT BELOW GLIDE PATH

Detects displacement of the aircraft below the ILS glide path. The acoustic warning has two phases - a gentle alert in which the message "GLIDESLOPE" is emitted at low volume for deviations of 1.3 or more dots below the glide path, provided that the aeroplane is below 1 000 feet. In the loud alert phase the same message "GLIDESLOPE" is spoken at higher volume when the deviation reaches or exceeds 2 dots and the altitude is below 300 feet.

This mode can be voluntarily inhibited by the crew after initiation by depressing a push-button for the purpose and has to be re-armed afterwards when the aeroplane goes below 50 feet or above 1 000 feet.

MODE 6: DESCENT BELOW MINIMA

During landings in adverse meteorological conditions the decision height ("bug" DH) selected on the radioaltimeter is made known by the GPWS through a spoken message "MINIMUMS" when this altitude is reached.

1.17.2 Inertial navigation system installed on the aircraft

The subject aircraft carried a DELCO inertial navigation system, Model Carousel IV, and P/N 788-3450-041.

Purpose of the system

- The Inertial Navigation System is a navigation and guidance system independent of ground-based navigational aids.
- The system computes deviations in the aeroplane's attitude in pitch, roll and yaw referenced to the local horizontal and vertical.
- The INS output data are used to guide the aeroplane automatically along a predetermined route, stabilize the radar, stabilize the signals of the magnetic compass system and display aircraft navigation and attitude data on the instruments.
- With the aid of air data input (TAS) the INS also supplies wind speed and wind direction data.
- The system is usually a triple installation, each system having its own control display unit.

Navigation Information

When the INS is operating the pilot can:

- Store a flight plan for a great circle flight.
- Update the flight plan before or during the flight.
- Obtain navigation and guidance data relating to the stored flight plan, e.g.:
 - Track angle and ground speed.
 - Heading (geographical north) and drift angle.
 - "Off-route" (cross-track) distance and track angle error relative to desired track.
 - Present position.
 - Time and distance to any way-point on the flight plan.
 - Time and distance between any two way-points en route.
 - Total time and distance to go in the flight plan.

- Desired track angle for the current segment.
- Time and distance between present position and any point on the route.
- Manual update of present position.
- Flight on parallel tracks to those provided in the flight plan.

System Description

The system consists of four units:

- Mode Selector Unit (MSU)
- Control Display Unit (CDU)
- Inertial Navigation Unit (INU)
- Battery Unit (BU)

Each system is automatically aligned and calibrated.

Each system continuously monitors its own operation and supplies failure warning codes whenever the output signals become undependable. These codes enable corrective action to be taken and the cause of the anomaly to be identified.

In a triple installation the 3 navigation units are self-checking.

In case of damage to the computer the system has an ATT (attitude mode) in which the INS behaves as an inertial platform, supplying attitude signals only. In this mode the control display unit does not operate.

Tolerances

a) Navigation accuracy

As a general rule, the permissible radial error shall not exceed 2 NM per hour of flight.

b) Terminal position error (ETP)

ETP is defined as:

$$\text{ETP} = \frac{\text{"Distance to go residual"}*}{\text{INS operating time in NAV mode (hours)}}$$

* Radial error between the actual position of the aeroplane on the apron and the INS computed position at the end of the flight.

The action to be taken using the ETP and Ground Speed Residual criteria are shown in the following Table:

G/S RESIDUAL	TERMINAL ERROR	ACTION TO BE TAKEN	
		DC-8 DC-10 B-747 A-300	
0 to 14 knots	E.T.P. \leq 3NM/H	NONE - INU WITHIN TOLERANCE	
	3NM/H \leq ETP \leq 5 NM/H	CHECK WHETHER ANY ENTRY OF E.T.P. OF 3 TO 5 NM/H LASTING MORE THAN 1 HOUR HAS BEEN MADE ON THE TWO PRECEDING FLIGHTS.	IF SO, DISMOUNT THE EFFECTED INU. IF NOT, WRITE IN FLIGHT LOGBOOK "OBSERVE INS No. - ON NEXT FLIGHTS".
	E.T.P. $>$ 5NM/H	DISMOUNT THE AFFECTED INU	
	-	IF THE G.S. RESIDUAL HAS BEEN \geq 15 Knots DURING THE FLIGHT OR PRIOR TO DEPARTURE, DISMOUNT THE AFFECTED INU.	
\geq 15 knots	-		

1.17.3 Instrument and precision approaches to runway 33 at Madrid/Barajas

The instrument approach manoeuvres to runway 33 shown in AIP-Spain are the following:

Inbound from the first quadrant:

- a) IAL/3 ILS CAT I RWY33 as of 29-04-83.

This manoeuvre consists of the following:

Proceed to VOR CPL, crossing it at 4 000 feet and leaving it by radial 297 maintain 4 000 feet until intercept intermediate approach point, follow localizer course heading 329° until intercept glide way at final approach fix at 4 000 feet, descending glide path to cross outer marker at 3 282 feet and middle marker at 2 142 feet.

- b) IAL/4 GP U/S as of 29-04-83.

Manoeuvre to be used if ILS glide path is inoperative.

The flight paths are the same as described in IAL/3. The difference consists in maintaining altitude 4 000 feet between VOR CPL and the intermediate approach fix (IF), crossing the marker (MA) which in this case is the final approach fix (FAF) at minimum altitude 3 300 feet, continuing descent to cross the marker (AA) at 2 230 feet.

- c) IAL/5 LO RWY33 as of 29-04-83.

Leave VOR CPL by radial 285 maintaining 4 000 feet until intercept and follow magnetic heading 329° direct to marker (FAF), crossing at 3 300 feet and continuing on same heading until reaching altitude 2 370 feet on 11 DME of VOR CPL (MAPT).

d) IAL/6 LO-LM RWY33 as of 29-04-83.

Manoeuvre exactly the same as preceding with the exception that it can only be used by aircraft carrying dual ADF.

It will be noticed that all these manoeuvres share the VOR DME of CPL as main aid on the arrival, initial approach and start of intermediate approach segments.

2. Analysis

The following analysis is based in the main on the CVR and DFDR records and the magnetic tape records of ATC communications with the aircraft and internal exchanges on the ground.

It proved extremely difficult to decipher some of the phrases spoken in the cockpit conversations owing to the fact that - except for exchanges with the ground - they were picked up entirely via the flight deck microphone.

2.1 Development of the flight

From the moment of take-off at Charles-de-Gaulle Airport, (Paris) at 2225:35 hours on 26 November 1983 until approximately 2326 hours, when the CVR record begins, the analysis is limited to the data provided by the radar trajectory and the communications with the French and Spanish control centres.

The aircraft followed its planned route at level 370, which was assigned to it.

From 2326 hours on, approximately, the analysis is supplemented by inclusion of the CVR tape recording.

Between 2326 hours and 2340 hours the crew was endeavouring to make radio contact on the company frequency with Avianca Operations at Eldorado (Bogotá). At 2340 the crew tuned its receiver to VOR-DME CPL (Madrid), estimating the distance at 132 miles.

Later on, being unable to make contact with Eldorado, the crew did so with Avianca Operations at Madrid-Barajas and exchanged various communications with this office.

At approximately 2346 hours the aircraft contacted Madrid-ACC to request descent. According to the CVR the crew commented among themselves that they were 107 miles away which, according to the last distance referred to, also corresponds to VOR-DME CPL. Thereafter ACC cleared the aircraft to descend and maintain FL 190, and this was confirmed by the crew who added that the aircraft was leaving FL 370. This took place approximately 30 miles before Barahona.

Various comments were then exchanged in the cockpit, practically none of which had anything to do with the flight, until 2352:50 hours when the pilot-in-command asked the co-pilot for their position.

From the cockpit conversations, co-ordination between ACC and APP and the message from ACC to the aircraft, it is clear that the latter crossed Barahona at approximately 2352:20 hours.

According to the CVR the aircraft left Barahona and ACC cleared it to proceed direct to CPL and continue descending to FL 90.

From the radar plot and the crew conversations recorded on the CVR it is fairly clear that the turn towards CPL was made about 3 minutes after crossing Barahona.

At 2356:32 hours, ACC-Madrid transferred the aircraft to APP and the crew made contact with the latter 12 seconds later. APP informed it that it still had radar contact and cleared it on approach to runway 33 at Barajas. The clearance was partly read back by the co-pilot.

There followed a few remarks unrelated to navigation and at 2358:23 hours approximately the altitude alert sounded, indicating that there was still 700 feet to go before reaching 9 000, which was the altitude selected.

