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

# AVIATION INVESTIGATION REPORT
# A09W0037

## RISK OF COLLISION

## BETWEEN
## AIR CANADA JAZZ
## BOMBARDIER CL-600-2D15, C-FDJZ
## AND
## AIRPORT MAINTENANCE VEHICLES (SNOW SWEEPERS)
## WHITEHORSE INTERNATIONAL AIRPORT, YUKON
## 06 MARCH 2009

Canada

# Aviation Investigation Report

# Risk of Collision

# Between
# Air Canada Jazz
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# and
# Airport Maintenance Vehicles (Snow Sweepers)
# Whitehorse International Airport, Yukon
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# Report Number A09W0037

## *Summary*

The Air Canada Jazz Bombardier CL-600-2D15 (registration C-FDJZ, serial number 15041), operating as JZA447, had been cleared to the Whitehorse International Airport, Yukon, for an approach. Whitehorse International Airport is located in a mountainous, non-radar environment and at the time of the occurrence a winter snow storm was moving through the area. An instrument landing system approach to Runway 31L was hand-flown by the captain using the head-up guidance system. On initial contact, no current position report or estimate for the airport was given by the crew or requested by the tower. Whitehorse tower requested JZA447 to report 10 miles final, and advised that sweeping was in progress. The crew of JZA447 acknowledged the request. The aircraft landed approximately nine minutes later, at 1350 Pacific Standard Time, after flying over two runway snow sweepers operating on the portion of the runway located before the displaced threshold for Runway 31L. A position report was not provided to Whitehorse tower at 10 miles final and no landing clearance was issued. The weather report issued 10 minutes after landing reported the ceiling as vertical visibility 600 feet, visibility of 3/4 statute mile in light snow and drifting snow with a runway visual range of 4500 feet.

# Other Factual Information

## History of the Flight

JZA447 departed Vancouver International Airport, British Columbia, at 1129, [1] on a scheduled instrument flight rules (IFR) flight to Whitehorse, Yukon, with 54 passengers and 4 crew members on board. The departure and en route segments of the flight were uneventful. The first officer was designated as the pilot flying (PF) for the leg, and the captain was designated as the pilot not flying (PNF).

At 1246, control of JZA447 was transferred from the Vancouver area control centre (ACC) to the Edmonton ACC North High Specialty, Klondike sector (Klondike sector controller), at the DUXAR reporting point. The aircraft was at FL360. [2] The Vancouver ACC controller advised JZA447 that radar service was terminated and instructed the flight to contact Edmonton ACC (YEG ACC).

At 1247, JZA447 contacted the Klondike sector controller and at 1254 was cleared to descend to FL340. At 1259, the captain requested direct ELTAG. ELTAG is the initial fix located on the localizer path for Runway 31L at Whitehorse, 18 DME (distance measuring equipment) southeast of the Whitehorse VOR [3] (see Appendix A). The request for direct ELTAG was refused due to the volume of IFR traffic flowing into Whitehorse at that time. The Klondike sector controller was sequencing four IFR arrivals into Whitehorse: an ATR-42 ahead of JZA447, and a Cessna Caravan and a Boeing 737 following JZA447.

At 1256, the North Low Specialty Whitehorse sector controller (Whitehorse sector controller) contacted Whitehorse Tower by air traffic control (ATC) interphone and provided estimated times of arrival (ETAs) for the first two inbound flights. The ATR-42 was estimating the Whitehorse VOR at 1321 and JZA447 was estimating the Whitehorse VOR at 1331. The on-duty tower controller at Whitehorse Tower entered 1331 (2131 Coordinated Universal Time) as the ETA on the flight progress strip for JZA447 (see Appendix B). The tower controller did not record a fix reference for this ETA on the flight progress strip. This was not required by the NAV CANADA *Air Traffic Control Manual of Operations* (ATC MANOPS).

At 1306, the Klondike sector controller advised JZA447 that if the flight arranged to reach the Whitehorse VOR at 1336 or later that would reduce the time in the hold. The captain acknowledged the information and asked if there were any missed approaches occurring at Whitehorse. The Klondike sector controller responded that the flight would be turned over to the Whitehorse sector controller very shortly and suggested asking that controller after the transfer.

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1 All times are Pacific Standard Time (Coordinated Universal Time minus eight hours) unless otherwise noted.

2 Flight level 360, approximately 36 000 feet above sea level.

3 VHF omnidirectional range navigational aid.

At 1306, the Whitehorse sector controller provided the Whitehorse tower controller with an updated ETA for the ATR-42, by ATC interphone, and advised the tower controller that JZA447 would have to “hold for a bit.” The tower controller advised three airport trucks on the ground control frequency that the ATR-42 would be arriving 25 minutes from then and that the Jazz flight would be following shortly after. The trucks were engaged in snow sweeping operations on the active runway.

