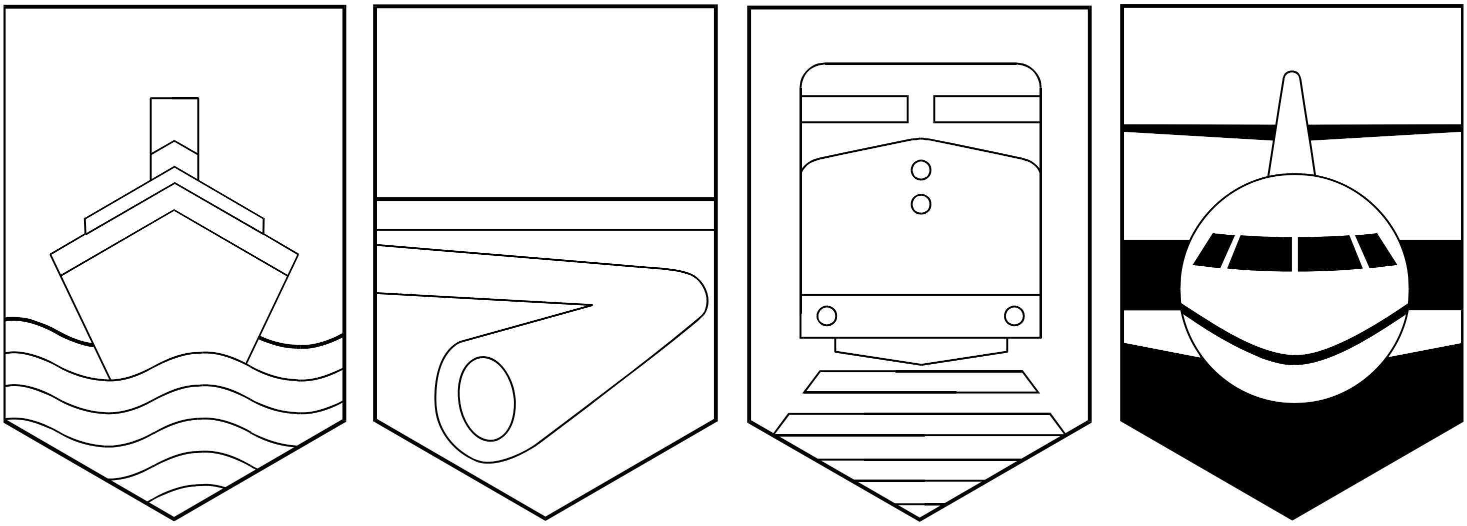
Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada



AVIATION OCCURRENCE REPORT

CONTROLLED FLIGHT INTO WATER

CANADA JET CHARTERS LIMITED
LEARJET 35 C-GPUN
MASSET, BRITISH COLUMBIA 8 nm NW
11 JANUARY 1995

REPORT NUMBER A95P0004

Canada

MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

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Canada Jet Charters Limited
Learjet 35 C-GPUN
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Synopsis

The Learjet 35 departed Vancouver International Airport, British Columbia, at 0035 Pacific standard time, on a one-hour medical evacuation flight to the Masset aerodrome in the Queen Charlotte Islands. On board the aircraft were two pilots and a medical team of three persons. During the instrument approach to runway 12 at Masset, the aircraft crashed into the ocean, eight nautical miles northwest of the Masset aerodrome. Intense Canadian military search and rescue operations, coupled with extensive civilian underwater searching, resulted in finding the aircraft wreckage and the bodies of two of the occupants; the other three occupants are presumed to have also perished in the accident. The aircraft was destroyed.

The Board determined that the crew most likely conducted the instrument approach with reference to an unintentionally mis-set altimeter of 30.17 in. Hg, and unknowingly flew the aircraft into the water. The circumstances leading to the incorrect altimeter setting could not be determined, nor was it determined why the crew did not detect the mis-set altimeter.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

On 11 January 1995, at 0035 Pacific standard time (PST)[1], the twin-engine Learjet 35 departed Vancouver International Airport, British Columbia, on a night, instrument flight rules (IFR)[2], medical evacuation (MEDEVAC) flight to the Masset aerodrome, on the northern end of the Queen Charlotte Islands. On board the Learjet were a flight crew of two pilots, and a medical team consisting of two attendants and a doctor. Their mission was to evacuate a patient from Masset and deliver her to Prince Rupert for treatment; the aircraft was then to return to Vancouver.

The flight-planned route was at flight level (FL) 390, direct to Sandspit then direct to Masset. Following routine communications with Air Traffic Services (ATS), at about 0144, the aircraft reported "outbound" from the Masset non-directional beacon (NDB) on the published NDB "A" instrument approach procedure to runway 12. Air Traffic Control (ATC) radar, situated near Sandspit, tracked the aircraft as it flew the approach. Radar data shows that the aircraft began a descent about 10 seconds after it had completed the procedure turn and was established on the final inbound approach track. Forty-three seconds later, at a point 8.8 nautical miles (nm)[3] from the threshold of runway 12 and on the final, inbound track, the aircraft disappeared from radar.

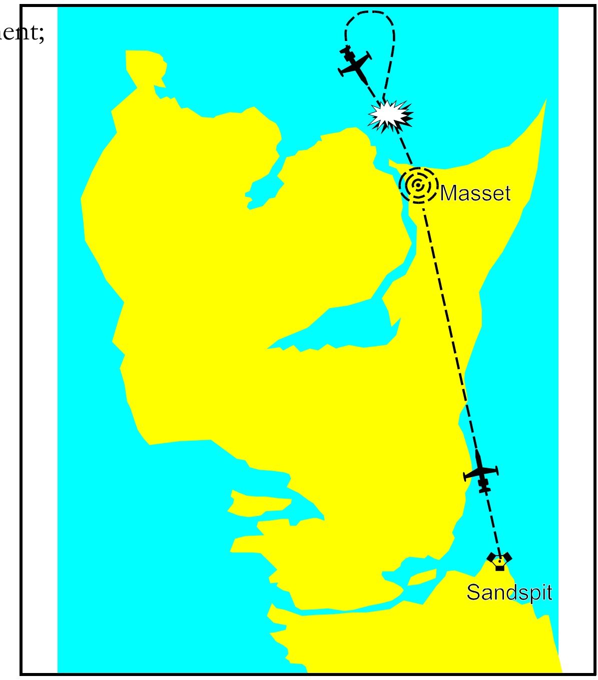


Figure 1 - Route of Flight

Department of National Defence (DND) Search and Rescue (SAR) aircraft began searching the area shortly after the aircraft was declared missing, and were later assisted by other private and military aircraft and vessels. On the second day of the search, flotsam from the aircraft was found in the area. Extensive underwater searching using sonar and underwater cameras found the aircraft wreckage on 31 January 1995, in 260 feet of water, near the last known position. The aircraft had been destroyed.

The bodies of two occupants were found several days after the accident, but the other three occupants have not been found and are presumed to have been fatally injured. The accident occurred at latitude 54°08′N and longitude 131°58′W, at about 0149 PST, during the hours of darkness in unknown weather conditions.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total

[1] All times are Pacific standard time (Coordinated Universal Time [UTC] minus eight hours) unless otherwise stated.

[2] See Glossary for all abbreviations and acronyms.

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

Fatal	2	3	-	5
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	2	3	-	5

1.3 *Damage to Aircraft*

The aircraft was destroyed by impact with the water.

1.4 *Other Damage*

None.

1.5 *Personnel Information*

	Captain	First Officer
Age	30	29
Pilot Licence	ATPL	ATPL
Medical Expiry Date	1 October 1995	1 July 1995
Total Flying Hours	4,550	2,880
Hours on Type	2,550	61
Hours Last 90 Days	123	61
Hours on Type Last 90 Days	104	61
Hours on Duty Prior to Occurrence	2.5	2.5
Hours Off Duty Prior to Work Period	26	86

1.5.1 *The Captain*

The captain held a valid Airline Transport Pilot Licence (ATPL) and a Group 1 instrument rating, valid until 01 November 1996. A category 1 Licence Validation Certificate (LVC) had been issued for this licence, with a limitation that glasses had to be worn during flight, and was valid until 01 October 1995. The captain's most recent Learjet 35 pilot proficiency check (PPC), which included an upgrade to captain status and an instrument rating test, was successfully completed on 31 October 1994.

The captain was hired by Canada Jet Charters Ltd. (the company) in September 1989 as a first officer for the Learjet aircraft. At that time, he had accumulated about 2,000 hours' flight experience on several small and medium single- and twin-engine aircraft. Until his upgrade to captain on 31 October 1994, he had flown the company's Learjet 25, 35, and 55 series aircraft as a first officer and had amassed about 2,450 hours on them. Since his upgrade, he had flown about 65 hours as pilot-in-command on the Learjet.

During his tenure with the company, the captain had flown many IFR operational and MEDEVAC flights, both day and night, and had flown into Masset on several occasions. His last flight before the accident was a night MEDEVAC from Prince Rupert on 09 January 1995, and previous to that, on 07 January 1995, he flew a MEDEVAC flight into Masset in C-GPUN.

Before joining the company, the captain had flown as a flight instructor providing basic, instrument, and multi-engine flying instruction. He had also been employed as a pilot with two other air carrier and charter companies in Vancouver operating Cessna 402, 414, and 421 aircraft.

A review of both the Transport Canada (TC) and the company files did not reveal any adverse aspects of the captain's aviation career and experience; the review identified a normal and competent progression of training, experience, development, and advancement.

1.5.2 The First Officer

The first officer held a valid ATPL and Group 1 instrument rating valid until 01 December 1996, and a valid class 1 instructor rating valid until 01 May 1996. A category 1 LVC had been issued for this licence, without limitation, and was valid until 01 July 1995. His first and only Learjet 35 PPC was successfully completed on 14 November 1994, during which he was evaluated as a first officer only. This classification is a common air carrier practice and allows for pilots, inexperienced on type, to accumulate on-the-job experience under the supervision of experienced captains.