Later on, the checks of the ILS approach chart to runway 33 were initiated prior to the manoeuvre and the pilot-in-command gave the order to tune to the MA frequency. The chart checks and descent list continued and were interrupted to notify APP that the aircraft had reached 9 000 feet. A fresh approach and continued descent clearance was received and acknowledged by the crew, which then returned to the descent checklist.

At 0002:36 (3:43) hours, the altitude alert sounded again, possibly indicating that 4 700 feet had been reached, since 4 000 had been selected.

Two minutes after setting 5° flaps, at 0003:16 (3:03) hours, the pilot-in-command ordered the gear down. Thirteen seconds later (0003:29) APP contacted flight AV011, transferred it to Barajas TWR and signed off.

While the communication with APP was taking place, the pilot-in-command began a turn on the autopilot but disconnected it after approximately the first third had been completed and re-connected it when the aircraft was heading towards MA.

During the turn the crew started the landing checklist and contacted Barajas TWR, which replied clearing to land on runway 33 and confirming the wind data. The crew selected 10° flap.

With the aircraft heading towards MA they began a gentle descent which subsequently increased without at any time exceeding the rate of 1 250 feet/minute.

About five seconds prior to impact the crew switched off the automatic pilot, probably as a consequence of the GPWS alert which had begun to sound 9 seconds before.

From the damage sustained by the aircraft on the first impact and the very short interval which elapsed between this impact and the following one, it is clear that the aircraft could not have been controlled by the crew.

2.2 Crew action

There is no evidence of any anomaly in Paris prior to this flight. The crew had stayed in the city 72 hours after arriving on flight AV010 on the first day, 24 November 1983.

Up to Saturday, 26 November, in the morning the crew understood that its flight would be Paris-Bogotá, without stopping at Madrid, for operational reasons of Avianca. Around mid-day on the same Saturday they were informed that the flight had been suspended and that they would perform Paris-Madrid only, after which the flight crew would remain on stand-by in Madrid until the following Tuesday and the auxiliary crew would continue the flight to Bogotá.

The flight crew performed the pre-flight operations. The only point worth noting is the delay of 1 hour 20 minutes which intervened while the aircraft waited for the 55 passengers from Frankfurt on Lufthansa flight 116 to arrive in Paris.

The aircraft took off at 2225:35 hours on 26 November 1983 from Charles-de-Gaulle Airport (Paris).

Neither the radio communications with French ATC nor the flight path of the aircraft through French airspace suggest any abnormality.

At 2331:30 hours, the aircraft was transferred from French ATC to Spanish ATC. It contacted ACC Madrid 20 seconds later, when it was flying at FL 370.

During this contact, when the co-pilot tried to read back the route assigned by ACC Madrid, he omitted two of the way-points and, in correcting himself, again omitted one of them. This fact must be noted in the analysis because errors of this sort in crew reports and contacts - especially in the reading of figures - occur frequently and in some cases are fundamental.

In passing over Pamplona the crew did not report overhead this point or inform control as required.

On the Pamplona-Barahona segment the crew twice mentioned its DME distance to the Madrid VOR (CPL).

At 2351:50, approximately 30 seconds before crossing Barahona, the pilot-in-command requested his position from the co-pilot. The latter was apparently tuning the VOR receiver and the pilot-in-command asked again whether he was selecting the Castejón VOR. The co-pilot replied that it was Barahona and mentioned the wrong frequency for the latter. When questioned by the pilot-in-command concerning this information he corrected the frequency figure. The pilot-in-command confirmed the frequency and pointed out that they were already passing Barahona.

Immediately thereafter it appears from the CVR tape that they selected the Castejón VOR and a comment by the co-pilot suggests that the aircraft was aligned on Castejón.

Approximately 35 seconds after it passed Barahona, ACC informed the aircraft that it was passing Barahona and cleared it to proceed direct CPL and descend to FL 90. The crew acknowledged.

After the pilot-in-command asked whether the clearance was direct to CPL, the co-pilot apparently attempted to insert the co-ordinates of the Madrid VOR into the INS. This is borne out by the subsequent comments, since the number which appears in the CVR transcript is "four forty-four" which is the distance in NM from the position of the aircraft to the first INS way-point after departing Paris TMA; this and the following remarks by the co-pilot indicate that the latter was having difficulties in inserting the CPL co-ordinates or that he punched the new point believing that it was VOR Madrid.

At 2353:23 the pilot-in-command realized that the co-pilot was having difficulties and suggested that he head for the VOR and ask the frequency. The co-pilot replied and gave the frequency, but did not select the VOR navigation system on the autopilot, with the result that the aeroplane continued flying towards Castejón in accordance with the INS instructions.

The pilot-in-command appears to have had doubts as to whether the CPL position had been inserted in the INS.

Later on he enquired whether they were cleared to FL 90, to which the co-pilot replied with a figure of "two nine nine". It was not possible to determine what this referred to and as a consequence the pilot-in-command repeated the question. This time the co-pilot confirmed clearance to FL 90.

The co-pilot gave the latitude of CPL and the pilot-in-command apparently began to insert it in the INS. Afterwards, the co-pilot gave the longitude and from the comments and repetitions between co-pilot and pilot-in-command it appears to have been the latter who inserted the CPL co-ordinates in the INS.

At approximately 2355:50 hours after these steps had been completed, the aircraft began turning towards CPL.

At 2356:10 a member of the cabin crew entered the cockpit to report on assistance rendered to a woman passenger and the pilot-in-command took the opportunity to pass the message that the auxiliary crew would take over for the flight to Bogotá.

At 2356:32 Madrid ACC contacted the aircraft and transferred it to Madrid-APP. The crew acknowledged and signed off, responding to the ACC greetings.

The aircraft immediately got in touch with Madrid-APP, which replied that it was still in radar contact, and cleared it to approach runway 33 at Barajas. The altimeter setting was provided and the co-pilot read back part of the clearance.

At 2357:46 a stewardess entered the cockpit and requested confirmation that the auxiliary crew would take over to Bogotá.

At 2358:30, when they were close to 9 000 feet, the co-pilot began the ILS approach chart checks to runway 33, giving the elevation of the airport.

The pilot-in-command immediately said "switch to the marker"; the pilot gave the final approach heading and localizer frequency, which the pilot-in-command repeated. The co-pilot went on to indicate that the crossing altitude of the marker was 2 382.

This information contained a reading error inasmuch as the digits for the thousands and hundreds were reversed, the correct figure of three two eight two being read out as two three eight two.

It appears that the pilot accepted this figure as valid since he did not correct the co-pilot, possibly because he only heard the last three digits (nine nine eight) of the airport elevation, in which case the difference from the figure two three eight two is logical, although it can be affirmed with certainty that he did not check his approach chart.

This may be the reason why the pilot-in-command continued descending below the 3 282 feet without having reached the marker.

At 2359:54 the pilot called for the descent check which began as follows:

F/E:	Landing Data
Captain:	Bugs Set
F/E:	Fuel set for landing

The list was interrupted when the pilot-in-command instructed the co-pilot to radio when they reached 9 000, although at the same time he asked if they were cleared. To this the co-pilot replied "We must go down further". Nevertheless, he informed APP that they were approaching 9 000 feet and APP confirmed "You are cleared to approach. Continue descent". The co-pilot repeated "will continue descent". The crew resumed the checklist, setting the altimeters to the local QNH. At this point the co-pilot had another hesitation in saying "Ten twenty-four Ten twenty-six, twenty-five point seven".

The flight engineer said "In board landing lights". Before answering this point on the list, the pilot-in-command called for flaps one, co-pilot confirmed and the pilot then responded to the previous point on the list which was pursued until once again the pilot commented "ready for ILS". Later on, after adjusting the radio altimeters to 200 feet, they completed the descent checklist.

At 0001:15 (5:04) hours the pilot-in-command called for flaps five and the co-pilot acknowledged and executed the order. At this moment the aircraft was flying at approximately 7 500 feet, IAS 245 kt, heading 230° and vertical speed -1 900 feet/minute, and was at a DME distance of 15.5 NM from the Madrid VOR (CPL).

At 0002:56 (3:43) the altitude alert sounded, indicating that the aircraft was passing 4 700 feet, since 4 000 feet had been selected.

At 0002:55 (3:24) the co-pilot apparently tuned his navigation equipment to the localizer frequency and set the heading for final approach of which he quoted "three thirty" and was corrected by the pilot-in-command "three twenty-nine, if you don't mind", which he acknowledged.

At 0003:16 (03:03) the pilot-in-command ordered "Gear Down". The gear down order - out of sequence - should have been given after 20° of flap, but was probably intended to reduce speed. At this point the aircraft was at an altitude of 4 100 feet, IAS 208 kt, heading 222°, vertical speed -273 feet/minute, 5° of flap and at a distance to go to CPL of 7 NM.