At 1309, JZA447 was turned over to the Whitehorse sector controller, and was cleared to ELTAG via direct, to descend to 12 000 feet above sea level [4] when ready. At 1314, the Whitehorse sector controller requested the flight’s global positioning system (GPS) distance from ELTAG. The captain responded 75 miles [5] from ELTAG, and the flight was cleared to 16 000 feet.

At approximately 1315, control of the aircraft was transferred from the first officer to the captain, in preparation for the captain to hand-fly the approach using the head-up guidance system (HGS). The first officer took over the PNF duties, including communications.

At 1316, the first officer reported vacating FL340 for 16 000 feet. At 1322, the Whitehorse sector controller requested JZA447 provide its passing altitude and GPS distance from ELTAG. The first officer reported the distance as 26 miles, then 25 miles, without reference to the passing altitude. When the Whitehorse sector controller requested the passing altitude again, the first officer reported through FL220 for 16 000 feet. The Whitehorse sector controller then cleared JZA447 to descend to 17 000 feet and to hold southeast, inbound on the localizer at ELTAG. The expected further clearance (EFC) time was 1340. The first officer read back the EFC time as 1345, which the Whitehorse sector controller acknowledged as correct.

At 1324, the flight was cleared to descend to 14 000 feet. At 1325, the flight was further cleared to descend to 11 000 feet while maintaining the present track prior to manoeuvring for the hold. At 1327, the first officer reported entering the hold at 13 000 feet for 11 000 feet. The Whitehorse sector controller replied that the flight needed to be at 11 000 feet, present track and instructed the aircraft to keep going in the same direction. At 1331, the first officer reported established in the hold at 11 000 feet. At 1332, the Whitehorse sector controller cleared the flight to descend to 10 000 feet and at 1333 the first officer reported level at 10 000 feet.

The flight preceding JZA447 landed at 1338 and the Whitehorse sector controller cleared JZA447 to the Whitehorse airport for an approach at 1339. The first officer read back the approach clearance correctly. [6] JZA447 did not advise the Whitehorse sector controller of the type of approach procedure they intended to carry out at Whitehorse, and the controller did not request this information, given the lack of approach alternatives in the existing low ceiling and visibility conditions. The Whitehorse sector controller then instructed JZA447 to contact

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4 All altitudes are above sea level unless otherwise noted.

5 All distances are nautical miles unless otherwise noted.

6 As soon as practicable after receipt of this type of clearance, it is the pilot’s responsibility to advise ATC of the type of published instrument approach procedure that will be carried out, the landing runway and the intended route to be flown.

Whitehorse tower on 118.3 MHz and report to centre leaving 9000 feet on the second radio. The instruction was read back as: "Contact eighteen three leaving niner thousand." The flight was on the outbound leg in the hold at that time, and about to turn inbound.

At 1339:35, the tower controller at Whitehorse was relieved for a break. During the transfer of position responsibility briefing the relieved tower controller advised the relieving tower controller that the recently arrived ATR-42 aircraft was taxiing in, that there were two trucks just entering the runway at Taxiway Echo (Taxiway E) to continue sweeping, that there were three more aircraft inbound and that none had contacted tower yet. The relieved tower controller also briefed the relieving tower controller on the runway surface conditions. The relieving tower controller was not advised that JZA447 was expected to have to hold.

After the flight was cleared to ELTAG the ETA of 1331 for the VOR was invalid, as the aircraft changed course and never went to the VOR. This information was not passed to the Whitehorse Tower and therefore the ETA of 1331 (2131 UTC) that had been entered on the flight strip was not updated. The information relating to the hold was not specifically required to be passed as part of the tower transfer of position check list, but for arrival and flow management reasons, it would have been appropriate for the relieved controller to advise the relieving controller that JZA447 was expected to have to hold. ATC MANOPS states that if data previously passed changes or an estimate varies by more than three minutes, that information is to be disseminated to the tower. [7]

At 1341, the JZA447 first officer contacted Whitehorse tower and advised the flight had been cleared for the approach. The relieving tower controller replied that the active runway was 31L, the surface winds were 310° Magnetic at 10 to 15 knots, and the altimeter setting was 29.46 inches of mercury. The relieving tower controller instructed the flight to report at 10 miles out and advised there was sweeping in progress. The first officer replied they would call 10 miles final. The relieving tower controller then provided the Canadian runway friction index (CRFI) and the runway surface condition (RSC) reports. There was no further communication between the aircraft and Whitehorse tower or Edmonton Centre until the aircraft was on the runway.

The flight crew established the required visual reference to the runway at approximately 300 feet above runway elevation and about 100 feet above the decision altitude. Initially the first officer and then the captain observed the two sweeper trucks operating near the beginning of the portion of the runway located before the displaced threshold. The first officer reportedly advised the captain that there were trucks on the runway and, perhaps unassertively, that the flight had not received a landing clearance. Neither pilot observed vehicles in or beyond the normal touchdown zone and neither called for a go-around. The captain, knowing that the flight had been cleared for an approach, believed the sweeper trucks were holding until the flight landed and elected to continue with the landing which was accomplished without further incident.

