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AVIATION INVESTIGATION REPORT
A07W0128

COLLISION AT TAKE-OFF

LIARD AIR LIMITED
DE HAVILLAND DHC-6 100 TWIN OTTER, C-FAWC

MUNCHO LAKE, BRITISH COLUMBIA
08 JULY 2007

Canada

Aviation Investigation Report

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Summary

At approximately 1235 Pacific daylight time, the Liard Air Limited de Havilland DHC-6-100 Twin Otter (registration C-FAWC, serial number 108) was taking off from a gravel airstrip near the Northern Rockies Lodge at Muncho Lake on a visual flight rules flight to Prince George, British Columbia. After becoming airborne, the aircraft entered a right turn and the right outboard flap hanger contacted the Alaska Highway. The aircraft subsequently struck a telephone pole and a telephone cable, impacted the edge of the highway a second time, and crashed onto a rocky embankment adjacent to a dry creek channel.

The aircraft came to rest upright approximately 600 feet from the departure end of the airstrip. An intense post-impact fire ensued and the aircraft was destroyed. One passenger suffered fatal burn injuries, one pilot was seriously burned, the other pilot sustained serious impact injuries, and the other two passengers received minor injuries.

Other Factual Information

Weather

The weather at Muncho Lake, British Columbia (B.C.) was suitable for visual flight. Sky conditions were high overcast, with the cloud bases above the level of the surrounding mountain ridges. Isolated rain showers were moving through the area. The temperature was estimated to be 15°C. The surface wind was described as southeast at approximately two knots, with occasional variations in speed and direction. The aircraft altimeters were set to field altitude prior to take-off and the altimeter setting was observed to be 29.95 inches of mercury.

The Company

Liard Air Limited (Laird Air) was a privately-owned company that offered fixed-wing air services to the public under Sections 702, 703, and 704 of the *Canadian Aviation Regulations* (CARs). The main base was at Muncho Lake, where the company operated in association with Northern Rockies Lodge. The majority of the flying activities were seasonal tourism flights, with primary consideration given to summer and fall fly-in fishing, hunting, and sightseeing tours in northern B.C.

The company operated a Cessna 185 on floats, a de Havilland DHC-2 Beaver on floats, a Cessna 172 on wheels and a de Havilland DHC-6-100 Twin Otter on wheels. The Department of Transport air operator certificate issued to Liard Air authorized Twin Otter visual flight rules (VFR) operations under Sections 702, 703, and 704 of the CARs, and Twin Otter instrument flight rules (IFR) operations under Section 704 of the CARs. The Twin Otter had been brought into the Liard Air fleet in 2001, following a reduction in scheduled air services to nearby northern communities. The decrease in scheduled flights made it difficult for international guests to access northern B.C. by air and the Twin Otter was purchased primarily to transport guests between Muncho Lake and the Vancouver and Edmonton International Airports.

The Airstrips at Muncho Lake

The company used two gravel airstrips at Muncho Lake. The lodge airstrip was located at Mile 462 of the Alaska Highway, within the highway right-of-way, immediately across from the Northern Rockies Lodge. This airstrip was at 2750 feet above sea level (asl) and it was oriented southeast/northwest. A post-accident survey determined that it was about 950 feet long and sloping upward about 2° in the northwest direction. Take-offs were usually accomplished towards the northwest due to high terrain to the southeast. The Alaska Highway crossed diagonally under the climb-out corridor approximately 100 feet beyond the northwest threshold.

A recently decommissioned rural telephone cable was suspended about 25 feet above ground, on poles, on the opposite side of the highway from the airstrip. Including the terrain upslope and the height of the telephone poles, the cable was approximately 47 feet higher than the southeast threshold. The distance between the southeast threshold and the telephone cable was approximately 1330 feet. A gravel road crossed the airstrip at about mid-point, approximately 455 feet from the southeast threshold.

The lodge airstrip was maintained by Liard Air (see Photo 1 – Lodge Airstrip). The southeast threshold was unmarked and indistinct, and approximately the first 100 feet of the surface forward of the southeast threshold was covered with grass and short brush. There were no windsocks on the airstrip and flight crews relied on the flags flying on tall poles in front of the lodge as wind indicators. The owner of Liard Air considered the airstrip to be 900 feet long. The

Photo 1. Lodge airstrip in direction of take-off.

airstrip had never been professionally surveyed to determine its exact length or slope.

The Muncho airstrip was located adjacent to the Alaska Highway approximately 10 kilometres south of the lodge. It was about twice as long as the lodge airstrip. Liard Air normally used the longer Muncho airstrip for Twin Otter operations involving the carriage of passengers and for all high-weight take-offs. When the Muncho airstrip was used, cargo, fuel, and passengers were transported back and forth by way of the Alaska Highway and the aircraft was repositioned via a five-minute shuttle flight. The Muncho airstrip was unattended; therefore, the operator parked the Twin Otter at the lodge airstrip to reduce the risk of vandalism to the aircraft. As well, when the aircraft was parked at the lodge airstrip, it was immediately available in the event of an emergency and it provided roadside advertising for Liard Air. The fuel load was normally maintained at or below 1500 pounds when the aircraft was at the lodge airstrip.