At 0003:29 (2:50) APP reported "Avianca zero one one approaching Charlie Papa Lima, continue approach Barajas three three and tower eighteen fifteen". The aircraft replied "good night, thank you".

Immediately after taking leave of APP the aircraft began a turn to the right when it was about 5.8 NM from CPL. The turn was concluded 37 seconds later with heading 283.7° towards MA, altitude 3 802 feet, speed 165 kt and distance to go to CPL approximately 4.8 NM.

The pilot-in-command began the turn before he had reached CPL, probably because he no longer had a DME distance to CPL or, perhaps, because there was a cumulative error in the INS which misled him into thinking that he was closer to CPL than he was. The ambiguous position information provided by control, or the possibility of some visual cue glimpsed through the two layers of cloud, may have helped to confirm this idea in his mind.

During the turn the pilot-in-command called for the landing checklist except flaps. After the first item of the five on the list the co-pilot made contact with Barajas TWR and, at the same moment, the pilot-in-command disconnected the autopilot. TWR answered the call, clearing the aircraft to land on runway 33 and giving the wind data. The aircraft only acknowledged the wind data. This contact took place between 0003:50 (2:29) and 0004:03 (2:16) hours. The pilot called for 10° flap, which was confirmed and executed by the co-pilot. The flight engineer continued down the list with "cabin signs" and was answered.

At 0004:17 (2:02) the autopilot was reconnected at the same time as the turn was completed. From this moment on the aircraft began a steady descent, probably because the pilot-in-command, in reconnecting the autopilot, forgot to put the altitude mode selector on altitude hold or, because he was expecting to reach 2 383 feet at the MA, deliberately continued the descent, operating the climb/descent control on the autopilot by hand.

At 0004:19 (2:00) the co-pilot informed the pilot-in-command that he had coupled the autopilot to the ILS and asked him to switch the autopilot A control to "Command". Asked by the co-pilot whether or not to leave it on ILS, the pilot-in-command told him to leave it in this configuration.

At 0004:35 (1:44) the co-pilot remarked to the pilot-in-command that as long as the autopilot switch was not moved to "Command", the autopilot would continue on the heading selected. The pilot-in-command agreed and, to judge by the phrase uttered at that moment, appears to have manipulated some switch on the autopilot. The co-pilot commented "It's engaged".

Six seconds later the pilot-in-command asked "Are the markers on the ADFs?", possibly because he had received an unexpected identification or in order to be sure that he was proceeding direct to the MA on his current heading. According to the CVR there was no audible reply to this question.

Later on the co-pilot mentioned the symmetric use of reverse thrust for this landing, because the thrust reverser on engine number 1 was inoperative.

At 0005:33 (0:46) hours the pilot-in-command called for 20° flap and the co-pilot acknowledged and selected the setting.

At 0005:42 (0:37) the co-pilot remarked "it looks as though it is the localizer and, if so, it is wrong. I hope!". This suggests that they thought they were closer to the MA than they actually were, maintaining the descent rate with the intention of reaching the MA at the pre-set altitude of 2 382 feet instead of the 3 282 feet shown on the approach chart.

No more comments are heard until 23 seconds later, at 0006:05 (0:14) hours when the GPWS gave the alarm.

The system operated within the prescribed limits and activated mode 2A, which emits the warning "TERRAIN, TERRAIN, WHOOP, WHOOP, PULL UP, TERRAIN". To inhibit the alarms on this mode it is necessary to:

- 1) Gain altitude for the warnings to change from "PULL UP" to "TERRAIN" (this change may occur spontaneously if the terrain levels off).
- 2) Gain at least 300 feet of barometric altitude above the altitude at which the last "PULL UP" was heard in order to silence the "TERRAIN" warnings.

At the same time as the GPWS warning was sounding, 10 seconds prior to impact, the pilot-in-command calmly said "OK, OK" and took no corrective action. Five seconds later, and five seconds prior to impact, the pilot-in-command again said "OK", disconnecting the autopilot at the same time and slightly reducing the aircraft's rate of descent.

At that moment, according to the DFDR data, the aircraft was flying at 144.4 kt (IAS), with a vertical speed of -1 250 feet per minute on a heading of 283.7° and at an altitude of 2 342 feet (AMSL).

One second before impact the co-pilot said "What does the ground say, Commander?". Judging by the mild tone in which the comment was made, it appears to be a reminder to the Captain to take positive action in response to the GPWS alert.

At 0006:19 the aircraft struck the ground at a speed of 139 kt (IAS), heading 284°, vertical speed -1 016 feet/minute and at an altitude of 2 249 feet (AMSL).

Immediately following this impact the "spoilers out, advance thrust" acoustic warnings can be heard on the CVR. This was the consequence of the fact that the speed brakes had been armed and the engines accelerated after the landing gear struck the ground. The alarms in fact behaved as if the aircraft were making an unsafe take-off.

Approximately 3 seconds after the first impact the aircraft again collided with the ground.

Between the second and third impacts two disjointed and unintelligible comments are audible on the CVR.

In the light of the above findings and the time that elapsed between the first and second impacts the aircraft was not controllable by the crew.

2.3 ATC Action

Information on the ETA of flight AV011 at Pamplona (PPN) was transmitted normally by Bordeaux ACC to Madrid ACC at 2326:24.

First contact of the aircraft with Madrid-ACC took place at 2331:50, when Madrid-ACC cleared the aircraft to Charlie Papa Lima (CPL) assigning it a route and transponder code, which were read back by the crew and corrected by Madrid.

At 2346:34 the aircraft was flying at FL 370 and requested descent. Madrid cleared it to FL 190 and the aircraft reported leaving FL 370.

At 2352:43 Madrid-ACC informed approach control (APP) by hotline (internal telephone line) as follows:

ACC: Hello, José, Avianca zero one one is at Barahona.
Shall I send him direct to Charlie Papa Lima?

APP: OK.

Immediately afterwards, at 2352:55, Madrid-ACC contacted the aircraft, informing it that it was crossing Barahona and clearing it to proceed direct to CPL and continue descent to FL 90. The aircraft acknowledged.

At 2356:32 Madrid-ACC transferred flight AV011 to Madrid-APP, and the aircraft acknowledged and said good-bye to Madrid-ACC.

Twelve seconds after this communication AV011 contacted Madrid-APP, which replied as follows:

Avianca eleven still in radar contact. You are cleared to approach Barajas runway 33, altimeter 1025.7.

The aircraft replied:

One zero two five seven cleared approach Madrid.

In the approach clearance no reference was made to the type of approach the aircraft was to make, the altitude at the initial approach fix was not given, nor was the crew requested to report overhead the point in question. The type of approach only has to be specified when any of the published approaches cannot be performed due to outage of radio aids or is restricted by meteorological conditions.

In this case all the radio aids were operative and the meteorological conditions permitted any of the published instrument approaches to be conducted. The clearance gave the pilot-in-command the option to choose whichever he wished.

The altitude at the initial approach fix was not specified because all the published instrument approaches to runway 33 at Barajas begin at 4 000 feet at CPL. The aircraft was not asked to notify overhead the initial approach fix (CPL) or report at any other position during approach, as this is optional for ATC when the latter needs to expedite the departure of other aircraft. In this case no other departure was scheduled.

At 0000:07 (6:12) another exchange took place:

AV011: Avianca approaching 9 000 feet.

APP: Roger. You are cleared to approach, continue descent.

Once again APP did not specify the type of approach to be made, nor the altitude at the initial approach fix; nor did it request the crew to report passing this point for the reasons explained in the preceding paragraph.

The crew acknowledged the message.

AV011: Will do, Sir.

At 0001:25 (4:54) APP passed the ETAs of flights AV011 and IB408 to TWR, of which the first was ambiguous and the second correct.

APP: Avianca 011 approaching CPL, continue approach Barajas 33 and the Tower 1815.

AV011: Good night, thank you.

The position report was ambiguous and imprecise and the distance in NM to CPL should have been specified instead of just saying "approaching". At this time the aircraft was about 6.8 NM from CPL.

At 0003:56 (2:23) the aircraft contacted Madrid-Barajas TWR:

AV011: Barajas, good evening, Avianca eleven.

TWR: Avianca zero one one, good evening, cleared to land runway 33. Wind 180/05.

AV011: 180/05 Over.

This was the last message received from the aircraft.

It is noteworthy that in all the communications neither the aircraft nor the ATC units requested or gave position information.

Following a change in controller shift ATC turned its attention to traffic in the holding pattern, which was cleared to the holding point of RWY 33.

At 0009:35 TWR, which still was unaware that AV011 had suffered an accident, called it as follows:

TRW: Avianca 011. Position?