The threshold for Runway 31L was displaced 1400 feet. Truck 81 and Truck 84 were both towing snow sweepers and were operating in tandem. The trucks had finished a full length sweep of Runway 13R and Truck 81 had turned around in the turn area on the displaced

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7 NAV CANADA Air Traffic Control Manual of Operations (MANOPS) 493.2.

threshold. Truck 84 was beginning to turn when the driver observed the aircraft on very short final. The aircraft's altitude over the beginning of runway surface was calculated to be 126 feet above ground, and it is estimated that the aircraft cleared the trucks by about 110 feet prior to landing in the normal runway touchdown zone, about 2400 feet past the trucks. At 1349 the Whitehorse sector controller queried JZA447 on centre frequency for their passing altitude. There was no response from the aircraft and at 1350 the relieving tower controller advised the Whitehorse sector controller that JZA447 was on the ground.

## *Aircraft Avionics*

Air Canada Jazz began flying CL-600-2D15 (CRJ705) aircraft in May of 2005, under *Canadian Aviation Regulations* (CARs) 705. At the time of the incident, the company operated 16 CRJ705 aircraft, each configured to carry 75 passengers.

The aircraft was fitted with a Rockwell Collins HGS4200. The HGS is an electronic and optical system that displays flight and navigation information on a retractable combiner that can be extended downward, similar to a sun visor, into the left-side pilot's forward field of view. The transparent combiner merges HGS symbology with the pilot's view through the windscreen (see Appendix D). The system is certified for all phases of flight and meets the requirements for low-visibility take-offs and manual Category III approaches, landings, and rollouts. Use of the HGS allows for precise aircraft control while enhancing pilot situational awareness.

The HGS 2100 was certified in 1994 and the HGS 4200, the next generation HGS in the CRJ705 line, was certified in 2002. Air Canada Jazz had operated the HGS 2100 and HGS 4200 systems since September 2001 and July 2006 respectively, during which time there had been no reported incidents or operational issues.

The aircraft was also fitted with a Collins 4200 FMS dual flight management system (FMS). Pilot interface with the FMS is via two control display units (CDUs).

## *Preservation of CVR Data*

The aircraft was fitted with a cockpit voice recorder (CVR) and a digital flight data recorder (DFDR). The flight recorders were not secured following the incident, and CVR information was lost due to continued operation of the aircraft. Section 6 of the *TSB Regulations* requires the owner, operator, pilot-in-command, any crew member of the aircraft and, where the incident involves a loss of separation or a risk of collision, any air traffic controller having direct knowledge of the incident, to report details of the incident to the Board as soon as possible and by the quickest available means. As well, Section 9 of the *TSB Regulations* requires the owner, operator and any crew member to preserve and protect to the extent possible any evidence relevant to a reportable occurrence.

The incident occurred on a Friday afternoon. The aircraft turn-around time in Whitehorse of approximately 35 minutes would have required immediate action be taken in order to protect the CVR. The TSB became aware of the incident the following Monday morning, after review of an email received Friday night through the NAV CANADA Aviation Occurrence Reporting (AOR) system (reference AOR 104912-V1). Air Canada Jazz did not report the incident to the TSB prior to the TSB contacting the company.

## *Whitehorse Aerodrome Information*

Whitehorse International Airport is a certified airport operated by the Yukon government, under the authority of a Civil Aviation Airport Certificate issued by Transport Canada. Where an airport certificate has been issued, the operator is required to maintain and operate the airport in accordance with applicable Transport Canada standards. Runway 31L is 9497 feet long by 150 feet wide; it has an asphalt surface. The threshold for Runway 31L is displaced 1400 feet to provide a greater take-off distance. The airport elevation is 2317 feet.

The airport is located in a non-radar (procedural), Class D airspace environment. The IFR transition zone for the airport extends to 18 000 feet for a radius of 40 miles around the airport. The control zone extends from ground level to 5300 feet for a radius of five miles around the airport.

The airport is situated in a valley with mountains in all quadrants, rising to approximately 4000 feet above airport elevation to the east and over 5000 feet above airport elevation to the west. The distance from ELTAG, the intermediate fix, to the runway threshold is 21.4 miles and the altitude loss from glidepath intercept to the runway is 6295 feet (glidepath angle 3.0˚). In terms of the approach length and altitude loss, the ILS 31L approach to Whitehorse is non-standard. The final approach fix is the Robinson beacon, which is 16.8 miles from the runway threshold. Approximately 9 minutes are required to complete the approach from the final approach fix at an approach speed of 140 knots.