The first officer was hired by the company in November 1994 as a first officer for the Learjet aircraft. At that time, he had accumulated about 2,800 hours' flight experience on several small and medium, single- and twin-engine aircraft. In his short time with the company, the first officer had flown about 60 hours as first officer on the Learjet, of which about 7 hours were spent in training. He had flown about 20 IFR operational and MEDEVAC flights, totalling about 55 hours, of which 27 hours were at night. He had not flown into Masset previously. His last flight before the accident was a night MEDEVAC into Cranbrook on 06 January 1995, and previous to that, on 05 January 1995, he flew a night MEDEVAC into Prince George.

Before joining the company, the first officer had flown as a flight instructor providing basic and multi-engine flying instruction, and he had worked for another air carrier in Vancouver as a first officer on Beechcraft 99 series aircraft. None of these aircraft flew above 18,000 feet.

The bulk of his flying with the company had been conducted with either the chief pilot or the company training captains. He had been on the line for nearly eight weeks, and had only begun flying with regular line captains on 22 December 1994.

A review of both the TC and the company files did not reveal any adverse aspects of his aviation career and experience; the review identified a normal and competent progression of training, experience, development, and advancement.

1.5.3 Crew Personality Profiles

Although they had only flown together for 1.2 hours, the captain and first officer were thought by their fellow employees to have interacted well, both as a crew and as fellow aviators.

The captain, a single man, was said to have been a quiet, compassionate, and meticulous individual. He was regarded as a conscientious pilot, respected by his peers and supervisors in the company. He had no significant outside pressures.

The first officer, a happily married man, was said to have been a well-adjusted and dedicated individual who was in the early stages of his aviation career. He was new to the company; nevertheless, he was regarded by his peers as helpful and energetic, and by his supervisors as a cheerful person with a positive, professional attitude. He did not have any significant outside pressures.

1.5.4 Pilot at the Controls

Eyewitnesses confirm that, when the Learjet taxied away from the company terminal at Vancouver, the captain was seated in the left seat. Additionally, the medical examination of the captain revealed injuries consistent with control manipulation during impact, indicating that he was likely flying the aircraft.

ATS audio tape recordings and company interviews indicate that the first officer made most of the radio communications upon departure from Vancouver and en route, although the captain's voice was also identified on the ATS tapes. It is common practice within the company that the pilot not flying make the radio calls; however, based on cockpit workload, either pilot may use the radio. Furthermore, by company convention, the captain normally flies the outbound leg and, at the captain's discretion, the first officer flies the return leg.

For these reasons, and because the captain would have likely preferred to fly the demanding[4] night approach into Masset, it is most likely that the captain was flying the aircraft. However, without cockpit voice recorder (CVR) information from the accident flight, there is not enough evidence to confirm that the captain was flying the aircraft when it struck the water.

1.6 Aircraft Information

Manufacturer	Bombardier Learjet Inc.

[4] This approach was conducted at night, in unknown weather conditions, with portable runway lights, but without any precision approach aids or approach lights.

Type	Learjet 35
Year of Manufacture	1976
Serial Number	35-058
Certificate of Airworthiness	Valid
Total Airframe Time	11,676 hr
Engine Type (number of)	TFE 731-2 (2)
Maximum Certified Take-off Weight	18,000 pounds
Recommended Fuel Type	Jet A / A-1 / B
Fuel Type Used	Jet A-1

The airframe and engines maintenance records for C-GPUN were reviewed for the period from April 1976 to the accident date. The review showed that the company maintenance practices were in accordance with requirements as specified in Air Regulations and Air Navigation Orders that pertain to their operations.

The aircraft was certified, equipped, and, with the exception of CVR testing, maintained in accordance with existing regulations and approved procedures.

The aircraft was purchased new by the company from Learjet. In October 1988, it was involved in a landing accident which caused substantial damage to the landing gear and wings (TSB occurrence report A88P0252). The aircraft was rebuilt by the manufacturer, returned to the company, and had since been in continuous service without further mechanical incident.

In accordance with company procedures, a copy of the aircraft weight and balance loading form for this flight was left behind at the company dispatch office at the Vancouver airport. The aircraft's weight at the time of the occurrence was estimated to have been 14,150 pounds, which is 3,850 pounds below the maximum certificated all-up weight. The centre of gravity was estimated to have been within the prescribed limits throughout the flight.

C-GPUN was not equipped with a ground proximity warning system (GPWS), but it had been in the past. A GPWS is an electronic system that automatically operates without any pilot input and provides pilots with a timely and distinctive warning, both visible and audible, that their aircraft is in potentially hazardous proximity to the earth's surface. GPWS has prevented many accidents where, until the warning was given, the pilots had been unaware that the aircraft was in danger because of its proximity to the ground or water. Air Navigation Order (ANO) Series II, No. 22 indicates that only turbo-jet aircraft in excess of 33,069 pounds are required to be fitted with GPWS; there was no regulatory requirement that Learjet 35 aircraft be so equipped. The Board is concerned that safety equipment is being removed from aircraft because it is not required by regulation.

1.7 Meteorological Information

1.7.1 Weather Reports for Masset

The Masset aerodrome had no provision for reporting weather conditions to an acceptable Atmospheric Environment Service (AES) standard. There was no calibrated meteorological equipment, nor was there an accredited weather observer. As a result, pressure altimeter settings and weather observations from Masset, if any, were informal and for general information only. The nearest approved weather observation station was the manned lighthouse at Langara Island, located about 35 nm west of Masset, which provided human-observed weather reports during daylight hours. At night, these observations reverted to hourly reports from the Automated Weather Observation System (AWOS) station at Langara Island. An AWOS located at Rose Spit, about 12 nm northeast of Masset, also provided hourly reports. An AWOS located at the Sandspit aerodrome, about 48 nm south of Masset, provided normal and ongoing weather observations. Weather observations were also available from the manned station at Prince Rupert, about 70 miles east of Masset.

In addition to other meteorological information, an AWOS station also measures atmospheric pressure using two separate electronic sensors. Mean sea level pressure is reported to the nearest 0.1 millibar (mb), while the altimeter setting is reported to the nearest 0.01 inches of mercury (in. Hg). The pressure sensors are fail-safe; that is, if one unit is out of tolerance more than 0.04 in. Hg, the altimeter setting information is not reported.

On the night of the accident, the Sandspit AWOS5 station was apparently functioning correctly. The Langara and Rose Spit AWOS1 stations--which do not transmit information concerning ceiling, visibility, or altimeter setting--were also functioning correctly. Both stations continued to report the mean sea level pressure and temperatures.

1.7.2 Sandspit Weather

The 0100 PST weather report at Sandspit was as follows: estimated ceiling 1,600 feet[5] overcast, visibility more than 9 miles, light rain, 987.8 mb sea level pressure, temperature 7 degrees Celsius, dew point 6 degrees Celsius, wind from 120 degrees true at 20 knots, and altimeter setting 29.17 in. Hg.

The 0129 special weather report was as follows: 100 feet scattered, estimated ceiling of 1,200 feet broken, 2,000 feet overcast, visibility 5 miles in rain, temperature 7 degrees Celsius, dew point 6 degrees Celsius, wind from 110 degrees true at 12 knots, and altimeter setting 29.17 in. Hg.

The 0136 special weather report was as follows: 100 feet scattered, estimated ceiling of 1,900 feet overcast, visibility 4 miles in heavy rain, temperature and dew point 6 degrees Celsius, wind from 120 degrees true at 16 knots, and altimeter setting 29.17 in. Hg.

The subsequent weather reports until 0800 PST continued to report the altimeter setting gradually rising from 29.17 to 29.20 in. Hg.

1.7.3 Masset Weather

According to the aerodrome manager at Masset, the weather conditions up to the time the aircraft was declared missing were not adverse. At 2330 on 10 January 1995, he had informed the Learjet pilot by telephone that the wind was from the southeast at about five knots, with light rain, and that the visibility was such that he could clearly see the lights on the NDB tower. The NDB tower is 585 feet high. When the aircraft called over the beacon outbound, the wind and visibility had remained unchanged, and the light rain had reduced in intensity. No local altimeter setting was requested by, or given to, the pilot. The actual inflight weather conditions offshore were not known.

1.7.4 Masset Weather Aftercast

During the early hours of 11 January 1995, a low pressure area (975 mb or 28.80 in. Hg) was centred 200 miles southwest of Masset. This feature was generating a moderate 15- to 25-knot northeasterly wind in the lowest levels along the north coast of Graham Island. Above 2,000 feet, the winds veered to the southeast with speeds of 25 to 35 knots. Vertical windshears of 10 knots per thousand feet of altitude were likely present between 2,000 and 4,000 feet. The air mass was moist and stable. A weak trough in the upper

5 All references to cloud height are in feet above ground level (agl).

atmosphere was generating broken layers of stratocumulus based at 2,000 feet and additional overcast layers of altostratus. The cloud shield also produced light and locally moderate rain. Scattered to broken layers of stratus cloud formed in the precipitation and produced local ceilings of 200 to 800 feet. In areas of offshore flow, such as Prince Rupert, the visibility was greater than six miles, but in areas of onshore flow, such as Masset, rain and fog patches would have reduced the visibility to one mile. The strong vertical windshears below 4,000 feet would have produced moderate turbulence at low level.

1.7.5 Flight Crew Briefings

An examination of the flight planning document left behind by the crew, and a review of the taped conversations between the crew and various ATS facilities, reveal that the pilots had obtained the most recent and appropriate forecast and actual weather conditions for the area, the destination, and the alternate and surrounding aerodromes, both before and during their flight. Just before descending from FL390, the first officer received and acknowledged a Sandspit altimeter setting of 29.17 in. Hg from Vancouver ATC. It could not be determined if he adjusted his altimeter at that time.

1.8 Aids to Navigation

The navigational aids available at the Sandspit aerodrome were an NDB, a very high frequency omni-directional range (VOR) station, and a distance measuring equipment (DME) system, which were all reported by ATS as serviceable at the time of the accident. The navigational aid available at the Masset aerodrome was an NDB, which was also reported as serviceable at the time of the accident. Although the beacon was owned and operated by the village of Masset, there is a formal arrangement with the DND at Canadian Forces Base (CFB) Masset to continuously monitor the performance of the beacon. The ATC Secondary Surveillance Radar (SSR) situated near the Sandspit aerodrome was fully functional at the time and received track and altitude data of the Learjet down to the point where contact was lost.