After APP had called TWR, enquiring whether it had AV011 on its screen, and received a negative reply, APP reported that it no longer had radar contact and suggested that TWR call the aircraft. TWR made four calls to AV011 between 0010:19 and 0011:12, and APP made one at 0011:03, without, of course, eliciting any reply.

At this point at least the communications failure procedures or the uncertainty phase should have been triggered, but efforts continued to be made to locate the aircraft.

At approximately 0019:00 SAR was informed and the ALERT PHASE triggered.

Probably the APP controller did not pay sufficient attention to his screen, or the radar blip was not sufficiently conspicuous to detect the aircraft's deviation in heading and altitude, and as a consequence the crew was not informed of its navigation error.

3. Conclusions

- a) The pilot-in-command and crew were properly licensed and qualified.
- b) The controllers were properly licensed and qualified and physically fit.
- c) The aeroplane carried a valid certificate of airworthiness, certificate of registration and maintenance certificate. The record shows that it was maintained in accordance with the prescribed maintenance programme.
- d) The navigation and approach aids were checked and found to be functioning correctly.
- e) There was no record of malfunction in the ATC communications or radar equipment.
- f) No evidence of abnormality in the functioning of the aircraft engines or systems was discovered in the investigation.
- g) The weight and centre of gravity of the aircraft were within the prescribed limits.
- h) Between Barahona and initiation of the turn on to the marker the crew did not perform the proper procedures and as a consequence committed an error of navigation.
- i) The crew flew below the sector minima for more than a minute before entering the CPL protection area.
- j) The crew lowered the gear ahead of time and out of sequence, in accordance with the ILS approach procedures and before initiating the turn on to the marker.

- k) The crew made the turn on to the marker and continued flying until the moment of impact without checking the distance to CPL or capturing any signal from the ILS approach system, and with nothing better to go on than the ADF identifications.
- l) The pilot-in-command accepted uncritically the erroneous altitude overhead the marker supplied by the co-pilot.
- m) The pilot-in-command did not take the required corrective action when the GPWS alarm signals were activated.
- n) The ACC controller transferred the aircraft to APP at a time and place different from those agreed upon.
- o) The APP controller, in handing off the aircraft, did not give any precise positional reference either to TWR or the aircraft.
- p) The APP controller transferred the aircraft to the TWR controller without having received any confirmation from the crew that it had intercepted any approach aid or had any visual cue.
- q) The APP controller did not maintain the required radar vigilance inasmuch as he did not inform the aircraft "radar service terminated".
- r) The communications phraseology and procedures employed both by the controllers and the crew did not conform to those recommended by ICAO.

CAUSE

The cause of the accident was that the pilot-in-command, without having any precise knowledge of his position, set out to intercept the ILS on an incorrect track without initiating the published instrument approach manoeuvre; in so doing he descended below all the area safety minima until he collided with the ground.

CONTRIBUTORY FACTORS

- a) Inaccurate navigation by the crew, which placed them in an incorrect position for initiating the approach manoeuvre.
- b) Failure of the crew to take corrective action in accordance with the operating instructions of the ground proximity warning system.
- c) Deficient teamwork on the flight deck.
- d) Imprecise position information supplied to the aircraft by APP.
- e) The APP controller, in failing to inform the aircraft that radar service had terminated, did not maintain a proper watch on the radar scope.

4.

RECOMMENDATIONS

- a) The phraseology recommended by ICAO must be used in all communications and ambiguous terms, both for position and altitudes or flight levels, must be eliminated.

- b) Flight crews should be reminded and instructed that they must strictly observe the operating standards and procedures, working as a team, comply with the prescribed cross-checks and not descend below the published safety levels or altitudes.
- c) To remind crews that navigation in terminal control areas must be based on radio and ground aids and that their position must be determined by the distance measuring equipment associated therewith, when it exists, and not be derived from self-contained airborne systems. Except where the aircraft is being vectored by radar, the approach manoeuvres must be initiated overhead the starting point of the manoeuvres in accordance with the published charts.
- d) To remind and instruct controllers that they are bound to follow strictly the prescribed operating standards and procedures, especially during transfer of control, identification and the provision of radar service to aircraft.
- e) Flight crews should be thoroughly familiarized with the use of the GPWS and the immediate action to be taken when a ground proximity warning is activated.

ICAO Note: Names of personnel were deleted. The Appendices were not reproduced.

ICAO Ref.: 246/83

No. 7

Airbus A300, OY-KAA, near Kuala Lumpur, Malaysia, on
18 December 1983. Report No. 2/83 released by the Department
of Civil Aviation, Malaysia

SYNOPSIS

The accident occurred during a manually flown instrument landing system (ILS) approach to Runway 15, at dusk in bad weather. The aircraft descended substantially below glide slope and struck trees at a height of 174 feet above mean sea level (amsl) approximately 2 km from the threshold along the extended centre line of Runway 15. The aircraft came to rest 1.2 km from the threshold. The aircraft experienced post-impact fire; however, evacuation was successfully accomplished with all passengers and crew safely evacuated. Minor injuries were limited to one crew and five passengers out of a total of 14 crew and 233 passengers.

It is concluded that the most probable cause of the accident was the flight crew's failure to follow procedural requirements coupled with insufficient monitoring during the approach in instrument meteorological conditions (IMC) and that the approach was continued to below the minimum descent altitude (MDA) without having positive visual references.

Following the accident, the Department of Civil Aviation, Malaysia, advised and invited representatives from the following to act either as accredited representatives or as technical advisers to the accident investigation:

Denmark:	Department of Accident Investigation
France:	Bureau Enquêtes Accidents
	Airbus Industrie
Malaysia:	Malaysian Airline System

The United Kingdom Accident Investigation Branch assisted in the cockpit voice recorder (CVR) and digital flight data recorder (DFDR) playback.

1. FACTUAL INFORMATION

1.1 History of the flight

The aircraft registration OY-KAA was leased by Malaysian Airline System (MAS) from Scandinavian Airline System (SAS). The aircraft was leased as three of MAS A300 aircraft were on a programme of heavy maintenance checks. The lease arrangement was approved by both the Danish and Malaysian Civil Aviation Authorities. The lease agreement stipulated for the aircraft to be operated by Malaysian crew and engineering maintenance supported by SAS. Associated with the lease agreement the senior crew of MAS were trained by SAS on aircraft differences. Subsequent in-house differences training for the rest of the Airbus operating crew was carried out by the MAS A300 Fleet Captain and SAS crew. The differences training covered differences in cockpit layout and associated systems.

At 1130 hours on 18 December 1983 the aircraft OY-KAA, callsign MH 684, departed Kuala Lumpur on a scheduled passenger flight for Singapore-Kuching-Singapore and back to Kuala Lumpur. The aircraft Captain flew the Kuala Lumpur-Singapore-Kuching sectors. The third sector, from Kuching to Singapore, was flown by the First Officer (F/O) who made an ILS approach and landed at Singapore.

The aircraft departed Singapore at 1853 hours for Kuala Lumpur with the F/O at the controls. At 1917 hours radio communication was established with Lumpur Control. MH 684 was cleared to descend to Kilo Lima NDB (non-directional beacon) to 5 000 feet, being number three in the approach sequence for Runway 15. A QNH of 1007 was given and the aircraft was advised that the airfield was under heavy rain showers. As the aircraft passed overhead Kilo Lima flying towards the Batu Arang VOR (VBA) it started to experience turbulence. The F/O had difficulty in maintaining a steady speed during the descent to 5 000 feet.

Meanwhile, a F27 aircraft (MH 147) was approaching for a landing on Runway 15 with a DC10-30 (MH 31) being number two. At 1920 hours the RVR (runway visual range) for Runway 15 was given as 1 900 metres. At 1922:40 hours MH 147 which was at four miles final warned MH 31 that the weather was closing in from the south of the airfield. MH 147 landed at 1925 hours whilst MH 31 was already on an ILS approach.

MH 684 was overhead VBA at 1929:10 hours at 3 500 feet and was then re-cleared to 3 300 feet for an ILS approach. The aircraft picked up a hold over VBA. While in the hold, the Captain requested the surface visibility. A RVR of 450 metres was given for Runway 15 and the aircraft was also advised of heavy rain showers over the airfield. The flight condition at this stage was described as moderate turbulence with occasional breaks in the clouds and the ground was occasionally visible. MH 31 reported approach lights in sight and was given a clearance to land with a surface condition as "100/13 knots, runway wet and raining". However, MH 31 initiated an overshoot procedure at 300 feet for reasons of heavy rain and inability to sight the runway or runway lights. All three operating crew of MH 31 reported seeing the approach lights moments prior to the overshoot.