The airport is serviced by several radio navigation aids, including a VOR with distance measuring equipment (DME), four non-directional beacons (NDB), a localizer and an instrument landing system (ILS). The VOR/DME is located 5.8 nm south of the airport, and is not aligned with the final approach path to the main runway (R13R/31L). The IFR approach options are an NDB/NDB approach for Runway 13R, an NDB/DME A approach for Runway 13R, a LOC(BC)/NDB/DME approach for Runway 13R, and an ILS or LOC/NDB/DME approach for Runway 31L. All radio navigation aids associated with the airport were functioning at the time of the incident.

## *Air Traffic Control Operations in Whitehorse*

Whitehorse tower operated daily from 0700 to 2100. Staffing was in accordance with unit guidelines at the time of the incident. The controller workload was assessed as light and non-complex. There were three controllers on the work schedule during the day of the occurrence; one was at the controlling position at the time of the occurrence. The relieved tower controller and the relieving tower controller were each working the combined airport and ground positions.

There was no dedicated supervisory position established at the Whitehorse tower. Whitehorse tower utilized a Unit Operations Specialist (UOS) to provide supervision as time and additional duties permitted and to complete proficiency checks on tower controllers. Whitehorse tower controllers were responsible for providing ATC services to aircraft flying within the Class D control zone and to aircraft and vehicles operating on the airport's runways and taxiways.

An Inter Unit Arrangement dated, 01 July 2000 detailed the responsibilities and established the operating procedures between the Whitehorse control tower and the Edmonton ACC for the provision of air traffic services within the Whitehorse Class D airspace. This arrangement specified that, unless otherwise coordinated, Edmonton ACC was to transfer communication on arriving aircraft to Whitehorse Tower five minutes prior to the aircraft entering the Whitehorse Class D airspace. In practice Edmonton ACC transferred communication with inbound IFR aircraft to Whitehorse tower as soon as there was no conflict with other arriving or departing IFR aircraft. This transfer of communication could occur any time after an approach clearance had been issued and could be as soon as at the top of descent, while the aircraft was in a hold or on final approach, depending on the circumstances. As a result there was a wide range of possible positions for arriving aircraft at initial contact. The transfer of communication did not imply a transfer of control, but allowed the airport controller to pass traffic and airport information to the aircraft in a timely manner, and clear the aircraft to land. In IFR conditions the responsibility for control of an arriving IFR aircraft was automatically transferred from the IFR unit to the tower after the aircraft had landed, as the tower had no way of visually verifying the position of the aircraft.

As the Whitehorse International Airport is located in non-radar airspace, IFR controllers at the YEG ACC maintained separation between IFR aircraft by procedural methods. Whitehorse tower controllers were required to develop and sustain a mental picture of arriving IFR aircraft locations, in IFR conditions, solely through communication with the aircraft and the use of flight progress strips, in order to coordinate the arriving traffic with local traffic and airport maintenance operations.

ATC MANOPS requires IFR unit controllers to forward to towers an ETA for arriving aircraft at least 15 minutes before the aircraft establishes communication with the tower. [8] This estimate will be for the aircraft position over an adjacent en route navigation facility, over the navigation facility serving the approach procedure to be used, at the airport or a point specified in an Arrangement. ETAs for IFR flights into Whitehorse were provided to Whitehorse tower controllers by the Edmonton ACC via an ATC interphone. In the case of the four aircraft that were arriving around the time of the incident, the centre controller had referenced a fix with each of the ETAs. The fix for the ETA for the first two arriving aircraft was the Whitehorse VOR. The fix for the ETA for the second two arriving aircraft was ELTAG. ATC MANOPS requires a transfer of radio communications to take place immediately prior to an aircraft entering the receiving controller's area of responsibility unless otherwise coordinated or as described in an Agreement or Arrangement. [9] ATC MANOPS does not require communication of the aircraft position during a communication transfer from an IFR unit to a tower.

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[8] NAV CANADA ATC MANOPS 493.1

[9] NAV CANADA ATC MANOPS 494.1

Flight crews on arriving IFR flights often voluntarily provided a position report at first contact with Whitehorse tower. Whitehorse tower controllers usually asked for a position report from the arriving aircraft at first contact if they could not see the aircraft or if the aircraft had not provided a position report. While optional, a request for a position report by Whitehorse tower controllers when the location of an aircraft was unknown assisted in establishing situational awareness.

At the time of the incident there were no written procedures on how Whitehorse tower controllers were expected to establish situational awareness of arriving aircraft in IFR conditions. In Whitehorse, judgement and individual technique instilled through training were the primary means controllers used to establish situational awareness, in order to preserve flexibility in operations. Techniques for obtaining and maintaining situational awareness were taught during basic training and during the on-site qualification phase of training.