The Flight Crew

Liard Air employed three pilots. The owner of Liard Air was chief pilot and operations manager for CARs Section 703 operations. He held a commercial pilot licence endorsed for single and multi-engine land and sea aircraft, with a group 1 instrument rating. He had flown in northern B.C., the Yukon, and the Northwest Territories for the past 26 years and had acquired approximately 12 000 hours flying time, including about 420 hours on the Twin Otter. He had flown the Twin Otter to and from the lodge airstrip many times.

The captain on the accident flight was chief pilot for Liard Air's CARs section 704 operations. He held an airline transport pilot licence (ATPL) and had accumulated 22 000 hours of flying time in a variety of small and medium-size fixed-wing aircraft, including corporate jets and turbo-prop aircraft. He had approximately 6000 hours of flight time on Twin Otters, including limited off-strip experience in both DHC-6-100 and DHC-6-300 aircraft in the distant past. He had retired from full-time corporate flying in 2002 and worked as a Twin Otter seaplane captain, flying a de Havilland DHC-6-300 aircraft in the Maldives between August 2006 and March 2007. He had passed a Twin Otter pilot proficiency check (PPC) on 27 August 2006. He had commenced employment with Liard Air on 01 June 2007 and had reported for duty at Muncho Lake on 10 June 2007. He had received the required company ground and flight training from the owner. Maximum performance short take-off and landing (MPS) take-offs had been discussed during training, although not demonstrated or practiced. The training provided by the owner had emphasized the use of 30° of flap for short field take-offs. The captain had flown out of the lodge airstrip three times, once as captain.

The first officer held an ATPL and had accumulated approximately 10 800 hours of flying experience, mostly in large aircraft. He retired from airline operations in 2005 and had turned to bush flying following his retirement. He had trained with, and flown briefly for, Liard Air in 2006, and had rejoined the company in May of 2007. Aside from his Liard Air experience, he had no background in short-field or bush-flying operations. He had received all required company training and recently passed a Transport Canada (TC) PPC on the Twin Otter. He had approximately 105 hours of Twin Otter flight experience, all of it on the accident aircraft. The first officer was approved to act as captain on Twin Otter flights originating from longer, paved runways. The first officer had flown out of the lodge airstrip three times, always as first officer. He had also witnessed several Twin Otter take-offs from the lodge airstrip.

Both pilots were well rested on the day of the occurrence. The crew and passengers intended to overnight with the aircraft in Vancouver and there was no evidence that the crew were under pressure to dispatch in a hurried manner to meet any flight deadlines.

The Liard Air Twin Otter Operation

Operating a small, seasonal commercial air service is a complex and challenging business. The operational control and record-keeping duties necessary to ensure regulatory compliance and to eliminate known risks create a significant administrative workload. In particular, the addition of the Twin Otter to the Liard Air fleet and the approval for CARs sections 703 and 704 Twin Otter flight operations had appreciably increased the administrative responsibilities within the company.

The 704 approval also required that the company recruit an experienced ATPL pilot for the 704 chief pilot position. This had proved to be a challenge. A former 704 chief pilot/operations manager had set up the Twin Otter operation. He left the company in 2006 after several years of employment. His replacement resigned in February 2007. A third pilot was hired in the spring of 2007 as 704 chief pilot and resigned shortly after completing the company training. The company voluntarily surrendered the 703 IFR and 704 privileges at that time. The 704 privileges were reinstated when the captain of the accident flight was hired and approved as 704 chief pilot. An amendment to the company operations manual was drafted to reflect recent changes within the company and that amendment was in the process of being reviewed by TC. A 704 operations manager had not been formally designated, although either the 703 operations manager or the 704 chief pilot would have met the experience requirements for the position.

The owner was fully involved in the day-to-day operations in Liard Air and he made nearly all of the managerial and operational decisions within the company. Although he considered the 704 chief pilot to be fully responsible for all aspects of the Twin Otter operations, the owner was highly influential in decisions involving Twin Otter flights. The aircraft was fitted with fewer than nine passenger seats at the time of the accident and, therefore, the accident flight met the regulatory requirements of CARs Section 703.

Pilots working for Liard Air carried out numerous non-flying support duties, such as refuelling, cleaning windows and interiors, removing and installing aircraft seats, replenishing oil and hydraulic fluids, organizing passengers, and loading and unloading cargo. Although the support duties added considerably to the daily flight crew workload, the duties were consistent with those expected of flight crews in similar small, commercial bush-flying companies that operate seasonally with minimal staff.