No evidence was found to indicate that any of the on-board aircraft navigation systems had malfunctioned, either during the accident flight or in recent service. None of the DND SAR aircraft or other aircraft responding to the scene of the accident reported any difficulty with the Masset NDB.

1.9 Communications

A review of the applicable ATS audio tapes revealed that radio communications between all ATS facilities and C-GPUN had been normal throughout the flight. The review identified the first officer as the flight crew member principally communicating with Vancouver Area Control Centre (ACC), and revealed that all communications characterized an alert and professional flight crew. The last radio transmission from the aircraft was the "outbound" report to the Masset aerodrome manager at the beginning of the approach to Masset on 123.2 MHz, the aerodrome traffic frequency. There had been no distress call, and at no time did the crew indicate they were experiencing any difficulties.

1.10 Aerodrome Information

1.10.1 Masset Aerodrome Information

The Masset aerodrome is located near the northeastern corner of Graham Island, about 1.5 miles north of the village of Masset. The aerodrome geographical reference point is at latitude 54˚01.29′N and longitude 132˚07.06′W, with a reference elevation of 24 feet above sea level (asl). It is registered as a public-use aerodrome and is operated and maintained by the Village of Masset. At the time of the accident, the only runway, runway 12/30, was 4,400 feet long and 75 feet wide. Apart from 200 feet of level gravel surface at each end of the runway, the paved surface was smooth asphalt in unremarkable condition.

A DND communication complex, CFB Masset, is situated about four miles east of the aerodrome, and is surrounded by a 30-foot tall enclosure fence, marked by obstruction lights on the fence support posts. The villages of Masset and Old Masset lie to the west of the aerodrome and have conventional residential and commercial lighting.

1.10.2 Runway Lighting

Canadian Aviation Regulations (CAR) Series III, No. 2, *Airport Regulations*, is the order respecting minimum lighting at aerodromes. On 19 October 1994, this CAR replaced the former ANO Series III, No. 2, the *Aerodrome Minimum Lighting Order*. In essence, however, the new CAR embodies the provisions and requirements of the former ANO; the obligation to ensure that appropriate lighting is available for an aircraft to land and take off at an aerodrome at night continues to rest with the pilot-in-command.

In part, CAR Series III, No. 2, section 3(1), requires that an aerodrome, where it is to be used at night, display lights "... to mark take-off and landing areas, [with] two parallel lines of fixed white lights visible in all directions for at least two miles." Section 3(2) of the CAR establishes the arrangement of the lights forming the parallel lines.

The runway lights used at Masset are individual, portable, battery-operated lights that are set up by the airport staff when required. At the time of the accident, the runway was lighted for an aircraft arrival on runway 12. The Village of Masset had issued written instructions to be followed with respect to the arrangement of this lighting. These instructions were in accordance with the applicable CAR, and the lighting on the night of the accident exceeded the CAR requirements. The only variation from the requirements was that the parallel lines of lights consisted of amber and white lights, placed alternately in line, instead of all white lights.

1.10.3 The NDB "A" Approach to Runway 12

In accordance with the instrument approach procedures published in the *Canada Air Pilot* (CAP) - *West* dated 08 December 1994, an aircraft conducting the Sandspit transition to the NDB "A", non-precision approach to runway 12 at Masset would initially cross the Masset NDB at an altitude of 3,600 feet asl and proceed outbound on a track of 300 degrees magnetic. It would then enter the procedure turn and maintain 1,600 feet asl, before descending on the final inbound track to the minimum descent altitude (MDA) of 600 feet for Category "C" aircraft; the Learjet was a Category "C" aircraft. In accordance with the remote altimeter setting procedures, 240 feet must be added to these altitudes as minima.

The aircraft's track during the instrument approach, as recorded by the ATS radar and the aircraft flight data recorder (FDR), closely matched the desired track as published on the CAP-West approach plate.

Appendix A (Instrument Approach at Masset) is a reproduction of the approved Masset NDB "A" instrument approach in effect at the time of the accident.

Appendix B (Altitudes Flown) is a representation of the actual approach altitude profile flown by C-GPUN, determined from both the ATC radar data and the aircraft FDR, compared with an approach profile flown at the indicated altitude, assuming that 30.17 was set on the altimeter sub-scale.

1.10.4 *On Approach to Runway 12 at Night*

On the night of the accident, the obstruction and security fence lighting on the CFB Masset communication complex was turned on, and the villages of Masset and Old Masset were illuminated with the usual village and street lighting. It could not be determined whether the Learjet crew saw any of this lighting.

During wreckage recovery, members of the investigation team in the recovery vessel, positioned in the area of the aircraft wreckage about eight miles offshore, at night, noted that the security fence lighting around CFB Masset was clearly visible. When accident investigators flew into Masset, their aircraft flew in on the NDB "A" approach to runway 12. During this approach, which was conducted during darkness and clear weather conditions, the DND facility lighting was visible from at least 10 miles offshore, and the runway lighting was not clearly visible until about three miles from the threshold of runway 12.

Because of the low intensity of the portable runway lights, the crew would not have seen them from an altitude of 800 feet asl during the final part of the procedure turn inbound to the aerodrome, or from a position of 8.8 miles from the runway, that is, the point of impact.

1.11 *Wreckage and Impact Information*

1.11.1 *General*

On 19 January 1995, a fishing trawler, seven miles north of the Masset aerodrome, pulled aircraft debris up in its net. These parts were later identified as sections of the cockpit and lower fuselage of C-GPUN. On 31 January 1995, underwater sonar located what appeared to be the wreckage in about 260 feet of water in a location that coincided with the final approach path for runway 12 at the Masset aerodrome.

The main wreckage of the Learjet was not positively identified until 08 February 1995. Underwater sonar mapping and optical inspection using a video camera mounted in a remotely operated vehicle (ROV) revealed that the wreckage site was concentrated in an area of about 100 square metres. The wreckage consisted of most of the aircraft except the cockpit and cabin section forward of the wings, which could not be located.

The Learjet had broken apart into several major components; the rear fuselage section and vertical fin, the horizontal stabilizer and elevators, the central wing section, the wing extensions, the tip tanks, and the two engines and pylons. A portion of the cockpit central instrument panel containing some engine performance gauges was also found. The landing gear was not found. The only part recovered of the main aircraft wreckage was the rear fuselage and vertical fin section which contained the flight recorders.

1.11.2 *Aircraft Wreckage Examination*

The parts of the cockpit brought up by the fishing boat were examined by TSB investigators, and the glareshield warning panel and fire T-handles were sent to the TSB Engineering Branch for examination and analysis. The T-handles were found in the stowed position.

The aircraft wreckage was examined intensively using the underwater video camera on the ROV and was recorded on videotape. The portion of the instrument panel containing the engine gauges was examined using the underwater video camera; it was not possible, however, to clearly or accurately read any of the gauges, nor could the underwater vehicle successfully recover the instrument cluster for later examination. The panel also contained the "set altitude" alerter device used by pilots to alert them of the next pertinent altitude; it was found to have a setting of between 800 and 900 feet. Such a setting could have been consistent with conventional instrument approach procedures; however, that the one-hundred-foot digits "8" and "9" were both visible in the window, that is, in an abnormal "mid-way" position, indicated that the original setting had been disturbed, presumably during the accident sequence. As a result, the setting on the device at impact could not be determined, nor could it be ascertained if, or when, this crew had entered a setting.

The rear fuselage and vertical fin section were taken to the TSB Regional wreckage examination facility in Vancouver and examined by TSB investigators with the assistance of an aircraft airworthiness representative from Learjet. Nothing was found to indicate that any structural failure or system malfunction had occurred before impact.

Of particular importance, the condition of the following components was noted:

1. Wing fuel crossflow valve was closed. (normal)
2. Fuselage fuel transfer valve was closed. (normal)
3. Left and right main fuel shut-off valves were open. (normal)
4. Left and right motive flow fuel shut-off valves were open. (normal)
5. Left and right hydraulic shut-off valves were open. (normal)
6. Left and right fire extinguisher bottles were charged at 600 and 650 psi respectively, with both firing "squib" devices intact. (normal)
7. Hydraulic accumulator was charged to 850 psi. (normal)
8. Horizontal stabilizer actuator was found in the -5.04 degree position.

Pulling the T-handle closes the main fuel shut-off valves and the hydraulic shut-off valve, among other things. Because the T-handles were stowed and the afore-mentioned valves were in the normal position, it can be concluded that the T-handles were not pulled.

The position of the horizontal stabilizer actuator indicates that, at the time of impact, the stabilizer was trimmed to a position within the normal range of movement, consistent with the aircraft attitude and configuration during the final stages of an approach. There was no evidence of control cable irregularities.

In summary, the underwater video analysis and the examination of the tail section found no evidence to suggest that the aircraft was not complete, intact, or functioning normally at the time of impact.

1.11.3 Engine Examination

An examination of the engines was carried out and recorded using the underwater video camera on the ROV. The video reveals significant rotational damage to the No. 2 (right) engine fan blades; such damage is consistent with that caused when an operating engine strikes water. There was no evidence of engine fire or other malfunction on either engine.

1.11.4 Light Bulb Examination

A section of the glareshield containing the warning light panel, autopilot controller, and the two fire T-handles was examined by the TSB Engineering Branch. These components all contained lamps which may have been illuminated at the time the aircraft experienced high impact forces. Lamps are routinely examined to determine if the filaments exhibit any deformation caused by impact forces. Depending on the severity of the impact, a glowing tungsten filament will typically exhibit deformation or stretching of its coils, whereas a cold filament may not exhibit any deformation or it may exhibit brittle type fractures. The results of the lamps examination are contained in TSB Engineering Report 8/95 and are summarized below.

The report identified that the lamps in the No. 2 engine fire T-handle, the map light, the augmentation aileron system (AUG.AIL) warning, and the right vertical gyro monitor (RVG MON) warning were likely on when they were subjected to impact forces sufficient to damage the filaments. The report continues, however, to say that it was unlikely that all three of these warning lights would have been on prior to impact; therefore, it is possible that some or all of the lights may have been activated during the initial impact.