Tower controllers normally issued a landing clearance to an inbound aircraft without waiting for a request from the aircraft. [10]

## *Flight Progress Strip Marking*

In ATC operations, flight progress strips are one of the principal tools used by air traffic controllers to record flight progress, especially in procedural or non-radar environments. The strips assist controllers to sequence arriving and departing aircraft and to recognize and assess potential conflicts. NAV CANADA flight progress strips contain 18 boxes and tower controllers can insert up to 24 individual pieces of information in the 18 boxes, as well as various slash marks to indicate that information has been passed (see Appendix B).

The flight progress strips at the Whitehorse tower are completed by hand by tower controllers, as information is received from Edmonton ACC. The flight progress strip for JZA447 displayed nine pieces of information in seven boxes. The ETA recorded on the flight strip was not referenced, and was not required by ATC MANOPS to be referenced, to a fix. The information on the flight strip identified the flight number and type of aircraft, and provided sufficient information to determine the expected order of arrival for JZA447. While ATC MANOPS 493.2 requires estimates to be updated if the estimates vary by three minutes or more, the original ETA for JZA447 was not updated at any time before the aircraft landed. The relieving tower controller considered ETAs recorded on tower flight strips to be inaccurate, and as a consequence did not rely on them to manage arriving aircraft. Tower controllers at Whitehorse occasionally used the wake turbulence clock, [11] which could be set to activate in a specific number of minutes, to augment their sense of timing or "internal clock."

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10 NAV CANADA ATC MANOPS 344.2

11 Wake turbulence clock – a timer used by tower controllers to facilitate the required wake turbulence separation during operations.

## *Traffic Volume at Whitehorse*

For the years 2004 to 2008 inclusive, the Whitehorse International Airport averaged approximately 24 000 movements [12] of combined itinerant/local traffic per year. This corresponds to an average of approximately 66 movements per day. Overall, this represents a relatively small traffic volume for an airport with a control tower, and controller workload may vary considerably throughout the day, depending on the traffic volume.

## *Snowplow Operations at Whitehorse*

Guidelines for winter surface maintenance at the Whitehorse International Airport are contained in the Whitehorse Snow Removal Action Plan. The action plan states that all paved runways, taxiways, and aprons shall be cleared to an acceptable standard using a combination of ploughing, sweeping, sanding or blowing dependent on crew availability. Airside operations have priority over groundside operations during storm conditions. The active runway was considered a Priority 1 area. Each ground vehicle was fitted with one VHF radio. Ground vehicle control was provided on the ground control frequency of 121.9 MHz. Vehicle-to-vehicle communication was accommodated on the ground frequency, and the vehicles did not monitor the tower frequency (118.3 MHz) when snow removal operations were underway.

Both equipment operators on the runway at the time of the incident held unrestricted airport airside vehicle operator's permits and restricted radio operator certificates (aeronautical). One had been an equipment operator at the airport for 15 years, the other for 10 years. There was no evidence to indicate that the performance of either operator was a factor in the incident.

## *Pilot Information*

| | **Captain** | **First Officer** |
|---|---|---|
| Pilot Licence | Air Transport | Air Transport |
| Medical Expiry Date | 01 April 2009 | 01 May 2009 |
| Total Flying Hours | 17 000 | 3800 |
| Hours on Type | 1000 | 700 |
| Hours Last 90 Days | 168 | 146 |
| Hours on Type Last 90 Days | 168 | 146 |
| Hours on Duty Prior to Occurrence | 8 | 8 |
| Hours Off Duty Prior to Work Period | 15 | 15 |

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12 NAV CANADA ATC MANOPS defines an aircraft movement as a take-off, landing or simulated approach by an aircraft.

## *Flight Crew General*

The captain and first officer had commenced a four-day pairing two days before the incident. The pairing began at 0630 on Wednesday, 04 March and was to end at 1700 on Saturday, 07 March 2009. The captain and first officer had not flown together prior to the pairing, and the first officer had flown only one day within the three weeks prior to this pairing. They had flown from Vancouver to Whitehorse twice in the two days prior to the incident; these two flights were the only previous flights into Whitehorse for the first officer. Visual flight rules (VFR) weather and light IFR traffic conditions prevailed during the two previous arrivals.

Both flight crew members had adequate rest the previous night and fatigue or duty time issues were not factors. On 05 March their duty day had ended at 1500 and they had remained over-night in Whitehorse. On 06 March their duty day had commenced at 0600 and they had departed Whitehorse for Vancouver at about 0700. Both pilots had met all initial, requalification and recurrent Jazz training requirements, including crew resource management (CRM) and line oriented flight training.

## *Captain Information*

Air Canada Jazz was formed by the consolidation of four smaller regional airlines, including Air BC, in 2002. The captain had been employed by Air BC and then Jazz, as a pilot, for 22 years. The captain held an airline transport pilot licence (ATPL), issued by Transport Canada on 30 November 1981, valid for single and multi-engine land and sea airplanes. The licence was endorsed for Bombardier CL65, de Havilland DH7 and de Havilland DH8. The captain had accumulated approximately 17 000 hours of flight experience, including approximately 1000 hours on the RJ705. The captain had been flying the RJ705 since October 2007. The captain had an extensive background in IFR flight operations in coastal and mountainous areas. The captain had flown into Whitehorse approximately 20 times during his career.