During the approach, the Captain of MH 684 noticed that he was not receiving the ILS indication. He queried the Controller and was informed that the ILS was "ON" and functioning. The crew then realised that the control box had not been set to 110.3 (the ILS frequency for Runway 15). When the ILS was finally indicating the aircraft was high above the glide-slope and to the right of the localiser. The flight continued with the F/O still at the controls and attempting to intercept the glide slope and localiser. The undercarriage was lowered at approximately five miles from touchdown with flap 25° selected at around the same time. The performance maintenance recorder (PMR) indicated a marked increase in the rate of descent after the lowering of the undercarriage and flap. Thirty seconds prior to the first impact and just as the aircraft was about to intercept the glide slope but still to the right of the localiser the Captain took over control. From this moment on, the PMR indicated that the aircraft was deviating below the 3° glide slope.

Moments after the Captain took over control heavy showers were affecting the aircraft. The Flight Engineer (F/E) selected the wipers "ON" at the same instance as the radio altimeter warning sounded. The cockpit voice recorder (CVR) and interviews revealed that the ground proximity warning system (GPWS) did not come on at this stage of the approach. When "minima" was called the aircraft was just about to impact the trees. The aircraft crashed at 1937:50 hours and came to rest 1 200 metres from the runway threshold.

There was post-impact fire on both wings and passenger evacuation was initiated 40 seconds after the aircraft came to rest. The evacuation of all passengers and crew was completed in less than five minutes. The Captain informed the control tower of the crash by radio at 1939:40 hours. Fire and rescue services were at the scene 10 minutes later and the fire was brought under control within an hour. At the time of the accident it was raining and the crash site was flooding with water to almost one metre in depth.

1.2 Injuries to persons

<u>Injuries</u>	<u>Crew</u>	<u>Passengers</u>	<u>Others</u>	<u>Total</u>
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	1	5	0	6
None	13	228	0	241

1.3 Damage to aircraft

The aircraft was badly damaged by impact and post-impact fires.

1.4 Other damage

A mixture of rubber, fruit and secondary forest trees was destroyed.

1.5 Personnel information1.5.1 Captain

The Captain, a Malaysian, aged 38, holds an Airline Transport Pilot's Licence No. 358 which was issued by the Department of Civil Aviation of Malaysia on 2 December 1975. It is valid until 30 April 1984 and was endorsed for Airbus A300 aircraft on 27 June 1980. His last instrument rating and proficiency checks were carried out on 25 September 1983. His last medical examination was on 13 October 1983. He had a grand total of 8 573 hours of which 1 893 hours were flown as Pilot-in-command of the A300. During the last 30 days he had flown 47 hours and his previous flight was a day earlier on 17 December with a rest period of 12-1/2 hours. He was trained on the "Differences Course" on 9 September 1983 and had flown for 12-1/2 hours on the SAS A300 leased aircraft. He was authorised to give First Officer landings and take offs on the A300. His total duty time up to the time of accident was 9 hours 30 minutes including one hour before flight at Kuala Lumpur. His last flight on the leased aircraft was on 18 November 1983.

1.5.2 First Officer

The First Officer, aged 23, holds a Commercial Pilot's Licence No. 457 issued by the Malaysian Department of Civil Aviation with a grand total of 2 623 hours. He had been flying the A300 since 9 May 1983 with a total of 338 hours and completed 60 hours in the last 30 days before the accident. His last medical check was done on 7 May 1983. His last flight on the leased aircraft was on 8 December 1983.

1.5.3 Flight Engineer

The Flight Engineer, aged 31, holds a Flight Engineer's Licence No. 35 issued by the Malaysian Department of Civil Aviation on 4 January 1977. His last medical examination was done on 11 August 1983. To date he had completed 3 664 hours of flight with 1 623 hours flown on the A300. In the last 28 days he had flown 32 hours. He completed the training for SAS/MAS aircraft differences on 12 October 1983. His last flight on the leased aircraft was on 27 October 1983.

1.6 Aircraft information

1.6.1 Type: Airbus A300 B4-120
 Registration: OY-KAA
 Manufacturer: Airbus Industrie, Blagnac, France
 Year of manufacture: 1980
 Serial No.: 122
 Owner: Registered in the name of Det Danske
 Luftfartsselskab A/S on 2 May 1983
 Certificate of airworthiness: Certified by Denmark Directorate of Civil
 Aviation and valid until 31 December 1984
 Last maintenance: "A" check
 Hours flown since maintenance: 58:03 hours
 Hours flown since new: 3907:03 hours
 Maximum regulated landing weight: 136 000 kg
 Estimated weight at time of
 accident: 105 000 kg
 Estimated fuel remaining at
 time of accident: 7 800 kg
 Defects: There were no recorded defects pertinent
 to the accident
 Maintenance history: The aircraft had been maintained to a
 Maintenance Master Plan W-83 approved by
 the Danish Directorate of Civil Aviation.

1.7 Meteorological information

The accident occurred at 1938 hours, 10 minutes after local sunset. The following weather conditions existed at Kuala Lumpur:

	<u>1930 hours</u>	<u>2000 hours</u>
Surface wind	070/13	340/04
Visibility	4 km	6 km
Cloud	2/8 500 2/8LB 1 700	2/8 700 2/8CB 1 700 4/8 22 000 6/8 26 000
Weather	Rain and thunderstorm east to southeast Thunderstorm and lightning northwest to southwest	Thunderstorm east to southeast Thunderstorm and lightning northwest to southwest
Surface temperature	25/24	24/23
QNH	1009	1009
Humidity	93%	95%
Runway conditions	wet	wet
RVR	450 metres	2 000 metres

1.8 Aids to navigation1.8.1 In the aircraft

The aircraft was equipped with the following navigation aids:

- a) Instrument Landings System comprising dual localiser, dual glide path and single marker beacon receiver.

- b) A weather radar system comprising a single transmitter/receiver and dual indicators.
- c) A dual radio altimeter system.
- d) A dual distance measuring equipment (DME) system.
- e) A dual air traffic control transponder system.
- f) A dual automatic direction-finding system.
- g) A dual VHF omni-range (VOR) navigation system.

A similar scale of equipment is fitted to the MAS fleet; however, there are several operational differences, the more significant ones being:

- Navigation source information for the horizontal situation indicators (HSI) is selected by switches on the 13VU panel (glareshield).
- The switches on MAS aircraft are two-position switches, the up position being 'INS NAV' (inertial navigation) and the down position being 'V/L' (VOR/localiser). The switches on OY-KAA are three-position switches, the up position being 'NAV' (inertial navigation), centre 'ILS' (instrument landing system) and down 'VOR' (omni-range).
- The VOR and ILS frequency selectors on the MAS aircraft are situated on the 13VU panel (glareshield). No. 1 controller, controlling No. 1 VOR and No. 1 ILS are located at the left-hand side and No. 2 controller, controlling No. 2 VOR and No. 2 ILS are located at the right-hand side. On OY-KAA the controllers located on the 13VU panel control Nos. 1 and 2 VORs only. Nos. 1 and 2 ILS are controlled by a separate controller on the 11VU panel (aft centre console).

The significance of this arrangement in a transition from VOR to ILS is:

MAS aircraft:

- a) HSI switch selected to V/L.
- b) VOR frequency selected on the individual Nos. 1 and 2 controllers (panel 13VU).

On transition to ILS: select appropriate frequency on Nos. 1 and 2 controllers.

OY-KAA

- a) HSI switch selected to VOR.
- b) VOR frequency selected on Nos. 1 and 2 controllers (panel 13VU).

On transition:

- a) Select appropriate frequency on ILS controller (panel 11VU).
- b) Select ILS on HSI switch.

For a flight director or autopilot coupled approach other switch and controller functions would differ but these are considered irrelevant to this analysis.

1.8.2 On the ground - radio aids

The relevant radio aids for Runway 15 consist of a VOR/DME beacon (VBA), a non-directional beacon (CE) and a locator beacon (NM). An ILS/DME and marker beacon are also provided for a precision approach to Runway 15. At the time of the accident, the VBA DME and the ILS marker beacon were unserviceable.

A flight check was carried out on 19 December by the DCA Calibration Unit and it was confirmed that the accuracy of the ILS for Runway 15 was within the permitted tolerances.

1.8.3 On the ground - visual aids

Runway 15 is equipped with a single white line and two crossbar approach lighting, high-intensity edge lights, wing bars and threshold lights. In addition, a 'T' visual approach slope indicator (VASI) system is also available. All these aids were switched on at the time of the accident.

1.9 Communications

No communication difficulty was reported.