The most critical item of concern raised by these findings was the possibility of fire in the No. 2 engine. A review of the electrical circuitry of the fire detection system reveals that it would have been possible to have had a false fire indication if the heat sensing elements were damaged or shorted out. The illumination of the No. 2 engine T-handle lights may have been the direct result of impact damage, and may be a false indication of an engine fire.

In summary, since the FDR had continued to record data for five seconds after the initial impact, electrical power was available to illuminate any warning lights that may have been activated because of associated structural or system damage during the breakup sequence. It could not be ascertained if any of the warning lights were illuminated before impact.

1.12 Medical Information

The LVC limitation that the captain had to wear eye-glasses during flight was imposed as a result of some deterioration in his long range vision; his short range vision was normal. Witnesses observed that the captain was not wearing his glasses at the time of departure from the ramp; however, he had reportedly worn contact lenses for some time and had flown with them regularly. It could not be determined if the captain was wearing glasses or the contact lenses at the time of the accident.

The medical examination and toxicological tests conducted on the captain did not identify any pre-existing medical conditions which could have affected his performance. There was no indication of incapacitation. A review of both pilots' medical records, examination results, and their most recent activities did not reveal any sign of physiological or psychological factors which could have affected their performance.

1.13 Flight Recorders

1.13.1 General

The aircraft was equipped with both a flight data recorder (FDR) and a cockpit voice recorder (CVR). Both recorders were recovered intact from the wreckage and analyzed by the TSB Engineering Branch.

1.13.2 Flight Data Recorder

At the time of the accident, regulation regarding the installation of the flight data recorders was contained in ANO Series II, No. 13, the *Flight Data Recorder Order*, which, in part, required that turbine-equipped, pressurized aeroplanes weighing more than 12,500 pounds be equipped with a serviceable and functioning FDR. The ANO also required that, in addition to the five mandatory parameters, further specific parameters were also to be recorded. An exemption from this additional requirement had been formally granted by TC to the company for their Learjet aircraft, including C-GPUN, on 07 December 1988.

The FDR on board the aircraft, a Sundstrand Universal digital FDR, had captured the last 25 hours of flight information with respect to nine parameters. Altitude information captured by the FDR is referenced to the standard altimeter setting of 29.92 in. Hg and, except when the existing barometric pressure equals this value, does not reflect the true altitude of the aircraft above mean sea level (asl).

The data recovered from the FDR was of good quality, and it provided investigators with an accurate record of the aircraft parameters up to the point of impact.

FDR data revealed an unremarkable flight from Vancouver until the top-of-descent (TOD) at FL390 at about 0127.

From TOD, the Learjet descended to an initial altitude of about 3,400 feet standard pressure altitude (pa) based on 29.92 in. Hg; based on the actual barometric pressure setting at the time, this altitude was about 2,650 feet asl. The aircraft then gradually climbed to about 3,650 feet pa (2,900 feet asl). At 0144:20 PST, the aircraft began a descent to about 1,400 feet pa (650 feet asl). Twenty-five seconds later, the aircraft climbed to maintain 1,650 feet pa (900 feet asl) until 0149 PST, when it began a descent to the initial impact point of about 750 feet pa (0 feet asl). The aircraft struck the water at a recorded airspeed of 138 knots on a heading of 107 degrees.

Appendix C (Indicated Altitudes) is a representation of the last 12 minutes of the primary altitude trace from the FDR at 29.92 in. Hg, with the same altitude trace duplicated for two other pressure settings, namely, 29.17 and 30.17 in. Hg. The trace marked "29.17" represents the true altitude of the aircraft above the water; the trace marked "30.17" represents what the pilot would have seen had his altimeter been set to this value.

This descent profile, to the point of impact, accurately corresponds to the required transition and instrument approach procedures; the altitudes flown do not. Concomitant with this descent profile were headings, airspeeds, and intervals nearly identical to those required by the approach. At no time did the FDR data indicate that the aircraft deviated from the flight planned route, or that the crew was experiencing any difficulty in flying the approach.

The FDR data indicate that the impact was at an elevation of 750 feet above sea level; however, the aircraft actually crashed at sea level. The FDR records data at an atmospheric pressure of 29.92 in. Hg, but the actual atmospheric pressure at the time was 29.17 in. Hg, which corresponds to a 750-foot difference in altitude.

1.13.3 Cockpit Voice Recorder

At the time of the accident, regulation pertaining to the installation of the CVR was contained in ANO Series II, No. 14, the *Cockpit Voice Recorder Order*, which, in part, required that turbine-equipped, pressurized aeroplanes weighing more than 12,500 pounds be equipped with a serviceable and functioning CVR. The ANO also stipulated that when a CVR became inoperative, and the FDR remained functioning, the aeroplane might be flown only to complete a planned itinerary to a maintenance base.

The CVR on board the aircraft was a Collins, four-track unit, which, by design, recorded the last 30 minutes of both internal and external communication with the pilots. The tape cartridge in this unit was found jammed; a review of the tape contents revealed that the unit had last functioned 12 days before the accident. As a result, no information regarding the accident flight was available to the investigation.

A cockpit-mounted CVR control unit contains the cockpit area microphone, a "phone" jack, a test button, and an associated meter. When the test button is pressed, a test signal is recorded onto the tape; a corresponding deflection of the needle on the meter indicates that the unit is serviceable. The test can be performed at any time electrical power is available to the CVR unit, but some companies carry out the test daily during the pre-start process. At the time of the accident, the company did not require pilots to conduct operational checks of the CVR units, nor was there any regulation requiring such tests.

Company aircraft maintenance schedules for the Learjet included a CVR performance check every 150 hours, which was scheduled to take place concurrently with a 150/300-hour engine zone inspection on both jet engines. This CVR test involved both aural and visual monitoring of the test signal using the "phone" jack and the meter. The last engine inspection was performed on 04 January 1995, but the CVR test was inadvertently omitted; the unit had jammed four days earlier. The cause of the malfunction could not be determined, but the character of the jam indicated that the tape would have suddenly stopped without warning and remained jammed.

1.14 Altimetry

1.14.1 Radio Altimeter

The Learjet was required by ANO Series II, No. 16, to be equipped with a radio altimeter (radalt). The aircraft was fitted with a radalt with direct scale reading of altitude from 0 to 2,500 feet, and incorporated a manual altitude setting knob and "bug," with an associated warning light. There were two repeater lights on each end of the central warning light panel, and all lights would have been illuminated whenever the radalt indicated an altitude less than the bug value set by the pilot. The bug can be set to below zero on the instrument, thereby disabling the warning light; some pilots find the warning light distracting, particularly at night, when flying at set minima. The electrical power to the radalt system is controlled by a single switch in the cockpit, operated by the left-side pilot.

Normal practice in the company was to set and maintain the radalt bug to below zero while the aircraft was en route. The MDA or the decision height (DH) for the approach was normally set on the radalt during descent from cruise altitude, or on passing the transition level at 18,000 feet.

The radalt was not found. TSB Engineering Branch analysis (LP 8/95) concluded that the altitude warning lights for the radalt, on the central warning panel, were not illuminated when they were subjected to accident impact forces; whether the lights were on immediately before impact could not be determined.

1.14.2 Pressure Altimeters

The aircraft was equipped with two altimeters, one on each side of the instrument panel. The left-side (captain's) instrument consisted of a Mode "C" encoding altimeter, an altitude alerter, and a Static Defect Correction Module. The pilot used and set the altimeter in the same way as a conventional barometric altimeter. The altimeter face scale was graduated in 20-foot increments from 0 to 1,000. The single pointer made one complete revolution for each one thousand feet of altitude. At the centre of the instrument face was a horizontal counter which read in hundreds and thousands of feet. Above and below this counter were the two altimeter sub-scale windows, graduated in both inches of mercury and millibars.

Directly associated with the captain's altimeter, the altitude alerter compares the indicated altitude to the value set in the "set altitude" device on the instrument panel. As the aircraft approaches 1,000 feet of a preset altitude, an altitude alert light and a momentary audio signal (chime) are activated. The light remains on until the aircraft is within 300 feet of the preset altitude. The chime will sound and the light will illuminate whenever the altitude deviates 300 feet from the preset value. Normally, company first officers set the alerter to either the MDA or the DH when extending the landing gear and flaps as the aircraft intercepts the final inbound leg of the approach.

The right-side (first officer's) altimeter was a conventional barometric altimeter, which indicated aircraft altitude in a presentation identical to the captain's altimeter. There was no altitude alerting device or static correction system connected to it. This would cause the right-side altimeter to read differently from the left-side altimeter. There is an acceptable differential published in the aircraft flight manual. This altimeter would not correspond to the captain's, with the normal differential of about 700 feet at FL390. By design, the differential decreases upon descent, and at lower altitudes, it diminishes to zero where the altimeters would indicate identical altitudes when set to a common sub-scale setting.

The FDR data for this accident flight indicated that this altimeter differential became negligible below 4,000 feet pressure altitude.

1.14.3 Altimeter Setting Procedures

In the *Designated Airspace Handbook* (TP 1820E), Canadian domestic airspace is divided into two finite areas, the Altimeter Setting Region (ASR) and the Standard Pressure Region (SPR). In summary, the ASR is an airspace of defined dimensions below 18,000 feet asl; airspace below 18,000 feet asl is also termed the "low level airspace." An SPR includes all the airspace at or above 18,000 feet asl and all low level airspace that is outside the specific dimensions of the ASR.

ANO Series V, No. 16, the *Altimeter Setting Procedures Order*, requires that pilots operating aircraft in the ASR continue to reset their altimeters to actual altimeter pressure settings at appropriate departure, en route, and destination aerodromes or reporting stations. Pilots operating aircraft in an SPR are required to set and maintain the standard altimeter setting of 29.92 in. Hg. Furthermore, when descending from the SPR into the ASR, pilots shall set their altimeters to the appropriate station altimeter setting immediately prior to entering the ASR. As a result of these procedures, professional pilots in high performance aircraft are constantly cognizant of the meteorological conditions, particularly barometric pressure, at destination aerodromes, and verifying and changing an altimeter setting is standard practice.