## *First Officer Information*

The first officer held an ATPL issued by Transport Canada on 17 June 2003, valid for single and multi-engine land and sea airplanes, and endorsed for the CL65. The first officer commenced flying training in 1996, and was issued a private pilot licence in 1997, a seaplane endorsement in 1997, and a commercial pilot licence, a multi-engine rating and an instrument rating in 1998. The first officer had logged approximately 3800 hours of flight time, including approximately 700 hours on the RJ705.

The first officer had been hired by Air Canada Jazz, as a first officer on the RJ, in January 2008, had transferred from the Toronto base to the Calgary base in July 2008, and from the Calgary base to the Vancouver base on 02 March 2009.

The first officer had obtained limited multi-engine turbine IFR flight experience while training as a commercial first officer at a FAR Part 135 cargo company in the United States, and had acquired approximately 1000 hours of VFR experience as a first officer flying Twin Otters. The first officer had limited experience in Canadian northern operations, specifically in operations involving non-radar, procedural airspace in mountainous terrain. Pilot records indicated the first officer had failed four of ten IFR flight tests. Transport Canada records of the historical failures were not available to Jazz at the time of the first officer's hiring.

## *Flight Crew Workload During the Approach*

Edmonton ACC needed to maintain separation of the four arriving aircraft by procedural means, and the flight was asked to provide several altitude and DME position reports during the descent to ELTAG. As well, the flight was issued supplemental hold entry instructions and seven clearances between the beginning of the descent to ELTAG and the landing. This increased the communication workload for the flight crew.

The flight crew first discussed the use of HGS for the approach approximately 100 miles from Whitehorse. The captain began hand flying the aircraft, using the HGS, about the time the first officer contacted Whitehorse tower, and continued to hand fly the aircraft for the entire approach. The captain felt it took almost 100 percent concentration to hand fly the aircraft using the HGS. In the past, the captain had used the HGS intermittently, such as during low visibility approaches. The captain had acquired an estimated 300 to 400 hours experience with HGS.

The incident flight was the first non-simulator flight where the first officer had participated in an HGS approach in near-minimum IFR conditions. All other actual HGS approaches which the first officer had experienced had taken place in VFR conditions. The duties, callouts and workload of the PNF were expected to be similar during a flight director approach, an autopilot approach, or an HGS approach. On this approach the first officer's duties, as PNF, were to monitor the progress of the approach and handle the ATC communications.

The HGS was selected to the A1 approach mode for the approach. The A1 mode is selected for manual (hand flown) ILS approach and landing operations to CAT 1 minimums. [13] In the A1 mode the combiner display is de-cluttered; the display does not provide beacon crossing indications. Images of the HGS Primary mode and the HGS A1 mode displays are presented in Appendix D. The combiner could display DME distances when available; however, DME distance was not available to the crew on this approach, as the Whitehorse VOR/DME was not tuned and the localizer did not provide DME distances.

The flight crew downloaded the Whitehorse ILS Rwy 31L approach into the FMS prior to initiating the approach. With the Whitehorse ILS Rwy 31L selected from the FMS database, distance to the threshold would have been counted down once the aircraft passed ELTAG. The distance remaining would have been displayed on the dual CDUs.

The HGS flashed on and off four times during the descent and hold, prior to the aircraft becoming established on the approach. Each time, the captain stowed and extended the combiner in order to realign it, and the flashing stopped. The first officer was concerned about malfunction during the approach.

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13 Reference Canada Air Pilot Instrument Procedures, General Pages: For Category 1 (CAT 1) instrument approach minimum ¼ statue mile ground visibility or 1200 feet runway visibility, decision height not lower than 200 feet above touchdown zone elevation.

The HGS malfunction was not recorded in the aircraft records and the system was not checked for recorded faults or error codes following the incident. A review of the aircraft maintenance records for the period 01 January 2009 to 31 July 2009 identified four recorded defects related to the HGS. On 05 July 2009 the HGS overhead unit was replaced due to "HGS fault light on intermittently with the display cutting in and out." The overhead unit was forwarded to the manufacturer for testing and repair; the manufacturer was unable to duplicate the fault as indicated during testing.

## *Relieving Tower Controller Information*

| | |
|---|---|
| Controller Position | Airport/Ground Controller |
| Licence | Airport |
| Medical Expiry Date | 01 April 2009 |
| Experience<br>-as a Controller<br>-in Present Unit | <br>11 years<br>7.5 years |
| Hours on Duty Prior to Occurrence | 1 |
| Hours Off duty Prior to Work Period | 22 |

The relieving tower controller held an Air Traffic Controller licence issued by Transport Canada on 17 February 1998. The relieving tower controller had joined NAV CANADA in July of 1997 and, with the exception of eight months in Ottawa tower in 2006, had been primarily stationed in Whitehorse since August of 2001. The relieving tower controller had completed recurrent training on 21 April 2008.