1.10 Aerodrome information

Runway 15 is 3 475 metres long and has a touchdown elevation of 69 feet AMSL with an obstruction-free approach slope of 1:50. For the final approach up to 2 NM on the centre line, the terrain undulates between 60 to 100 feet AMSL with isolated spot heights up to 250 feet AMSL to the left of centre line. The approach area to Runway 15 is almost devoid of any form of lighting from buildings and roads.

1.11 Flight recorders

1.11.1 Flight data recorders

The aircraft was equipped with a Sundstrand digital recording system.

The installation included both a crash-protected mandatory recorder, namely the digital flight data recorder (DFDR) and a complementary performance maintenance recorder (PMR). Both recorders received their data from the flight data acquisition unit (FDAU) but via different digital data channels.

1.11.2 Digital flight data recorder

The aircraft was equipped with a Sundstrand DFDR No. 981-6009-014, Serial No. 3488. The recorder was subjected to heat and fire damage. The heat had penetrated through the protective shield, the reels and tape guide were discoloured and the wires at the recording head were beginning to burn. The Vic alloy (metal) tape outside the reel was damaged by heat. The tape was discoloured for a length of 0.9 m, rough in texture and brittle, and was stuck to the tape guides. The tape was broken on removal and was spliced together to get a readout.

The readout obtained from the DFDR contained only the manufacturer's test programme on all four tracks. This suggested that the DFDR was not capable of data acquisition, the test programme was not erased by the eraser heads and the DFDR was inoperative. Abnormalities with the DFDR were not reflected in the cockpit in that the "DFDR FAIL" light was not illuminated.

The DFDR was last installed on 2 November 1983 and the fact that there was no data on the tape other than the manufacturer's test programme suggested that the DFDR had been inoperative since installation. The reason why this failure was not indicated on the "DFDR FAIL" light is being further investigated by Airbus Industrie together with Sundstrand and the Department of Accident Investigation - Denmark. Therefore the DFDR provided no evidence to assist the investigation because the recorder was inoperative.

1.11.3 Performance maintenance recorder

The aircraft was also equipped with a complementary Sundstrand performance maintenance recorder (PMR), Part No. 981-6102-601 Serial No. 387. The PMR magnetic tape consisting of 12 recording tracks was contained in an easily replaceable cassette and it was recovered intact from the avionics compartment.

The PMR readout was initially carried out by Airbus Industrie under the supervision of the French officials. Difficulties were experienced at this initial readout by Airbus Industrie using their routine readout process due to abnormal jitters on the tape. Then a copy of the tape was made on an IBM tape which could be used by the French official laboratory.

A readout of the PMR was obtained and tabulated and graphic data for the accident flight were produced. Sufficient valid data were available on the tape to enable a detailed analysis of the accident to be made.

1.11.4 Cockpit voice recorder

The aircraft carried a Sundstrand 4-channel cockpit voice recorder (CVR), Part No. 980-6005-056, Serial No. 7021. The CVR experienced heat damage and during removal the tape was fused to the recording head. The tape was not severed during removal but was broken during the first playback and was spliced together. Associated with heat damage, the tape was noticed to be stiff and brittle with bits of oxide stripped off the tape.

The CVR readout was conducted by the United Kingdom AIB. A transcript of the tape was obtained of which the final 5 minutes and 20 seconds of the flight were useful. The bulk of the tape, however, was of no use as electrical power supply from the aircraft batteries was still available and therefore the recorder continued to run after the accident, recording only ground noise.

1.11.5 DFDR and CVR location

The DFDR and CVR are located in the "aft cabin underfloor compartment". Both recorders were found under several inches of debris consisting of insulation, flooring and galley equipment. Both recorders experienced considerable heat damage. Both recorders' protection boxes had been sent to Bureau Enquêtes Accidents for heat and fire damage assessment by the French official laboratories, with a view towards relocating them aft of the rear pressure bulkhead.

1.12 Wreckage information

1.12.1 Accident site

The position at which the aircraft had initially struck the trees was at a height of 174 feet AMSL along the extended centre line of Runway 15 at a position 2 km from the runway threshold. It then struck the ground with the right-hand gear 436 m down track, lifted off the ground for approximately 36 m, then struck the ground at a stream embankment and slid for 109 m before coming to final rest at a heading of 149°Mag. and 1.2 km from the Runway 15 threshold. The accident site consisted of a mixture of rubber, fruit and secondary forest trees and the swathe cut through the trees covered a distance of approximately 606 m.

A survey of initial impact with trees and the initial ground impact marks made by the RH gear, and the broken trees along the swathe indicated that the approach path was a descent of 4.5° with a bank to starboard of 7° to 8° .

1.12.2 Wreckage

The wreckage was intact except that both main gears and engines were torn and the cabin and cockpit roofs were completely burnt.

The right-hand (RH) gear first impacted the ground followed by the left-hand (LH) gear, then the aircraft lifted off the ground for about 36 m, then both gears and engines struck a stream embankment at a meander causing both gears and engines to separate from their mounts and attachments. The RH engine was sheared off from the pylon and the RH gear torsion links were sheared releasing the shock absorber assembly together with the bogie beam and wheel assemblies. Both the engine and the landing gear were located in the stream meander at a distance of 76 m from the main wreckage. The LH engine was sheared off the pylon and came to rest 40 m from the main wreckage. The LH gear was sheared off and the shear consisted of a smooth withdrawal of the forward trunnion from the spherical bearing and a rupture of the rear trunnion.

It was established that both engines and main gears were torn off due to impact with the ground. The nose gear collapsed and was trapped in the nose gear bay.

The tail section was broken as a result of post-crash fire and not due to impact. The floor structure above the bulk cargo compartment had collapsed, this probably intensified the fire at the tailcone which then weakened the surrounding structure. The weight of the tail empennage subsequently caused the tailcone to break at Frame 78/79. Whilst the wreckage was intact, the flight and cabin compartments from the nose section right through to the aft pressure bulkhead from floor level upwards were totally consumed by post-impact fire. Both wings remained attached to the fuselage and the RH wing experienced impact damage to front spar at Ribs 2, 4 and 26. Associated with the slats deployment, slat tracks 6, 7, 8 and 9 were displaced as a result of impact damage and these displaced slat tracks had ruptured the fuel canisters in the fuel tanks hence causing fuel to leak. This RH wing was burnt between Ribs 18 to 24, outboard of pylon and also at Rib 2. The LH wing experienced impact damage to front spar at Rib 18 and slat track rupture of fuel canister at slat track No. 1. The LH wing fire was confined to inboard of the engine pylon.

Examination of the wreckage at site and together with PMR data indicated that No. 1 engine was rotating at about 68% N_1 , No. 2 engine at 64% N_1 , landing gear were down and locked, slats and flaps were fully extended to 25° and the aircraft was 5° nose up trim and the approach speed was about 150 kts.

The control pedestal assembly was burnt but it could be established that the flaps lever was selected down, spoiler was armed, fuel levers were at shut off and power levers were above idle.

There was no evidence of aircraft system malfunction or loss of parts prior to initial impact with trees and it was established that at initial impact with trees the aircraft was in a landing configuration. There was also no evidence of a lightning strike or an in-flight fire.

1.13 Medical

Medical records indicated that four passengers had suffered backache and they were treated and discharged the following day. One elderly lady suffered a backache and was discharged after two days. The Flight Engineer had laceration of his third and fourth fingers and a torn tendon. He was warded for four days.

1.14 Fire

The aircraft experienced post-impact fire and at final ground impact, fire was seen at the RH outboard wing and LH inboard wing. The initiation of the fire was due to fuel spillage from the damaged wing tanks and it was ignited due to impact or an electrical discharge after impact. The right wing suffered fire damage outboard of the pylon (between Ribs 18 to 24) and inboard at Rib 2 in close proximity to the fuselage. The left wing fire was confined to inboard of the pylon.

The very selective deployment of exit doors, namely LH Doors 1 and 4, RH Doors 1 and 2 prevented the spreading of fire into the cabin via opened escape doors. The propagation of the fire was also retarded because of the intense tropical rain and fuel was being dispersed by the flood water. The evacuation of all passengers and crew took approximately five minutes. The Captain was the last to leave and when he was at the mid-cabin section he noticed visible smoke in the aft cabin. The propagation of the external fire into the cabin via the rear RH fuselage and cabin windows probably took six to nine minutes and cabin flashover throughout the cabin was probably completed in ten minutes. The "flashover" phenomenon is characteristic of fires in an enclosed space. Essentially what happens is that due to heat most materials decompose to produce gases which are in themselves combustible. These build up below the ceiling, getting progressively hotter, until they ignite resulting in virtually instantaneous spread of fire throughout the cabin.