The Masset aerodrome lies within the ASR. During this accident flight, the aircraft would have been required to fly in the ASR for the departure from Vancouver and the approach at Masset, and in the SPR while en route at FL390.

1.14.4 Remote Altimeter Setting

Normally, pilots fly instrument approaches using the current altimeter setting for the destination aerodrome. At certain aerodromes, however, where a verified local pressure setting is unavailable, approaches are flown using a current altimeter setting from a nearby aerodrome. Such an altimeter setting is considered a "remote" setting, and authorization for its use is published in the top, left-hand corner of the CAP approach plate. When the remote altimeter setting is used, the pilot must apply an altitude correction factor to all published instrument procedure minimum altitudes.

In the Masset NDB "A" instrument approach, the remote setting procedure was authorized for the Sandspit pressure setting, and the approach plate advised that the altitude correction factor of 240 feet had to be added to all altitude minima. For example, the published procedure turn altitude was 1,600 feet, but to comply with the remote altimeter setting procedure, aircraft were required to conduct the turn at 1,840 feet, that is, 240 feet higher than published.

1.14.5 True Height versus Altimeter Setting

Altitude information indicated by an altimeter, although technically "correct" as a measure of air pressure, may differ greatly from the actual height of the aircraft above mean sea level or the ground. Such variation is the result of the continually changing barometric pressure, and it is compensated for by incorporating a pilot-controlled sub-scale mechanism in the altimeter.

This same altitude variation is also caused by the aircraft itself travelling between areas of differing air pressures, and unless the pilot again adjusts the altimeter sub-scale setting on the altimeter, the indication of the actual height above terrain will be erroneous. A similar situation would occur when an aircraft transitions between the ASR and the SPR.

Whether a pilot inadvertently sets an incorrect altimeter setting on the sub-scale, or flies into an area of differing pressure without adjusting the sub-scale, the result is the same--the altimeter reading will be erroneous. This error is an amount proportional to 1,000 feet indicated altitude for each in. Hg of barometric pressure that the sub-scale is in error. If the actual station pressure is a lower value than the one set in the altimeter sub-scale, the aircraft's true altitude is lower than the figure displayed by the altimeter. For example, if the station pressure is 29.17 in. Hg and the altimeter sub-scale is set to 29.92 in. Hg, the aircraft's true altitude is 750 feet lower than the altitude displayed by the altimeter.

1.14.6 C-GPUN Altimeter Settings

At 0110, the first officer acknowledged a message from Vancouver ACC which indicated that the station pressure at Sandspit, 48 miles south of Masset, was 29.17 in. Hg, and that the station pressure at Prince Rupert, about 70 miles east of Masset, was 29.26 in. Hg. At 0125, the first officer acknowledged another message from ACC which relayed the most recent Sandspit pressure of 29.17 in. Hg.

Sandspit was the nearest station to Masset issuing a current, verified altimeter setting, and, in accordance with procedures, both pilots were required to have set the Sandspit setting on their altimeter sub-scales before the aircraft descended below 18,000 feet on the descent to Masset.

Radar and FDR data confirm that the aircraft altitude was in accordance with the altimeter setting procedures from take-off until the descent from FL390; it cannot be determined what altimeter settings were used, or set, in the aircraft during the descent from FL390. The data in the following table do show, however, that the aircraft was consistently at an incorrect altitude from at least the Sandspit transition procedure to impact. Note that the values are averaged.

Procedure	CAP altitude required	Remote setting altitude required	Altitude data FDR	Altitude difference
Transition	3,600	3,840	2,900	700/940
Procedure Turn	1,600	1,840	900	700/940
MDA	600	840	0*	600/840

* impact

1.15 Company Operational Information

1.15.1 Crew Resource Management Training

There was no formal crew resource management (CRM) training provided to the company pilots. In August 1993 and September 1994, the company invited TC System Safety personnel to provide pilot decision making (PDM) training. The training was well received by the company and by those pilots who attended. The captain attended both courses, but the first officer had not yet been hired by the company.

Without the benefit of a functioning CVR, it is not possible to determine how this flight crew interacted during the accident flight. CRM methods are designed to improve the quality of communication, problem solving, and decision making; this creates an increased level of situational awareness and should reduce errors.

1.15.2 Crew Coordination

The company had no written standard operating procedures (SOPs) for their aircraft, nor did TC require air carriers to have them. TC recommends that companies have SOPs because they greatly improve crew coordination and overall operational safety. The procedures of flying the Learjet are introduced to the pilot during the initial ground and flight training phase, as well as in the line indoctrination.

During interviews with company pilots, it was determined that there was variation in the conduct of flight procedures between captains. Every six months, during ongoing flying training, the company training captains reviewed and identified standard flight procedures, but there was no formal standardization training.

In the absence of SOPs, normal company procedures for an approach would have included an approach briefing, descent checks, landing checks, and altitude calls. According to the company training captain, the pilot flying (PF) would brief the pilot not flying (PNF) before the descent, or at a convenient time, indicating his intentions for the approach and the altitudes to be flown in accordance with the appropriate approach plate.

During the descent, the PF would call for the descent checks and the checklist would be completed by the challenge and response method. The item "altimeter setting" was in the descent check. The company procedure required that the destination altimeter setting be set on the right-hand side altimeter, even though the aircraft might be well above 18,000 feet.

As the aircraft descended out of 18,000 feet asl, the PF would call for the transition checklist and both pilots would acknowledge the altimeter setting. Throughout the approach, the PNF would call out any pertinent altitudes and any significant deviations from the approach profile. The standard altitude calls were 1,000 feet above minima, 100 feet above minima, and minima.

1.15.3 Crew Scheduling

There is presently no regulation that explicitly requires the pilot or the company to keep track of duty times; a record is required to be kept, however, which monitors pilot flight times. The new CARS addresses this issue by ensuring that the air carrier sets up a system that monitors the flight time, flight duty time, and rest periods.

The investigation revealed no signs of any deviation from any flight and duty time regulations with respect to the crew in this accident; they had been given the opportunity of adequate rest periods before flight, and had not flown, or been on duty, in excess of the limits imposed by regulation.

1.15.4 Flight Training

ANO Series VII, No. 2, the *Air Carriers Using Large Aeroplanes Order*, section 47(1) states, in part, the following with respect to pilot flight training:

> The initial flight training provided by an air carrier for a pilot before he serves as a pilot flight crew member shall include, in each type of aeroplane he is to fly,
> (b) flight instruction and practice in
> (iii) take-offs and landings by day and by night.

The company's TC-approved operations manual did not state that the night flying training as specified in the ANO was required. Although the company did not specifically conduct the required night flying training, the company did conduct night flying line indoctrination with all company pilots.

The captain had received the initial night flying training when he joined the company, but the first officer had not. The first officer, however, had received about 20 hours of line indoctrination at night with the company chief pilot and the company training captains, which included night take-offs and landings.

1.16 Transport Canada

1.16.1 Program Approvals

TC assigns a Principal Operations Inspector (POI) to each air carrier. The POI responsible for the company at the time of the accident was assigned to them in 1991. One of the duties of the POI is to give the air carrier direction when it submits an Operations Manual amendment. The company training program, Section 12 in the Operations Manual, was approved by the POI on 06 October 1992.

1.16.2 TC Audits

The most recent TC operational audit conducted on the Canada Jet Charters Vancouver base before the accident was on 27 and 28 January 1992. The designated TC Audit Manager was the POI assigned to the company. The audit found no non-conformance findings. TC conducted an operational audit of the Canada Jet Charters Calgary base on 25 March 1992. Again, the TC Audit Manager was the POI for the company and there were no non-conformance findings. Both audit reports indicated that the company was "... maintaining a satisfactory standard in accordance with appropriate sections of the regulations."

The TC *Manual of Regulatory Audit* (MRA) was published in October 1991, and in part stated the following:

> 2.11 POI AND PAI RESTRICTIONS
>
> To maintain the impartiality of the audit process, Principal Operations inspectors (POI) and Principal Airworthiness inspectors (PAI) should participate in audits of their assigned companies only in an advisory capacity, assisting the appropriate Team Leader.

Chapter 3, Section 1.3 of the MRA required that a specialist inspection be conducted on an annual basis. The following areas of specific interest were identified as mandatory:

- a. company check pilot programme;
- b. flight crew training records;
- c. dispatch and flight watch;
- d. flight documentation;

e. passenger safety; and
f. dangerous goods control and records.

Note: Item "c" included a review of the flight and duty times.

During the review of the TC files, no reference to these specialist inspections was found, except for item "f" - dangerous goods. On 07 December 1993, a dangerous goods audit conducted by TC found that this aspect of the company operations was being conducted in accordance with the *Dangerous Goods Act and Regulations*.

The MRA further stated that all companies would be audited after initial certification and subsequently, regardless of compliance record, at least every three years. In accordance with this directive, the next TC operational audit was due in January 1995; at the time of the occurrence, there was no record of a written notice that the next audit had been scheduled.

In the MRA, Chapter 3, 4-3 Checklists, section OP-9, the items A.12, A.13, and A.14 required evaluation of certain flight and duty time issues. The forms used on previous TC audits did not contain reference to flight and duty times, nor was any related comment found therein.

Section OP-6 of the MRA, Flight Crew Training Programmes, required in part that the audit manager evaluate the flight crew training given by a company. There was no specific reference to the night flying training requirements specified in the appropriate sections of ANO Series VII, Nos. 2 or 3. The night flying requirements pertinent to the company were not commented upon in the last TC audit at either base.

1.16.3 Inspector Line Flying

In accordance with TC Policy Letter AARCB 1990, No. 47, TC Air Carrier inspectors could have flown as flight crew members with an air carrier. A Line Flying Program (LFP) had been implemented to allow TC inspectors to maintain current operational line experience and concurrently provide TC with a core of inspectors who have a more complete and present-day appreciation of the overall air carrier industry.

One of the qualifying conditions for inspectors on the LFP was that "... the Inspector should not be the Audit Manager or Team Leader for Audits of the Carrier that he flies with but may act as an Audit Team member or as an advisor for a Regulatory activity."