The relieving tower controller had been involved in three ATC related incidents at Whitehorse in the past two years. One incident involved a potential conflict between a landing aircraft and a vehicle; the other two incidents involved a potential conflict between two landing aircraft. NAV CANADA had conducted an internal Operations Safety Investigation (OSI) after all three incidents. The two most recent OSI reports indicated that the relieving controller was counselled and provided a confidence check prior to returning to duty.

The relieving tower controller had been awake for approximately five hours prior to the incident, following 22 hours off duty. The relieving tower controller reported for work at 1300. The relieving tower controller had received a position transfer briefing, beginning at 1339:35, and had taken over the combined airport and ground controller positions at about 1340. The relieving tower controller had occupied the control position for about one minute when JZA447 initially contacted Whitehorse tower. During the few minutes following initial contact with JZA447, the relieving tower controller monitored and issued instructions to the equipment operators on ground frequency and organized the work station, including the flight strips, to the relieving tower controller's preference.

When JZA447 had first contacted Whitehorse tower the relieving tower controller believed, based on experience with transfers of communication from Edmonton centre for arriving IFR aircraft, that the flight was 40 to 45 miles south of Whitehorse. After the transfer of communication took place the relieving tower controller intended to establish situational awareness by having the flight report 10 miles final, which was 5 miles prior to the aircraft entering the Whitehorse control zone. It was estimated that it would take 10 minutes or less for the aircraft to transition from a point 40 to 45 miles south of the airport to 10 miles final. The flight was instructed to call 10 miles final at 1341. JZA447 landed nine minutes later at 1350.

The relieving tower controller had routinely instructed arriving IFR aircraft to call 10 miles final when sweeping was in progress on the active runway. This provided a window of three to four minutes prior to landing, which the relieving tower controller considered sufficient to remove the vehicles from any point on the runway and issue a landing clearance to the arriving aircraft. The relieving tower controller had begun using the "Call 10 miles final" instruction while working as a controller at an airport in eastern Canada from 1997 to 2000.

Other Whitehorse tower controllers normally instructed IFR aircraft arriving in IFR conditions to report by ELTAG (located on the localizer path 21 nm from the threshold of Runway 31L), or by the Robinson beacon, (located 16.8 miles from the threshold of Runway 31L), and again crossing the Klondike beacon (located 4.2 miles from the threshold of Runway 31L). This provided a window of five to seven minutes to move the vehicles off the runway and clear the aircraft to land. The landing clearance was usually issued after the aircraft reported by the Klondike beacon.

## *Prospective Memory*

Prospective memory refers to the ability to remember to do "something in the future". The "something in the future" is typically a task that would not normally be done at that future time, but is required to be done this time only. A prospective memory task is not a learned task and for a prospective memory task to be completed as intended it should be associated with cues that are not related to the ongoing primary task. [14]

Dismukes and Nowinski [15] defined a prospective memory task as having three features:

1. an intention to perform an action at some later time when circumstances permit,
2. a delay between forming and executing the intention, typically filled with activities not directly related to the deferred action,
3. the absence of an explicit prompt indicating that it is time to retrieve the intention from memory – the individual must "remember to remember."

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14 Marsh R.L., Hicks, J.L. and Cook, G.I. (2005). On the relationship between effort toward an ongoing task and cue detection in event-based prospective memory. Journal of Experimental Psychology: Learning Memory and Cognition, 31, 68-75.

15 Dismukes, K.; and Nowinski, J. (2007). Prospective memory, concurrent task management and pilot error. In Kramer, A., Weigmann, D. & Kirlik, A. (Eds.) Attention: From Theory to Practice, Oxford University Press.

The request by the Whitehorse sector controller for JZA447 to call leaving 9000 feet and the request by the relieving tower controller for JZA447 to report 10 miles final are both examples of prospective memory tasks. In the first example, the first officer integrated the 9000-foot call back request into the initial call to the Whitehorse tower. This is an example of a prospective memory cue (reaching 9000 feet) triggering the primary task of completing the communication transfer to Whitehorse tower. In the second example the 10 mile final request had no visible or audible cue counterpart for either the captain or the first officer. That is to say, the prospective memory task to call 10-mile final had no cue at all.

## *Meteorological Information*

The 1300 aviation routine weather report (METAR) issued for Whitehorse on 06 March was as follows: winds 340º True (T) at 16 knots, visibility ½ statute mile (sm), runway visual range (RVR) for Runway 31L 3000 feet, no change in trend, snow and drifting snow, vertical visibility 300 feet, temperature -7°C, dew point -10°C, altimeter 29.44 inches of mercury, remarks snow 8/8, sea level pressure 1016 hPa.