As the new 704 chief pilot, the captain had dedicated himself during his first few weeks on the job to familiarizing himself with his duties and company policies and procedures, and bringing the paperwork necessary to run the company up-to-date. In addition to his administrative duties, he had flown approximately 65 hours in the 29 days he had worked at the lodge.

Pre-flight Planning

The primary purpose of the flight was to transport a Northern Rockies Lodge guest to the Vancouver International Airport. The original plan had been to use the Cessna 172 for the trip, which required a refuelling stop in Prince George, B.C. On the morning of the accident, it was decided to use the Twin Otter, due to the possibility of encountering marginal VFR or IFR weather en route to Prince George.

The owner had discussed the possibility of using the Twin Otter for the flight with the captain at about 0715 Pacific daylight time (PDT) [1]. At that time, the wind and temperature were favourable for a Twin Otter take-off from the lodge airstrip. The captain had subsequently departed on a Cessna 185 seaplane flight and had reported back to the owner via radiotelephone at 0844 that there were low ceilings in the Rocky Mountain Trench, along the route to Prince George. Based on that information, the owner had decided the Twin Otter

1 All times are Pacific daylight time (Coordinated Universal Time minus seven hours).

would be used for the trip to Vancouver. The flight was to depart from the lodge airstrip with one passenger at about 1300. The fuel load was not discussed, although the captain had anticipated a fuel load of about 1600 pounds, which was sufficient for a VFR flight to Prince George. Following the discussion, the owner had instructed the first officer to remove several cabin seats and fill the aircraft with fuel. The first officer had questioned the owner about the feasibility of departing from the lodge airstrip with full fuel and was assured there was no problem. The owner had asked for full fuel so as to provide IFR fuel reserves in the event that the crew had to file IFR en route to Prince George.

The owner had subsequently authorized a second passenger for the flight. This passenger was to travel to Vancouver with the aircraft to arrange a grocery backhaul to the lodge. This passenger later decided that in order to assist in arranging the grocery order, another passenger would also travel. The operator was unaware that this third passenger was on the flight until after the accident.

The captain had returned from the Cessna 185 seaplane trip at 1115. At that time he was advised that the Twin Otter was full of fuel and that two additional passengers had been added to the flight manifest. The first officer had completed a weight and balance report which indicated the take-off weight would be 9956 pounds. The weight and balance information had been passed verbally to the captain. Rarely were passengers flown out of the lodge airstrip. However, on this occasion, the decision was taken to leave from the lodge airstrip.

At about 1010, the owner had departed Muncho Lake in the Beaver seaplane with several lodge guests on a flight to a lake about 40 miles to the southwest. The guests were scheduled to spend several hours fishing. On take-off from Muncho Lake, the owner noted that there was no wind and that aircraft acceleration was slow. He also observed clouds spilling over the top of the mountains to the east, an indication of south-easterly winds, and, on arrival at the destination lake, the winds were increasing from the south. After the owner arrived at the destination, he attempted to contact the captain at the lodge by satellite phone, at about 1235, to discuss the changing conditions with the captain; however, he was unable to reach the lodge, as the accident had just occurred.

The Take-off

The captain called for a standard take-off during the take-off briefing. The briefing spelled out that the take-off would be rejected straight ahead if any problems were encountered before the aircraft became airborne. There was no discussion regarding aircraft acceleration and a no-fly reject point was not established. The take-off run commenced in a northwest direction with about 86 feet of usable runway behind the aircraft. The flaps had been selected to 30° and engine torque pressures were advanced to 20 pounds per square inch (psi) prior to brake release. The captain had briefed the first officer to trim both engines to 42 psi torque pressure after the brakes were released and the first officer rapidly advanced the power levers after the aircraft began to roll.

Early in the take-off roll, the first officer observed 40 psi torque pressure on the left engine and 42 psi on the right engine, and advised the captain that the torque pressure was not quite fully up on the left engine. There was no call to reject the take-off. Approximately halfway down the airstrip, the captain applied full aft elevator and the aircraft became airborne momentarily and then settled back onto the ground. The captain responded by advancing both power levers to the forward stops. The aircraft drifted approximately 20° to the left as it neared the end of the airstrip and became airborne after a ground run of approximately 695 feet.

The captain initiated a right turn immediately after lift-off to avoid the telephone cable and to follow the Alaska Highway corridor, and the right outboard flap hanger contacted the shoulder of the highway. The aircraft subsequently flew over the highway, struck the telephone pole and cable, and then crashed into a rock embankment at the edge of a dry creek channel.

The Aircraft

The aircraft was certified in accordance with existing regulations. The wreckage was examined at the accident site. All control surfaces were accounted for at the accident site and all damage to the aircraft was attributed to the impact forces and the severe post-impact fire. The aircraft was fitted with Pratt and Whitney PT6A-20 engines. The engines were visually examined following removal from the airframe and there was no evidence of a mechanical failure. Due to the almost complete destruction of the aircraft by the crash and fire, it could not be conclusively determined whether any pre-impact failure or system malfunction contributed to the accident; however, none were reported or identified.