The TC inspector who has been assigned to the company as the POI since 1991 participated in the line flying program with Canada Jet Charters Limited until it was abandoned in about September 1994.

1.17 Additional Information

1.17.1 Radar Information

ATC radar tracked the aircraft as it flew from Vancouver to Masset and flight path data were analyzed. The altitude data transmitted by the aircraft's Mode "C" altitude encoder, and recorded by the ATS radar, were always referenced to the standard pressure setting of 29.92 in. Hg. The pressure source for the encoding unit on the aircraft was the captain's altimeter static pressure source corrected by the static defect correction module. The data were recorded in units of 100-foot increments and, for example, an altitude of 3,420 feet would have been recorded as "035". The radar data corresponded with the FDR data.

The radar data reveal an unremarkable flight from Vancouver until the Learjet descended to about 3,500 feet, which it maintained until 0140:56 PST. The aircraft then held 3,600 feet until 0144:28 PST when it descended to 1,300 feet. Shortly thereafter, the aircraft climbed to maintain 1,600 feet. At 0148:35, it left 1,600 feet and reached 800 feet at 0149:18; radar contact was lost and the transmitted aircraft data ceased at this time.

The radar data indicated that the aircraft had followed normal and expected navigational progress and flight route procedures. The aircraft's headings, distances, and speeds during the transition and the instrument approach were seen to have been in accordance with the published procedures on the CAP-West approach plate.

1.17.2 Controlled Flight into Terrain

Controlled flight into terrain (CFIT) accidents are those in which an aircraft, capable of being controlled and under the control of the crew, is flown into the ground, water, or obstacles with no prior awareness on the part of the crew of the impending disaster.

Various factors have been identified in CFIT accidents; generally they include some combination of perception limitations, attention/timing/task management, non-compliance, procedural errors, deficient intra-cockpit interactions, and loss of situational awareness.

1.17.3 Low Barometric Pressure

There are numerous documented cases concerning pilots applying incorrect altimeter settings in situations of unusually low barometric pressure. A common thread in most of these occurrences is that each pilot had entered a sub-scale setting which was 1 in. Hg in error, that is, the altimeter was mis-reading by 1,000 feet. In most of the occurrences, effective cockpit resource management identified the error after it had been made.

In Canadian domestic airspace, barometric settings in the low 29 in. Hg pressure region are infrequent. As a result, pilots can develop the habit of concentrating upon only the decimal part of the setting.

Ultimately, it is the flight crew's responsibility to ensure that the correct altimeter setting is applied, and to maintain good cockpit communication to catch any errors.

2.0 Analysis

2.1 Introduction

Nothing was found to indicate any mechanical defect or aircraft systems malfunction before impact; nor was there any direct implication of the relevant aviation systems, facilities, or services available and being used by the aircraft during the accident flight. There were no indications of any flight crew physiological and psychological factors that could be considered causal in this accident.

Weather was considered not to have been a causal factor in this accident. Rather, it was seen that the circumstances of the accident were principally affected by operational factors which occurred during the descent.

It was necessary, therefore, to concentrate on crew performance issues to determine how this accident occurred. The analysis focuses on the probable approach profile for C-GPUN leading to water impact, the possibility of unintentional altimeter setting error, cockpit crew coordination, and controlled flight into the water.

As well, the analysis includes information regarding the company and the role of TC as the approving and regulating agency.

Although data from the FDR were greatly beneficial to the investigation and helped establish the aircraft's complete flight profile, the absence of pertinent CVR data prevents any in-depth analysis of the crew's performance, their decision-making processes, their operational circumstances, or the influences leading up to the accident. CVR testing and serviceability issues are also analyzed.

2.2 Descent Profile

Recorded Vancouver ACC radar data show that the aircraft followed the required track during the transition from Sandspit to Masset, and during the instrument approach procedure to the point where radar contact was lost. FDR and radar data both reveal that the aircraft was holding definite altitudes. This demonstration of positive control indicates that the pilot was flying the approach according to established procedures, and that the aircraft and crew were proceeding with the flight without any apparent difficulty. The lack of any emergency radio communication also supports the premise of normal inflight circumstances.

Just before descent from FL390, the first officer had acknowledged a Sandspit altimeter setting of 29.17 in. Hg. Although it could not be determined if he had adjusted his altimeter at that time, it should have been changed in accordance with normal practices. He would likely have not made any further change to his altimeter sub-scale after that time since no more pressure settings were relayed to the crew.

The captain was likely flying the aircraft. In this case, if his altimeter was set correctly, there is no apparent reason for him to have maintained consistently low altitudes and flown into the water. It must be concluded that his altimeter was incorrectly set.

The most likely causal element of the accident, the mis-setting of the altimeter, probably occurred during descent through the transition level at 18,000 feet but certainly before the Sandspit transition procedure to Masset, either by error or omission.

2.3 Masset Weather

Without quantitative weather reports from credible observers, the actual weather conditions at Masset are unknown. Nonetheless, the aerodrome manager, relying upon his exposure to, and experience of, previous weather conditions which were suitable for similar aircraft operations, assessed that the existing general weather conditions were not adverse.

Although the weather at the aerodrome does not necessarily reflect the offshore conditions, given the proximity of the accident site to the aerodrome, those conditions are likely to have been similar. The Masset weather aftercast identified the formation of fog patches and these may have been present offshore.

Regardless of the aerodrome or offshore weather conditions at the time of the accident, the circumstances precipitating the lower-than-required altitudes occurred without relation to the weather conditions.

2.4 Possible Scenarios

2.4.1 General

The absence of any pre-impact aircraft deficiencies, the absence of any emergency call from the crew, the conscientiously flown instrument approach, and the aircraft attitude at impact as interpreted from the FDR all indicate that the pilot was in control of the aircraft when it struck the water. There are three possible explanations, none of which can be refuted with certainty, as to why the aircraft flew the whole approach with a consistent altitude error.

The following scenarios are based on all of the available information. They are conjectural in that they describe what could have happened and do not necessarily represent what did happen. They are, however, the most plausible scenarios with respect to the crew's altitude mismanagement and their lack of awareness of that mismanagement. Reference to Appendices A and C will assist in understanding the scenarios. In the following discussions, each scenario is tested against all the available information.

Meaningful analysis can only be applied to that part of the descent profile where "hard" altitudes are required. For this accident, there are only six such altitudes:

1. Sandspit transition at 3,600 feet;
2. procedure turn altitude of 1,600 feet;
3. MDA altitude of 600 feet;
4. remote altimeter setting MDA altitude of 840 feet;
5. Sandspit remote altimeter setting transition at 3,840 feet; and
6. remote altimeter setting procedure turn altitude of 1,840 feet.

2.4.2 Altimeter Sub-Scale Setting 29.17

An altimeter set to the appropriate barometric pressure of 29.17 in. Hg would have indicated the true height of the aircraft above the water.

The pilot received this altimeter setting during his pre-flight weather check and it was also relayed to him by ATC. Available information shows that the aircraft flew at specific, controlled, and consistently low altitudes during the complete instrument approach at Masset, and if 29.17 in. Hg was set, the aircraft would have been flown in the final descent until the altimeter read zero. Consistently flying low and descending until the altimeter reads zero are not the actions of professional pilots. It can be concluded, therefore, that the aircraft was not being flown with reference to an altimeter set to 29.17 in. Hg.

2.4.3 Altimeter Sub-Scale Setting 29.92

This scenario assumes that the pilot flew the aircraft with reference to an altimeter set to the standard barometric pressure of 29.92 in. Hg.

The initial level off for the Sandspit transition was at an indicated altitude of 3,400 feet, after which the aircraft maintained an indicated altitude of 3,600 feet. This last altitude corresponds to the 3,600-foot standard transition altitude required, and is likely the altitude chosen by the pilot. This altitude profile suggests that the pilot undershot his minimum altitude by at least 200 feet, before climbing back up to maintain the required altitude.

The subsequent procedure turn level-off at an indicated altitude of 1,400 feet, followed by a quick climb to an indicated altitude of 1,650 feet, indicates that the pilot again undershot his minimum altitude on the approach plate, before quickly climbing back up to the 1,600 feet required. The inbound descent would have progressed until water contact at an indicated altitude of about 750 feet.

Although the 29.92 setting theory is plausible, it requires several other abnormal factors to have been in place.

Firstly, the captain would have had to miss resetting his altimeter on descent through 18,000 feet, and to have continued the flight without recalling the changeover requirement. The captain had flown high performance Learjet aircraft for the last five years and would have changed altimeters at the transition level at least twice on most flights. Furthermore, professional pilots in high performance aircraft are constantly attuned to the meteorological conditions at destination aerodromes, and verifying and changing an altimeter setting is a standard practice. With such long-engrained habits, it is most unlikely that he would not have reset his altimeter. As well, the first officer would have had to miss this changeover. A significant distraction, however, could have caused them both to overlook the sub-scale change.

Secondly, the approach profile suggests that the pilot undershot the 1,600-foot procedure turn minimum by about 250 feet and maintained that altitude for almost 60 seconds before correction. Although it is possible that the pilot missed his level-off altitude through inattention or distraction, such a deviation would have been a significant error for a pilot of his calibre, and in sharp contrast to the demonstrated precision during other parts of the approach. It is unlikely that low-level turbulence would have had such a marked effect on the precision of levelling out at this minimum.

Thirdly, the scenario does not consider the remote altimeter setting requirement. A pilot of the captain's standard would likely not have ignored this additional altitude requirement. As well, since the crew did not request or receive a local altimeter setting from the Masset aerodrome manager during the time they were in communication with him, it could be assumed that the captain had decided to continue the approach procedure using the remote setting from Sandspit.

Finally, at the low altitudes where the two altimeters should have been consistent with each other, an altitude discrepancy of 750 feet would have been visually obvious during scans or cross-checks, since the angular difference of the pointers would have been 90 degrees on the instrument faces. This analysis assumes that the first officer had changed his altimeter at the TOD, in accordance with company standards. There is nothing to confirm that he did or did not; on the other hand, the first officer did acknowledge an altimeter setting just before descent from FL390, a time consistent with the company procedure regarding the first officer altimeter changeover.