The cabin from the flight compartment to the rear pressure bulkhead was completely destroyed from floor level upwards. Below floor level there was hardly any damage except for the floor structure above the aft bulk cargo compartment, which had collapsed due to the weight of the galley and toilet units and therefore the aft bulk cargo compartment was severely burnt.

1.15 Survival aspects

The accident was survivable. The aircraft struck the ground at a shallow angle and decelerated evenly over trees and ground with very low "g" forces. Calculations revealed that it did not exceed 3g throughout the crash. The clear path of the accident area has helped the deceleration forces dissipating evenly over some 545 m with half the distance in water over the ground, estimated around 1 to 2 m deep. No one was seriously injured during the crash. All the seats retained their positions throughout the crash. All passengers and crew, with the exception of six, did not suffer any injuries during the crash and the subsequent evacuation from the aircraft. Injuries experienced by the six were considered minor, as five passengers were treated and discharged for backache and the Flight Engineer had lacerations on his left hand fingers.

The deployment of the escape slides was carried out selectively as there was a post-impact fire. The cabin crew identified Doors 1R, 2R, 1L and 4L as suitable for evacuation as these were located well away from the ground fire. Door 1R could not be opened as it was obstructed by tree branches. Most of the passengers evacuated through Door 2R as the slide rested firmly on high ground. Door 1L was also extensively used despite the slide being ruptured by a tree stump during initial evacuation. The cabin crew held on to the ruptured slide to facilitate passenger evacuation and approximately 90 people evacuated using this slide. Door 4L slide deployed into a fast-flowing stream with rising water level and less than 10 people used this exit.

The very selective deployment of escape doors and slides had prevented any injury due to fire and this had also prevented the spread of fire into the cabin via open exit doors.

1.16 Tests and research

The aircraft is equipped with two instrument landing systems (ILS). Both Bendix ILS receivers, Model RIA32A, Part No. 2070724-3203, Serial Nos. 1935 and 2057 were removed for bench performance tests and all the parameters measured were within the tolerance defined in the Maintenance Manual.

The aircraft is equipped with a ground proximity warning system (GPWS), Sundstrand MK II. The GPWS is designed to provide aural and visual warnings of potentially dangerous flight paths relative to the ground. On this aircraft Mode 5 (excessive glide slope deviation) of the GPWS was permanently inhibited by externally grounding the mode inhibit pin. Therefore Mode 5 warning for excessive glide slope deviation was not available on this aircraft.

When carrying out the test function by pressing the cap of either the terrain light, this triggers a self-test of the system, both terrain lights come on and the voice warning calls, "glide slope, whoop whoop pull up, whoop whoop pull up, whoop whoop pull up".

This situation is considered misleading as GPWS Mode 5 was permanently inhibited but the glide slope voice warning will come on when carrying out the self-test.

GPWS Mode 5 inhibition is reflected in the Airbus Industrie Flight Crew Operations Manual in that a dotted line between the glide slope receiver 1 to the GPWS computer for glide slope deviation will suggest the system is not active and the interpretation for Mode 5, descent below glide slope (full provision) will mean that not all A300 will have this system active.

Associated with lease and operation of this aircraft, a Difference List was prepared by SAS to highlight differences between the SAS and MAS A300 aircraft. In the SAS supplied and MAS reproduced copies of the Difference List, the inhibition of GPWS Mode 5 warning was not reflected as it was in the prepared Difference List used when discussing the lease of the aircraft in Stockholm. The crew were not aware that GPWS Mode 5 warning was inhibited.

The GPWS computer was tested by Sundstrand Data Control Inc. and it was concluded that the GPWS computer was serviceable but with one exception. The audio output level was 0.3 volt below specification and was reset.

The aircraft flight profile was flown on the simulator and with the GPWS Mode 5 warning active, it was established that the soft "glide slope warning" would come on for about 10 seconds followed by another 20 seconds of hard "glide slope warning" prior to impact with ground. It was also established on the simulator that at the onset of hard warning, a go-around was initiated and successfully executed.

GPWS Mode 5 warning is a Malaysian Civil Aviation Department requirement but it is not a Danish Civil Aviation Authority requirement. Although there is a difference in airworthiness requirements between the two countries it must be noted that, even though the pilots had no knowledge of the deactivation of GPWS Mode 5 warning, this should not in any way influence their way of operating the aircraft.

The aircraft is also equipped with beam deviation warning which is a requirement by several authorities for Category II approach. (All Malaysian airports are approved for Category I approach only.) The reason for Mode 5 being inhibited is to avoid confusion between the two different warnings. The beam deviation warning provides visual warning of excessive runway centre line and glide slope deviation when the 'flight director' is in use and the appropriate mode selection is made. Prior to the accident and during the ILS approach neither the Captain nor the Co-pilot could confirm that the warning was activated.

1.17 Other information

The aircraft was leased from SAS as three of MAS A300 aircraft were scheduled for a heavy maintenance programme. The aircraft was leased so as to maintain MAS services during the period when MAS A300 were undergoing the heavy maintenance programme.

The operational aspect of the lease was discussed between MAS and SAS on 1 and 2 August 1983. The lease arrangement was for the aircraft to be flown by MAS technical crew after successfully completing the differences course and route check. The maintenance of the aircraft was carried out by SAS personnel supplemented by a team of MAS engineers appropriately trained by SAS and approved by SAS and the Danish Authority.

The Department of Civil Aviation (DCA) was approached by MAS on 4 August 1983 regarding leasing of the aircraft. The DCA on 16 September 1983 replied to MAS that it had no objection to MAS leasing the aircraft from SAS and that the aircraft can remain on Danish registry and it can be operated by MAS crew.

1.18 New investigation technique

None.

2. ANALYSIS

2.1 Weather

The last sector Singapore-Kuala Lumpur was flown by the F/O and as stated by the crew there was no apparent problem on the flight until approaching KL (Kilo Lima) where the flight was cleared to descend from 7 000 to 5 000 feet. There were weather build-ups around the vicinity of Subang Airport. The flight experienced some bad turbulence around this area and between 1917 hours to 1925 hours when the aircraft was approaching the VBA holding area. As stated by the crew and passengers, it was evident that the weather was uncomfortable for them. The crew admitted that the weather was deteriorating but also indicated that it was not the worst weather that they had experienced. The Captain was fairly confident that his F/O could handle the aircraft.

At 1917:40 the controller advised all aircraft that the airport was experiencing heavy showers. MH 684 was cleared to 5 000 feet for VBA. At the same time a Fokker F27 (MH 147) was approaching for a landing on Runway 15. MH 147 confirmed that heavy rain was seen coming from the southern end of the airport and was moving in a northerly direction. At 1920:20 the controller again cautioned all aircraft that the RVR (runway visual range) was reducing to 1 900 metres for Runway 15. Two minutes 20 seconds later MH 147 reported four miles final and they had the runway in sight and cautioned MH 31 which was number two in the landing sequence that the weather was closing in very fast. At 1925 hours MH 147 landed and MH 684 reported over Kilo Lima and proceeding to VBA at 5 000 feet. At 1926:50 hours MH 684 was cleared to descend to 3 500 feet and was approaching overhead VBA.

As stated by the Captain, there was no reason to be alarmed by the weather report, but after the cautioned note by MH 147, the Captain began to feel apprehensive and at 1929:22 hours during the holding pattern he requested the RVR and it was given as 450 metres. Even though the limitation for attempting a landing was below the Company minima of 800 metres he elected to continue in the hope of seeing the runway in the next few minutes.

During the course of the investigation the Captain of MH 31 mentioned that he was able to see the approach lights close to MDA but commented that he could not see the runway lights which caused him to overshoot at MDA. As the weather was turbulent coupled with a heavy downpour, the Captain considered that the approach should not be attempted by his F/O, even though this sector was supposed to be flown by the F/O. He, therefore,

took over control before commencing the ILS approach, from which he subsequently overshot. It was quite evident that the weather was deteriorating very fast and it was also moving in a northerly direction. However, there was no evidence of wind shear in the approach area.

2.2 Cockpit differences - ILS selection

On the MAS A300 the ILS selector switches are located at the glareshield panel and each switch has two positions; in the "up" position it will indicate VOR/ILS - marked V/L. In the SAS aircraft this particular switch has three positions instead of two. It has "up, centre and down" (NAV/ILS/VOR). The centre position will give the ILS function, with the additional requirement for the centre control box to be set to the correct frequency. Without this frequency being set, both the First Officer and the Captain will not have the ILS function. It was established that the centre pedestal box frequency setting was not selected to the correct frequency until 1935:50 hours, one minute and 50 seconds before the crash. This was after confirmation by the controller that the ground ILS was serviceable and functioning normally.