The *DHC-6 Series 100 Flight Manual* contains engine torquemeter pressure setting data that is used to calculate the required take-off power. It should be possible for the pilot to set the torque derived from the chart without exceeding any of the engine operating limits. Calculated take-off power settings for the existing conditions were 39.5 pounds of engine torque pressure.

The aircraft was equipped with a cockpit voice recorder (CVR). The CVR was downloaded at the TSB Engineering Laboratory. CVR analysis of the ambient noise indicated that the propellers were rotating between 2180 and 2160 revolutions per minute (rpm) during the take-off. This compared favourably with the aircraft flight manual (AFM) limit for propeller rotation of 2200 rpm on take-off. The aircraft was not equipped with a flight data recorder (FDR) and none was required by regulation.

Aircraft Weight and Balance

The weight and balance report indicated the aircraft was at 9955 pounds, or 1624 pounds under the maximum gross weight of 11 579 pounds at take-off. The aircraft had been filled with Jet A fuel and the fuel weight had been calculated as 2500 pounds. The useable fuel capacity of the Twin Otter is 315 imperial gallons. The operations manual referenced a weight of 8.4 pounds per imperial gallon for Jet A, for weight and balance purposes. At 8.4 pounds per imperial gallon, a full load of fuel would weigh 2646 pounds. Allowing for fuel burn for start and taxi, the fuel load at take-off would likely have been 2600 pounds.

There was no evidence to indicate that the weight of the onboard tie down straps and survival gear had been accounted for in the weight and balance report. Journey log records indicated the survival gear weighed 60 pounds and the tie-downs were estimated to weigh about 10 pounds. Including the additional fuel, survival gear and tie-down weights, post-accident calculations indicated that the aircraft was at or slightly above 10 100 pounds at take-off.

Post-occurrence centre of gravity (c of g) calculations using actual passenger locations and weight and moment data indicated that the aircraft c of g was near the forward limit, at 23 per cent mean aerodynamic chord (MAC). The approved c of g range is between 20 per cent and 36 per cent MAC.
Liard Air used a SeeGee™ calculator to perform Twin Otter weight and balance calculations. The SeeGee™ calculator requires a starting value called an operating index (OI) that represents the empty weight configuration of the aircraft. The OI is calculated from the aircraft empty weight and moment using a formula provided by the manufacturer of the calculator. Examination of the OI's for various empty weight passenger seating configurations for C-FWAC indicated that the index information was erroneous.

The weight and balance report prepared by the first officer indicated the starting SeeGee™ OI for the eight-passenger seat configuration was 12.8. This value was obtained from a weight and balance document that was prepared for the aircraft. Post-occurrence calculations determined that the value should have been 11.9. Further investigation revealed that the OI being used for SeeGee™ calculations by Liard Air was identical to the result produced by a formula called the "basic index" described in de Havilland document PSM-1-6-8. This is the aircraft manufacturer's weight and balance handbook for the DHC-6. The OI being used was between 0.5 and 1.0 units greater than the correct SeeGee™ OI values. When using the SeeGee™ calculator, starting with a higher OI is equivalent to assuming a further aft c of g, which means that the final result would indicate a c of g further aft than the actual c of g.

Aircraft Performance

The *DHC-6 Series 100 Flight Manual* describes three take-off procedures. Section 2 of the manual describes the normal operating procedures for a normal take-off using 30° of flap. Supplement 12 in section 5 of the manual describes the normal operating procedures for a normal take-off using 10° of flap, and part 5 of the Supplemental Operating Data section of the manual describes the normal operating procedures for a maximum performance short take-off and landing (MPS) take-off using 30° of flap. MPS procedures require that the control column be held fully aft from the beginning of the take-off roll until lift-off and the aircraft becomes airborne at a speed below the minimum control speed with the critical engine inoperative (Vmc).

All post-accident take-off performance calculations were based on an estimated temperature of 15°C, pressure altitude of 2720 feet, and a two-knot tailwind. At a weight of 10 000 pounds, using normal take-off procedures with 30° of flap on a level, dry concrete surface, the aircraft would have required approximately 1700 feet to clear a 50-foot obstacle. Using normal take-off procedures with 10° of flap on a level, dry, concrete surface, the aircraft would have required about 1350 feet to clear a 50-foot obstacle. Using MPS take-off techniques on a dry, hard, level surface, the aircraft would have required about 1175 feet to clear a 50-foot obstacle. Using normal take-off technique with 30° of flap on a dry, level concrete surface, the maximum weight at which the aircraft could clear a 50-foot obstacle with 1250 feet of take-off distance available in the existing wind and temperature conditions was 8900 pounds. To achieve these take-off distances, all take-off procedures required take-off power to be applied before brakes are released. The take-off charts did not provide any means to compensate for the uphill slope of the runway or the gravel surface, both of which would have increased the distance needed to take-off and clear a 50-foot obstacle.