2.4.4 Altimeter Sub-Scale Setting 30.17

This scenario assumes that the pilot flew the aircraft with reference to an altimeter set to an incorrect barometric pressure of 30.17 in. Hg but had applied the 240-foot correction factor to all the approach altitude minima.

The initial level-off for the Sandspit transition was at an indicated altitude of 3,650 feet, after which the aircraft maintained an indicated altitude of about 3,850 feet. This last altitude nearly corresponds to the 3,840-foot remote transition altitude required. The profile is consistent with the pilot erroneously levelling off at the 3,600-foot minimum before recalling his obligation to add 240 feet because of the remote altimeter requirements.

The subsequent procedure turn level-off at an indicated altitude of 1,650 feet, followed by a quick climb to an indicated altitude of 1,900 feet, was also consistent with the pilot descending to the original approach plate profile minimum, before quickly climbing back up to the 1,840 feet required. The inbound descent would have progressed until water contact at an indicated altitude of about 1,000 feet.

This scenario assumes two normal and expected actions: that the pilot changed his altimeter setting on descent through the transition level as required, and that the captain was applying the required remote altimeter correction factor to his minimum approach altitudes.

How the pilot was to set 30.17 instead of 29.17 on his altimeter sub-scale is not known. Because of the simple adjustment mechanism on the altimeter itself, it is physically easier and quicker to turn the altimeter adjustment knob to arrive at a figure of 30.17 from an existing value of 29.92, than it is to turn to 29.17. It has been shown that pilots can become accustomed to concentrate upon the decimal part of the altimeter setting and pay less attention to the whole number. It is possible that the pilot turned the altimeter setting knob in the shortest direction to 30.17, did not recognize his error, and mistakenly thought he had set 29.17. From then on, the altimeter reading would have constantly been 1,000 feet higher than the actual altitude.

It is conceivable that the pilots obtained an erroneous local altimeter setting for Masset. However, the airport manager, the only person who could have passed them a Masset altimeter setting, stated that he did not pass any altimeter setting to the crew. If the crew had received an erroneous altimeter setting, they should have noticed the large pressure differential between Sandspit and Masset, only 48 nm away, and they would have had to ignore the recent meteorological advice from three different sources of the barometric pressure in the area. Furthermore, any such altimeter setting from Masset would not be approved for the conduct of an instrument approach.

2.4.5 Summary

Regardless of the actual circumstances generated by the altimeter sub-scale settings, the principal event leading to the lower-than-required altitudes was either mis-setting, or omitting to set, one or both altimeters. The scenario that best fits the available information is that the crew mistakenly set 30.17 on the sub-scale of their altimeters. Why neither crew member detected the error could not be determined.

2.5 Controlled Flight into Water

In consideration of the weather conditions, the dark night, and the lighting conditions, there would have been few visual cues to help the crew establish their altitude. Any peripheral lighting would probably have been of no benefit to the crew in being alerted to their low altitude. As well, at this particular phase of the approach, both pilots would likely have been concentrating upon their respective duties inside the cockpit and might not have had the opportunity to look outside.

Since the mis-set altimeter was indicating altitudes which the captain had planned and had expected to see, he would have been unaware of the actual low altitude over the water, except if he had observed the radio altimeter. Had the crew set the radalt bug to below zero to prevent the warning light distracting them, the only indication of low altitude would have been the reading of the instrument itself. As the crew continued to perform their normal approach and landing activities, they may have been distracted from their task of monitoring the radalt.

2.6 Flight Recorders

2.6.1 FDR

There is no doubt that the FDR data contributed greatly to the progress of the investigation into this accident. Without the information of the whole flight path, it would have been impossible to confidently assess that the aircraft was in controlled flight immediately before impact; the only other source of flight path information was the ATC radar data which, by itself, was insufficient for detailed scrutiny of the aircraft flight profile. These two independent sources of flight path information corroborate the determination of the aircraft profile.

2.6.2 CVR

It is highly likely that the last 30 minutes of the crew's communications would have yielded valuable information concerning the circumstances leading up to the accident. Such information could have led to determining, for example, the reasons why the crew did not set the correct altimeter settings and why they did not detect their low altitudes.

The nature of the tape cartridge failure was such that any test performed before the failure would not have given reason to suspect the unit, or have given maintenance any indication of impending failure. Nevertheless, it was clear that, because the CVR failed on 30 December 1994, 12 days before the accident, any test subsequently performed on the unit would have failed and identified the unit as unserviceable. The omission of the scheduled maintenance test on 04 January 1995, therefore, prevented the immediate detection of the failed recorder. The lack of pre-start CVR functional checks further reduced the potential of detection of the failure; had this simple pre-start test, even though not required by regulation, been performed on any of the flights before the accident, the unserviceability would have been found and the aircraft would not have been serviceable for initiation of the flight.

2.7 TC Monitoring

TC monitoring of the company was not in accordance with TC policies in several respects, as follows:

1. the two most recent operational audits of the company had been conducted by the company POI, although TC recognizes that, to maintain impartiality, the POI should participate in an advisory role only;

2. TC had approved the company operations manual which had no reference to the required night flying training in ANO Series VII, No. 2;

3. the last TC audit reports did not contain reference to any flight and duty time inspection by the audit team;

4. the company's next scheduled audit was due during the month of the occurrence; there was no record of a written notice to the company that an audit had been scheduled;

5. some annual mandatory specialist inspections had not been done; and,

6. the POI had been line flying with the company.

3.0 Conclusions

3.1 Findings

1. Other than the first officer not receiving the formal night training as specified in ANO Series VII, No. 2, the flight crew were properly licensed and qualified for the flight.

2. The weight and centre of gravity of the aircraft were within prescribed limits.

3. With the exception of the CVR servicing, the aircraft was maintained in accordance with regulatory requirements intended to ensure the safe operation of an aircraft.

4. Nothing was found to suggest that the aircraft was not intact or functioning normally before it struck the water.

5. Some aspects of Transport Canada's audit and surveillance of the company before the accident were not in accordance with the Transport Canada *Manual of Regulatory Audit*.

6. C-GPUN was not equipped with a GPWS, nor was there a regulatory requirement that it be so equipped.

7. It is likely that the crew of C-GPUN unintentionally mis-set one or both altimeters to 30.17 in. Hg.

8. The crew did not detect the altimeter error and unknowingly flew the aircraft into the water.

3.2 Causes

The crew most likely conducted the instrument approach with reference to an unintentionally mis-set altimeter of 30.17 in. Hg, and unknowingly flew the aircraft into the water. The circumstances leading to the incorrect altimeter setting could not be determined, nor was it determined why the crew did not detect the mis-set altimeter.

4.0 Safety Action

4.1 Action Taken

4.1.1 Operator Actions

Since the accident, the operator has implemented a daily, operational, pre-flight check of the CVR. This check is performed by the pilot on the first start of the day and is recorded in a dedicated log.

4.1.2 Controlled Flight into Terrain (CFIT)

The circumstances of this occurrence are typical of a CFIT incident. CFIT occurrences are those in which an aircraft, under the control of the crew, is flown into terrain (or water) with no prior awareness on the part of the crew of the impending disaster. Over the eleven-year period from 01 January 1984 to 31 December 1994, 70 commercially operated aircraft not conducting low-level special operations were involved in CFIT accidents in Canada. In view of the frequency and severity of such accidents, the Board is conducting a study of CFIT accidents to identify systemic deficiencies. The study will include, *inter alia*, an examination of CFIT data involving the use of aircraft radar altimeter systems and Ground Proximity Warning Systems.

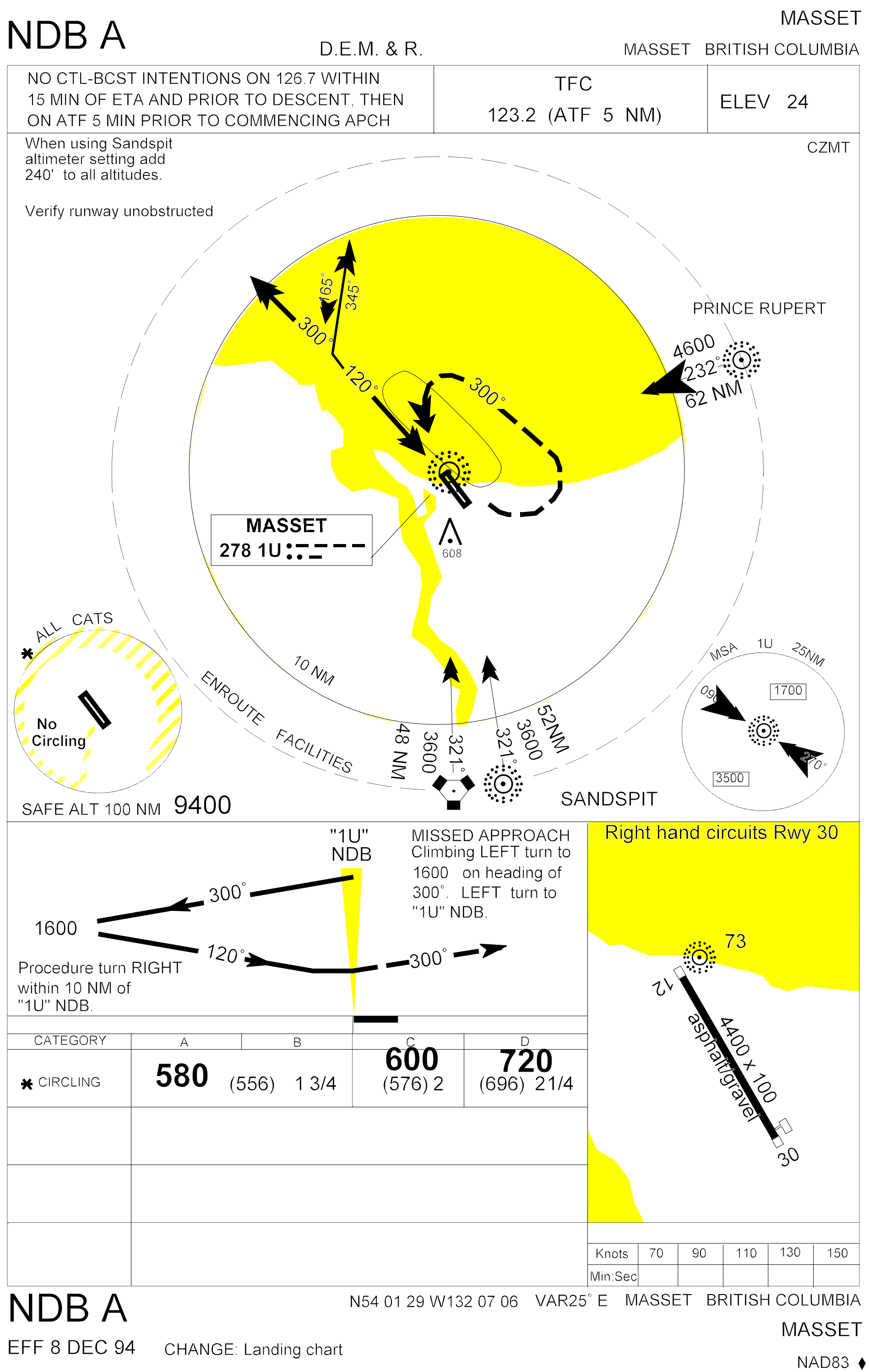
Transport Canada has recently produced a training package entitled "Preventing CFIT." The package, which includes a video, CFIT case studies, and questions, will be distributed to Regional Aviation Safety Officers (RASOs). The RASOs will present the material primarily to small air taxi operators in order to enhance pilot and operator awareness of those factors which can contribute to CFIT accidents. Flight Safety Foundation is currently producing a similar package targeted at regional air carriers, and Boeing Aircraft is producing a package for large air carriers.