It could not be established conclusively why the appropriate ILS selection was not made much earlier during the approach. The Captain last flew this aircraft 30 days before and it could only be assumed that he was still not that familiar with the ILS selection mode.

2.3 Crew competency and co-ordination

After tuning the ILS, the aircraft was still fairly high on the glide slope and had drifted to the right of the centre line. The F/O was having difficulty in putting the aircraft back onto the glide slope and localiser. Despite this problem the Captain did not attempt to take control of the aircraft. From the CVR it was established that he was quite satisfied to give and repeat the instructions "fly the aircraft, fly the aircraft" to the F/O. This is considered inadequate and not specific enough for any correction to be made by the F/O. The lack of specific instructions to the F/O and failing to take over controls may be attributed to the fact that the Captain is not rated as a flying instructor with the necessary training background.

This sector was designated as the F/O's sector; however, it was evident that the F/O was experiencing difficulties in establishing the aircraft for the correct ILS approach. This could only suggest that his competency and proficiency have not reached the desired level for him to fly sectors, albeit under the supervision of the Captain.

The pre-landing checks were completed at around 1936:52 hours. The PMR indicated that the rate of descent (ROD) increased to 1 123 feet/min. and the aircraft went below the glide slope. There was no attempt to arrest the high ROD. The 1 000 feet flags check, as was required by Company procedures, was not called out by the Captain who was performing the function of the Pilot not flying.

The Captain decided to take over control of the aircraft about 30 seconds before impact. He continued the flight and turned left but could not remember whether he was low or high on the glide slope, but believed that he was on glide slope and had only the localiser to worry about.

He stated that he was on instruments until minima was called. When he looked up he saw lights and continued the approach and the aircraft hit the trees a few seconds later.

When the Captain had taken over control, the F/O, who had reverted to his Co-pilot function, did not make the 200 feet and 100 feet call-out before MDA, as was

required by Company procedures. He did not make any call-out as he was attempting to set the INS switch to read 'wind', apparently to check for any wind shear indication.

Just before reaching MDA the F/E was required to switch on the wipers. In order to reach the switches he had to stretch out and possibly loosen his seat belts. The radio altimeter alert sounded and the aircraft passed the MDA. The MDA call "minima", as required by Company procedures, was only made six seconds later and in another four seconds the aircraft impacted the trees. It is evident that the F/E's attention was diverted at a critical moment, resulting in the late MDA call.

In an attempt to determine crew fatigue and tiredness a sampling check was carried out on this flight schedule. The various reports and comments from other crew operating on this particular schedule MH 681/684, that is Kuala Lumpur - Singapore - Kuching - Singapore - Kuala Lumpur, revealed that this schedule is particularly hectic and at times very pressing and demanding. It is also interesting to note that these sectors are particularly short sectors and thus require a high degree of alertness and concentration, particularly the final sector into Kuala Lumpur at dusk. Due to scheduling requirements, the operations is forced to complete these sectors at around 1930 hours.

After passing VBA it became apparent that the crew was having problems in stabilising the aircraft for the final approach to Runway 15. The correct ILS frequency was selected late and the necessary check height calls, as required by Company procedures, were not made or were made late. The weather was bad with a RVR of 450 metres, well below the Company minima of 800 metres, yet the Captain failed to appreciate the situation and instead elected to continue with the flight. The F/O was having problems in flying the aircraft but the Captain did not take over the controls nor did he give any particular corrective instructions. When he did finally take over, he failed to notice the high ROD.

It is evident that the Captain did not pay sufficient attention in attaining the correct and safe approach path. It is also evident that neither the F/O nor the F/E monitored the aircraft's progress properly or if they did they failed to give the appropriate warnings when they were necessary. The monitoring deficiencies persisted throughout the approach and such a failure is indicative of a breakdown in monitoring, a critical failure in this case as the approach was made on instruments and in bad weather.

2.4 Approach procedure

Before the installation of the ILS for Runway 15, it was common practice for instrument approaches to be made using the VBA VOR/DME. With the availability of the ILS, it is considered more appropriate to direct all arrivals to the CE beacon. Although this has no bearing on the cause of the accident, it will help to reduce the cockpit workload by reducing the amount of manoeuvring and monitoring before capturing the ILS.

2.5 GPWS

Mode 5 (excessive glide slope deviation) of the GPWS in the leased SAS A300 was permanently inhibited. However, in the SAS supplied and MAS reproduced copies of the Difference List, the inhibition of Mode 5 warning was not reflected and consequently the crew were not aware of the inhibition. Moreover, when the self-test was carried out the glide slope voice warning will come on indicating that the system was functioning.

3. CONCLUSIONS

a) Findings

- (i) The aircraft had been properly maintained and its documentation was in order. There was no evidence of any technical failure or malfunction in flight prior to impact.
- (ii) The operating crew were qualified and properly licensed to operate the A300 Airbus aircraft.
- (iii) The status of the radio navigational aids on the ground and in the aircraft was adequate for the ILS approach.
- (iv) The weather was deteriorating from the southern end of the runway with heavy showers covering the surrounding areas. The runway visual range was 450 metres.
- (v) The approach lights, the runway lighting and the "T" vasis were operating normally. However, the approach area was waterlogged up to one metre deep mainly concentrated around the approach lights.
- (vi) The DFDR provided no evidence to assist in the investigation because the recorder was inoperative. However, the complementary PMR provided useful evidence in the investigations.
- (vii) Associated with DFDR investigations, it was found that the procedure for post-installation check on the DFDR was not correctly reflected in the SAS Maintenance Manual. The Manual reflected a Teledyne thumb wheel flight data entry panel against the Hamilton Standard push-button type.
- (viii) The DFDR and CVR are located in the "aft cabin underfloor compartment" and they both experienced considerable heat damage.
- (ix) The aircraft experienced post-impact fire. Associated with slats deployment, wing slat tracks were displaced as a result of impact damage. These displaced tracks had ruptured the fuel tank canisters causing fuel to leak.
- (x) The DME/VBA was unserviceable together with the reported unserviceability of the outer marker beacon.
- (xi) There was no evidence of any toxicological, physical or psychological problems that could have affected the performance of the operating crew of MH 684 prior to the accident.
- (xii) The cockpit differences, especially in respect of ILS switching, could have affected the performance of the crew during a time of heavy cockpit workload.
- (xiii) The First Officer experienced difficulty in controlling the aircraft on the ILS approach and whilst this difficulty was recognised by the Captain, he failed to give remedial instructions to the First Officer to correct the situation.
- (xiv) The Captain's decision to take over control was too late as he still had to establish the aircraft on the localiser. In doing so he failed to detect and correct a high rate of descent which resulted in the aircraft descending below the glide slope.

- (xv) The required procedures and call outs during the final ILS approach were not complied with, contrary to Company operating procedures. There was a breakdown of the overall monitoring of the instruments during the approach phase.
 - (xvi) There is a possibility that tiredness could have contributed to the manner in which the approach was conducted.
 - (xvii) The practice of holding aircraft at VBA instead of at CE for the ILS approach for Runway 15 is not compatible with an expeditious flow of traffic and tends to increase cockpit workload.
 - (xviii) The inhibition of GPWS Mode 5 glide slope warning was not known to the crew and the availability of glide slope voice warning during test was misleading. However, these should not in any way influence the safe operation of the aircraft.
- b) Cause

The most probable cause of the accident was the flight crew's failure to follow procedural requirements coupled with insufficient monitoring during the approach in instrument meteorological conditions (IMC) and that the approach was continued to below the minimum descent altitude (MDA) without having positive visual references.

4. SAFETY RECOMMENDATIONS

It is recommended that:

- 1) MAS should review its present training policies with a view towards improving cockpit discipline and flying competency.
- 2) MAS should review the present procedure requiring the Flight Engineer to select wipers.
- 3) The procedure for holding of aircraft should be done at CE as this will reduce cockpit workload for all aircraft coming in for ILS approaches.
- 4) The Department of Civil Aviation should review the adequacy of the operational supervision exercised by the Department over MAS.
- 5) The present location of the CVR and DFDR should be reviewed as both the CVR and DFDR suffered considerable heat damage.
- 6) In respect of GPWS installations where all modes are available and operational, it is recommended that they should not be deliberately inhibited. However, if one of the modes is inhibited, the inhibited mode should not show up during test.
- 7) Consideration should be given to the rescheduling of Flight MH 684 as the present operating schedule can be very demanding on the crew.
- 8) The future leasing of aircraft should actively involve both MAS and the DCA at the early stages of discussion so as to achieve minimal cockpit, engine and system differences and compatibility in airworthiness requirements and regulations. The current practice is to inform the DCA only after the lease has been signed.

ICAO Note: The Appendices were not reproduced.

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