Since MPS procedures do not provide the level of safety required by regulations, they may be used only when specifically authorized. In Canada, operators conducting MPS Twin Otter take-offs require specific authorization in the form of an operations specification from TC. For a company to be approved for MPS operations, the chief pilot or senior pilot responsible for DHC-6 training must receive a minimum of two hours of MPS familiarization in a simulator equipped to faithfully recreate MPS normal and abnormal operations. Line pilots who are authorized to conduct MPS take-offs require annual training supervised by the training pilot that received the MPS familiarization in the simulator and the company MPS procedures must be set out in the operations manual. The aircraft must have a fully-serviceable autofeather system installed and operating. Liard Air was not authorized to conduct Twin Otter MPS take-offs under an operations specification approval. None of the Liard Air pilots had received MPS simulator training, the company operations manual did not set out MPS procedures, and the aircraft was not equipped with an autofeather system.

The owner had flown the Twin Otter from the lodge airstrip many times in the past and had adopted procedures that resembled an MPS take-off.

The DHC-6-300 series aircraft provide a significant performance advantage over the DHC-6-100 series aircraft, particularly in short-field and off-strip applications.

The Company Operations Manual

The *Liard Air Ltd. Operations Manual* contained detailed information on the manner in which operations shall be conducted. The operations manual stated that a company weight and balance calculation form will be completed for each flight and that aircraft take-off and landing weights shall not exceed those which would allow the aircraft to meet performance requirements for take-off and/or landing at any aerodrome used. The operations manual also stated that before departure the pilot-in-command shall calculate and adjust the take-off weight of the aeroplane as required to ensure that it does not exceed the maximum take-off weight specified in the aircraft flight manual for pressure altitude and ambient temperature at the aerodrome where the take-off is to be made. The operations manual required the following factors to be taken into consideration in determining the take-off weight:

- the pressure altitude at the aerodrome;
- the ambient temperature;
- the runway slope in the direction of take-off; and
- the total wind component at time of take-off, where not more than 50% of the reported headwind component nor less than 150% of the reported tailwind component are considered.

Take-off performance calculations were seldom completed by Liard Air pilots for flights originating from the lodge airstrip and a take-off performance calculation was not completed before the accident flight. The operations manual stated that operational control of a flight was delegated to the pilot-in-command of that flight and that the pilot-in-command was responsible for flight preparation procedures.

Standard Operating Procedures (SOPs)

Standard Operating Procedures (SOPs) may be issued by a company to standardize procedures used by flight crews in the performance of their duties. SOPs may supplement and expand on the information contained in other publications, such as an operations manual or aircraft flight manual. Liard Air did not have an SOP for Twin Otter short-field operations nor were they required to.

Records of Previous Take-offs Out of the Lodge Airstrip

The aircraft journey log records were examined to determine typical aircraft weights on recent flights out of the lodge airstrip. The aircraft had departed from the lodge airstrip at least 29 times between 11 May 2006 and the date of the accident. Thirteen flights had been single-pilot flights; 16 flights had been two-crew flights. One passenger had been carried on one of the flights. Take-off weights ranged from 7170 pounds to 9578 pounds. Take-off weight had exceeded 8500 pounds on seven occasions. The owner had been the captain on six of these flights and the captain on the accident flight had been captain on one of these flights. The take-offs at weights above 9000 pounds had been accomplished in cooler temperatures and favourable northwest winds.

Plan Continuation Bias and Expectation Bias

An article recently published by the Flight Safety Foundation (FSF) titled *Pressing the Approach* [2], discussed two human biases that are known to contribute to flight crew errors in judgement and decision making. Although the FSF article referred to these biases in the context of approach accidents, an understanding of these biases helped to explain the human factors elements that may have contributed to this accident. The article stated that plan continuation bias appears to underlie what pilots call "press-on-itis", which the FSF found to be involved in a high percentage of accidents. The researcher's analysis suggested that this bias results from the interaction of three major components: social/organizational influences, the inherent characteristics and limitations of human cognition, and incomplete or ambiguous information. The article also discussed another inherent and powerful human cognitive bias called expectation bias. Expectation bias contends that when someone expects one situation, he or she is less likely to notice cues indicating that the situation is not quite what it seems. Expectation bias is worsened when crews are required to integrate new information that arrives piecemeal over time in incomplete, sometimes ambiguous, fragments.

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2 Benjamin A. Berman and R. Key Dismukes, Ph.D. "*Pressing the Approach*." Flight Safety Foundation, *Aviation Safety World*, December 2006.