4.1.3 Standard Operating Procedures (SOPs)

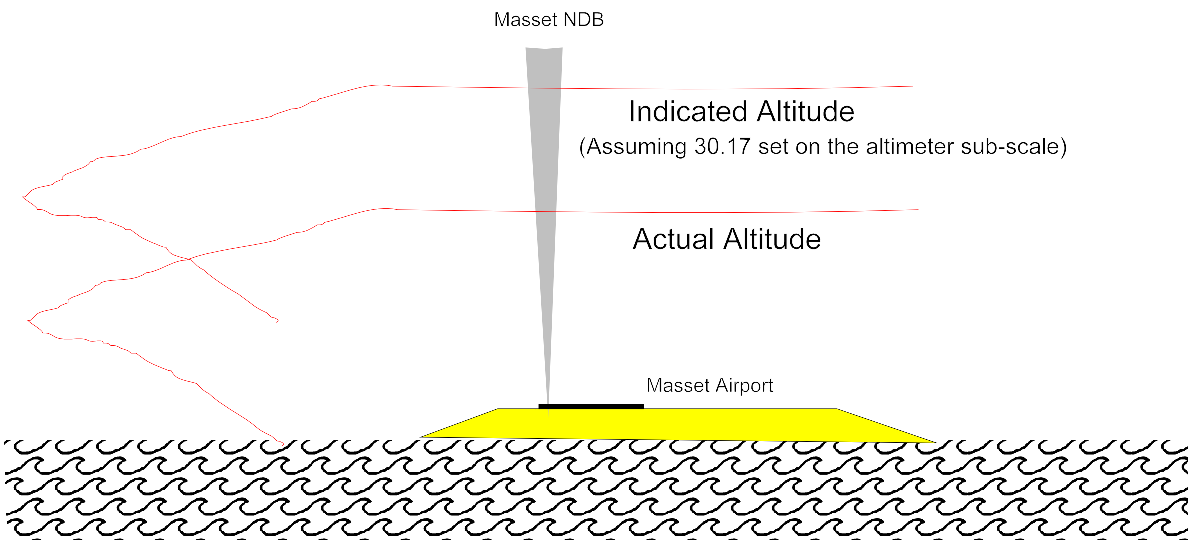
SOPs improve crew coordination and operational safety. The draft Canadian Aviation Regulations, expected to be promulgated in 1996, require air operators who operate aircraft requiring two or more pilots to establish and maintain SOPs. These regulations also require that SOPs be taken into account during pilot training and testing.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 03 January 1996.

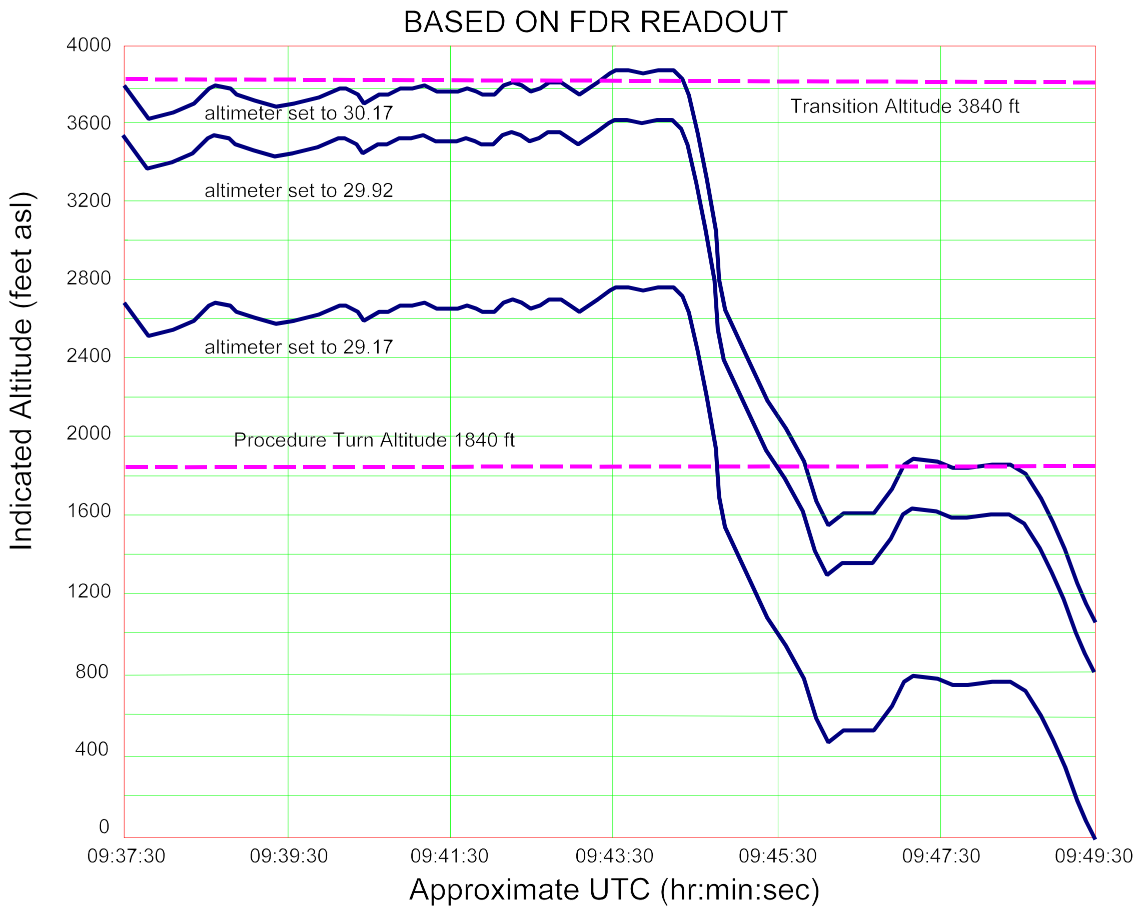
Appendix A - Instrument Approach at Masset



Appendix B - Altitudes Flown



Appendix C - Indicated Altitudes



This is a representation of the last 12 minutes of the primary altitude trace from the FDR at 29.92 in. Hg, with the same altitude trace duplicated for two other pressure settings: 29.17 and 30.17 in. Hg. The trace marked "29.17" represents the true altitude of the aircraft above the water; the trace marked "30.17" represents what altitude the pilot would have seen on his altimeter had it been set to 30.17.

Appendix D - List of Supporting Reports

The following TSB Engineering Branch laboratory reports were completed:

LP 8/95 - Caution Lights Examination;
LP 23/95 - Flight Recorder Analysis;
LP 24/95 - Under Water Search Evaluation; and
LP 25/95 - Underwater Acoustic Beacon Analysis.

These reports are available upon request from the Transportation Safety Board of Canada.

Appendix E - Glossary

ACC	Area Control Centre
AES	Atmospheric Environment Service
agl	above ground level
ANO	Air Navigation Order
asl	above sea level
ASR	Altimeter Setting Region
ATC	Air Traffic Control
ATPL	Airline Transport Pilot Licence
ATS	Air Traffic Services
AWOS	Automatic Weather Observation System
CAP	Canada Air Pilot
CAR	Canadian Aviation Regulations
CFB	Canadian Forces Base
CFIT	controlled flight into terrain
CRM	crew resource management
CVR	cockpit voice recorder
DH	decision height
DME	distance measuring equipment
DND	Department of National Defence
FDR	flight data recorder
FL	Flight Level
GPWS	ground proximity warning system
IFR	instrument flight rules
hr	hour(s)
in. Hg	inches of mercury
LFP	Line Flying Program (TC)
LP	Laboratory project (TSB)
LVC	Licence Validation Certificate
mb	millibar(s)
MDA	minimum descent altitude
MEDEVAC	medical evacuation
MHz	megahertz
MRA	Manual of Regulatory Audit (TC)
NDB	non-directional beacon
nm	nautical miles
pa	pressure altitude
PAI	Principal Airworthiness Inspector
PDM	pilot decision making
PF	pilot flying
PNF	pilot not flying
POI	Principal Operations Inspector
PPC	Pilot Proficiency Check
PST	Pacific standard time
radalt	radio altimeter
RASO	Regional Aviation Safety Officer
ROV	remote operated vehicle
SAR	Search and Rescue
SOP	standard operating procedure
SPR	Standard Pressure Region

SSR	Secondary Surveillance Radar
TC	Transport Canada
TOD	top of descent
TSB	Transportation Safety Board of Canada
UTC	Coordinated Universal Time
VOR	very high frequency omni-directional range
'	minute(s)
°	degree(s)
°M	degrees of the magnetic compass

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