Occupant Survivability

The impact forces were survivable. All occupants remained mobile after the accident and all were able to exit through the right cockpit door. The post-impact fire (PIF) erupted in the cabin during the impact sequence and all occupants were doused in jet fuel prior to getting out of the aircraft. The captain received serious burn injuries and one passenger suffered fatal thermal injures.
The main fuel tanks in the DHC-6 Twin Otter are located in the fuselage below the passenger cabin floor and between the main landing gear attachment points. Field examination of the wreckage indicated that one or both main landing gear may have penetrated the adjacent fuel cell at impact, which released fuel into the cabin. Potential ignition sources included friction sparking due to the steel main landing gear contacting rocks and electrical arcing due to impact-damaged wiring being powered by the battery.

It is known that for aircraft with a maximum certified weight of 5700 kilograms or less, PIF contributes significantly to injuries and fatalities in accidents that are otherwise survivable. There are no airworthiness standards for fixed gear CAR 3 [3], FAR 23 [4], or CAR 523 [5] aircraft that are specifically intended to reduce the risk of PIF, either by containing fuel or preventing ignition, or both, in crash conditions.

The TSB published a Safety Issues Investigation Report (SII A05-01) in 2006 titled *Post-Impact Fires Resulting From Small-Aircraft Accidents.* The report revealed that fire or smoke inhalation were identified as either partly or solely the cause of death for nearly 30 per cent of the 728 fatalities and nearly 35 per cent of the 231 serious injuries that occurred in 521 small-aircraft accidents involving PIF. The report made three recommendations to TC, the Federal Aviation Administration (FAA), and other foreign regulators to address the safety deficiencies related to common unsafe conditions that contribute to the development of PIFs and to fire-related injuries and fatalities. TC and FAA responses to the recommendations contained no action or proposed action that will reduce or eliminate the risks associated with deficiencies that contribute to PIFs in small aircraft; therefore the responses were assessed by the Board as “unsatisfactory”.

The first officer’s shoulder harness broke at impact and was found several feet away from the wreckage. It had not been exposed to the post-impact fire. The recovered section of the harness was forwarded to the TSB Engineering Laboratory for examination. The harness was composed of three sections forming a Y. The upper portion connected with an inertia reel and the two lower straps connected with the lap belt. The webbing had deteriorated well beyond the wear limits specified by the manufacturer. Areas of cuts, fraying, and pre-existing abrasion damage were observed on the webbing, and the colour of the broken section was faded from the original

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3 United States Civil Aviation Regulation 3 – Certification Standards.

4 United States Federal Aviation Regulation 23 – Certification Standards.

5 Canadian Aviation Regulation 523 - Airworthiness Standards.

dark blue. Webbing samples were cut from the two shoulder straps and pulled to destruction in a tensile-testing machine. The webbing samples failed the manufacturer's specification for minimum breaking strength.

The webbing broke in the upper portion connecting with the inertia reel. This was the weakest part of the restraint system as there was only one strap to support the crash load.

Analysis

The weather conditions were suitable for visual flight and field examination of the wreckage gave no indication that a pre-occurrence mechanical problem had contributed to the accident. Although the performance of the left engine was slightly less than that of the right engine during the take-off roll, the torque pressure on both engines exceeded the expected take-off power setting of 39.5 psi torque pressure for the existing temperature and pressure altitude, and the propeller rpms compared favourably with normal take-off values. The analysis will therefore discuss the organizational and management factors that contributed to the aircraft being operated outside of its performance capabilities on the accident take-off.

Organizational and Management Factors

The operational control and the risk management practices that existed within Liard Air did not recognize and reduce or eliminate the risks associated with take-offs from the lodge airstrip. Liard Air was in a state of administrative transition at the time of the accident due to several recent changes in key personnel; the Twin Otter operation was most affected by this transition.

A number of organizational policies and procedures that may have prevented the accident were either violated, not used, or missing. The Liard Air operations manual was written to ensure safe flight operations and to eliminate potential errors in flight crew judgement. Although a weight and balance calculation had been accomplished prior to the accident flight, the aircraft weight was not used to calculate take-off performance, as required by the operations manual. Take-offs from the lodge airstrip had come to be regarded as routine, without a need to calculate take-off performance prior to each departure, and aircraft loading was based mostly on the intuition and judgement of the owner and/or flight crews.

Liard Air had an unwritten company policy that the lodge airstrip would be used primarily to store the Twin Otter and that Twin Otter departures from the airstrip would be carried out with crew only and minimum fuel on board. Records of previous take-offs from the airstrip indicated that the policy of not carrying passengers out of the lodge airstrip was rarely violated, although take-offs were occasionally accomplished with heavy fuel loads. On the day of the accident, this policy was violated in two ways: the take-off was attempted with three passengers and the aircraft had a full load of fuel.

Training provided by the owner to the captain emphasized the use of 30° of flap for short-field take-offs when 10° of flap would have resulted in lesser distance to climb to 50 feet. Considering the elevation, length, slope, and gravel surface at the lodge airstrip, MPS procedures may have been required at times for higher weight take-offs; however, neither the company nor the aircraft were approved for MPS operations and neither flight crew member had received appropriate MPS training.

The owner of Liard Air was the main decision-maker within the company. He was entirely familiar with the company's daily operations, he was highly influential with respect to how flights were to be carried out, and he had significant experience with Twin Otter operations on the lodge airstrip. These elements, combined with his direct input at the pre-flight planning phase of the accident flight, contributed to the flight crew expectation that the take-off could be accomplished successfully. As well, the regular direct oversight that he provided in the Twin Otter operation may have resulted in ambiguity with regard to the duties and responsibilities of those involved with the Twin Otter operation.

Despite regular use of the lodge airstrip and recognition by the owner that take-off weights were a critical consideration in these operations, there was no SOP for Twin Otter short-field operations. An applicable SOP would have formalized and set the non-MPS limits for short-field operations, thereby reducing the risk associated with lodge airstrip operations.

The Work Setting

The work setting and work expectations at Liard Air were unlike those found in the corporate or airline environments that were most recently familiar to the captain and the first officer. The operational support provided in corporate and airline operations, in the form of dispatchers, ground crews, locally available maintenance personnel, and highly-formalized operational procedures rarely exist in similar small, seasonal bush-flying operations. As a result, flight crews working for seasonal bush-flying operators often rely heavily on local knowledge gained through experience with a particular operator and are typically more self-reliant when it comes to making day-to-day operational decisions. As well, the operational challenges encountered in confined, short-airstrip environments can be significantly different from those encountered in corporate and airline operations, where longer runways and obstacle-free climb-out corridors are the norm.

The Flight Crew

The captain and the first officer were themselves the final line of defence in the system. Both were relatively new to the Liard Air working environment and to lodge airstrip operations. The captain had been hired and appointed chief pilot about five weeks prior to the accident. His initial administrative workload as chief pilot and his flight duty obligations were significant, which may have reduced the time available to experience, recognize, and evaluate the risks associated with Liard Air flight operations from the lodge airstrip. Critical information regarding the accident flight was provided to the captain in a somewhat piecemeal fashion between the time of the original early morning discussion and the departure; however, the captain expected the take-off would be successful, based on his belief that both the owner and the first officer had discussed and considered the take-off weight.

The first officer was more familiar than the captain with the circumstances leading up to the flight, having taken most of the morning to prepare the aircraft. His expectation of a successful take-off was likely based on his conversations with the owner and the captain. He verbally provided the captain with weight and balance information; aside from that, he appears to have placed full responsibility for the decision to attempt the take-off on the captain, who was only peripherally involved with the flight planning.

The captain had recently been flying DHC-6-300 series aircraft in the Maldives. Although that experience involved only float-equipped Twin Otters, his recent familiarity with the higher performance capabilities of the DHC-6-300 series aircraft may have conditioned him to anticipate a higher level of aircraft performance in the Liard Air DHC-6-100 series operations. As well, both pilots were aware that the aircraft had been operating out of the lodge airstrip for several years, which reinforced their expectation that the take-off should be successful.

Pre-flight Planning

Pre-flight planning is an essential component of any flight and flight crews are required by regulation to avail themselves of all obtainable information pertinent to a flight prior to departure. Because the DHC-6 Twin Otter is a very capable short-field aircraft, it is commonly used on short, unprepared airstrips where there is little margin for error in flight crew judgement or performance. In all cases when operating in short-field environments, it is imperative that flight crews recognize and operate within the take-off performance limitations of the aircraft.

Pre-flight load planning for the accident flight primarily involved the owner and the first officer. The captain agreed to take-off from the lodge airstrip with one passenger. He went flying soon after and had no direct input into the later decisions to add full fuel and two extra passengers to the flight. The owner also went flying and was therefore no longer in a position to closely monitor the progress of the pre-flight preparations or consider the addition of a third passenger on the aircraft. Although the first officer spent most of the morning preparing the aircraft, he prepared only a weight and balance report and did not complete a take-off performance calculation.

Critical information regarding the significance of surface wind, temperature, and aircraft weight on operations specific to the lodge airstrip may not have been communicated to the flight crew during training. Despite changes in wind and temperature conditions and the much higher than normal take-off weight for lodge airstrip departures, neither pilot recognized the need to reconsider the take-off weight. The final decision to attempt the take-off represented a collective failure on the part of the owner, the captain, and the first officer to recognize and manage the risks associated with lodge airstrip operations.

Centre-of-Gravity (c of g)

The aircraft was being operated within the prescribed c of g limits at the time of the occurrence; however, the SeeGee™ calculator OI values being used by Liard Air pilots were between 0.5 and 1.0 units greater than the correct SeeGee™ OI. As a result, whenever the SeeGee™ calculator was used for flight planning, the actual c of g of the aircraft would have been forward of the calculated c of g.

The Take-off

The aircraft was not positioned so as to use the entire airstrip before commencing the take-off and the brakes were released prior to the engines achieving take-off power. Both of these elements made it less likely that the aircraft would achieve the necessary obstacle clearance altitude. The use of the lodge airstrip left no margin for error and once the take-off roll began, there was little time to evaluate the aircraft's performance and if necessary reject the take-off. Had the flight crew identified a suitable reject point for the take-off and had the take-off been rejected due to the aircraft not being airborne at that point, the accident risk would have been reduced.

The aircraft used most of the available airstrip during the take-off and drifted approximately 20° to the left during the latter part of the take-off for unknown reasons. This required the initiation of a steep bank to remain over the highway corridor on climb-out that reduced the climb performance of the aircraft and increased the likelihood of the aircraft contacting the telephone cable.

Considering the airstrip length and slope, the wind and the temperature conditions, the location of the telephone cable, and the take-off procedures that were used, the take-off was attempted at a weight that exceeded the obstacle clearance performance capabilities of the aircraft. Had a take-off performance calculation been accomplished prior to take-off, it would have identified that the distance available was inadequate for take-off under these conditions.

Occupant Survivability

The first officer's shoulder harness assembly had been weakened by age and ultraviolet light exposure. As a result, it failed within the design limits.

As demonstrated by this accident, PIF presents a great risk to the occupants of small aircraft. The impact forces were within the range of human survivability, all occupants remained mobile, and all were able to egress the aircraft after impact; however, one serious injury and one fatal injury occurred as a result of the intense PIF. There are no airworthiness standards specifically intended to contain fuel and/or to prevent fuel ignition in crash conditions in fixed-gear CAR 3 and FAR 23 aircraft. TC and FAA responses to the recommendations in SII A05-01 contained no action or proposed action that will reduce or eliminate the incidence of PIF in small aircraft accidents. Consequently, there is a high probability of future similar PIF occurrences, and, as demonstrated by this accident, occupants of small aircraft continue to be at risk of sustaining PIF-related injuries and fatalities.

The following TSB Engineering Laboratory reports were completed:

LP 66/2007 - CVR and Performance Analysis
LP 77/2007 - Shoulder Harness

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

Findings as to Causes and Contributing Factors

1. The take-off was attempted at an aircraft weight that did not meet the performance capabilities of the aircraft to clear an obstacle and, as a result, the aircraft struck a telephone pole and a telephone cable during the initial climb.

2. A take-off and climb to 50 feet performance calculation was not completed prior to take-off; therefore, the flight crew was unaware of the distance required to clear the telephone cable.

4. The southeast end of the airstrip was not clearly marked; as a result, the take-off was initiated with approximately 86 feet of usable airstrip behind the aircraft.

5. The take-off was attempted in an upslope direction and in light tailwind, both of which increased the distance necessary to clear the existing obstacles.

Findings as to Risk

1. Operational control within the company was insufficient to reduce the risks associated with take-offs from the lodge airstrip.

2. The take-off weight limits for lodge airstrip operations were not effectively communicated to the flight crew.

3. Maximum performance short take-off and landing (MPS) techniques may have been necessary in order to accomplish higher weight Twin Otter take-offs from the lodge airstrip; however, neither the aircraft nor the company were approved for MPS operations.

4. The first officer's shoulder harness assembly had been weakened by age and ultraviolet (UV) light exposure; as a result, it failed within the design limits at impact.

5. The SeeGee™ calculator operating index (OI) values being used by Liard Air Twin Otter pilots was between 0.5 and 1.0 units greater than the correct SeeGee™ OI values; therefore, whenever the SeeGee™ calculator was used for flight planning, the actual centre of gravity (c of g) of the aircraft would have been forward of the calculated c of g.

6. There are no airworthiness standards specifically intended to contain fuel and/or to prevent fuel ignition in crash conditions in fixed-gear United States Civil Aviation Regulation 3 and United States Federal Aviation Regulation 23 aircraft.

Safety Action

Safety Action Taken

Following the accident, Transport Canada conducted a regulatory audit on the company. The Twin Otter was not replaced and the operator voluntarily gave up the *Canadian Aviation Regulation* section 704 privileges on the company's air operator certificate.

Following this accident, the owner initiated the following corrective action within Liard Air:

1. Every pilot employed by Liard Air Limited will receive and be required to read and sign a letter that summarizes the pilot's responsibilities in the operation of Liard Air Limited aeroplanes.

2. The operator purchased and installed satellite telephones in each floatplane to improve direct communication between pilots.

3. *The Liard Air Limited Maintenance Control Manual* has been amended to require any seatbelt in any company aircraft to be replaced after 10 years, even if the manufacturer has not put a life on the seatbelt.

4. Weight and balance samples for various loading configurations in company aircraft have been calculated and a computer program is now in use for weight and balance calculations at the home base. The weight and balance calculations and the formulas used will only be the ones issued by the aeroplane manufacturer.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 07 October 2008.