A special report issued at 1310 was as follows: winds 350°T at 18 knots gusting to 30 knots, visibility ¾ sm, RVR for Runway 31L 3000 feet, no change in trend, light snow, vertical visibility 500 feet, remarks snow 8/8.

The METAR report issued at 1400 was as follows: winds 350°T at 15 knots gusting to 24 knots, visibility ¾ sm, RVR for Runway 31L 4500 feet, no change in trend, light snow and drifting snow, vertical visibility 600 feet, temperature -8°C, dew point -12°C, altimeter 29.47 inches of mercury, remarks snow 8/8.

## *Jazz Standard Operating Procedure (SOPs)*

The Air Canada Jazz *CRJ Aircraft Operating Manual (AOM) Volume 2* provides guidance in the form of Standard Operating Procedures (SOPs) for the Jazz CRJ 100, 200 and 705 aircraft. SOPs are the guide to the proper conduct of a flight. Section 2.7.3 of the *AOM* states that, “When weather is reported at or less than published DH/MDA and/or visibility in statute miles or RVR on the approach plate, the captain will fly the approach using the HGS when available.”

The flight crew obtained the 1300 Whitehorse weather via the aircraft communications addressing and reporting system (ACARS). The Whitehorse METAR for 1300 indicated the surface visibility was half of a statute mile. This was the published minimum visibility in statute miles for the ILS 31L approach.

SOPs are not required to include guidance information that would exactly replicate all the standards contained in the CARs. Consequently, Jazz SOPs do not provide specific guidance for reporting procedures for IFR flights into control zones in non-radar environments.

## *Regulations and Aeronautical Information Manual Information for Control Zone Operations*

*Canadian Aviation Regulation (CAR) 602.96 (3) (g)* requires pilots operating into a controlled aerodrome to obtain clearance to land from the appropriate air traffic control unit. The Transport Canada *Aeronautical Information Manual* (AIM) contains information on rules of the air and air traffic control procedures for operating aircraft in Canadian Domestic Airspace. Throughout the AIM the term "should" implies that Transport Canada encourages all pilots to conform to the applicable procedure. The term "shall" implies that the applicable procedure is mandatory because it is supported by regulations.

Section RAC 4.4.3 of the AIM states that at controlled airports, a pilot must obtain landing clearance prior to landing, and that normally the airport controller will initiate landing clearance without having first received the request from the aircraft. The reference also states that should this not occur, the onus remains upon the pilot to request such clearance in sufficient time to accommodate the operating characteristics of the aircraft being flown. RAC 4.4.3 also describes that a landing clearance will normally be given when an aircraft is on final approach, and if a landing clearance is not received, the pilot shall, except in case of emergency, pull up and make another circuit.

AIM Section RAC 9.8 provides guidance for flight crews making initial contact with control towers. RAC 9.8 states that if pilots are in direct communication with an ACC or a terminal control unit, the IFR controller shall advise the pilot when contact is to be made with the tower, and unless on radar vectors to final approach, pilots should give the tower their ETA to the facility for the approach they intend to fly. Whenever an ETA is passed, the pilot should specify the point, fix or facility to which the ETA applies. Neither flight crew member was familiar with this guideline.

AIM section RAC 9.9 provides guidance for flight crews regarding what to expect for approach position reports at controlled airports. RAC 9.9 states pilots conducting an instrument approach to, or landing at, a controlled airport shall only make position reports that are requested by the appropriate ATC unit. As an example, pilots may expect ATC to request a report by the Final Approach Fix (FAF) or a specified distance on final.

## *Jeppesen Supplemental Information for Whitehorse*

Air Canada Jazz crews are supplied with Jeppesen aeronautical navigation charts. The Jeppesen approach plate for the ILS or LOC/ NDB/ DME approach to Runway 31L at Whitehorse can be found in Appendix A. Additional supplemental information for Whitehorse was provided in Air Canada Jazz Jeppesen binders (see Appendix C). The Jeppesen supplemental information states in part:

> At the present time, Whitehorse is a non-radar environment. Position reporting at DUXAR on 126.7 is required. Provide an estimate for Whitehorse. Crews should be aware that the non-radar environment may result in arrival delays during poor weather conditions. Edmonton Center may require frequent DME information during your descent. Descent/approach clearance is issued by Edmonton Center. Contact is possible within about 150 NM of YXY. The ILS can be flown directly from the commonly used inbound tracks.

## *Tests and Research*

On 14 April 2009 Whitehorse approach and landing simulator trials were conducted at the CAE training facility in Toronto.[16] Two TSB investigators and two Rockwell-Collins HGS representatives were present as part of the investigation into this occurrence. The CRJ simulator used for the trials was a flight crew training simulator. The simulation trials were designed to provide insight into the workload and situational awareness characteristics for both the PF and the PNF under two approach conditions:

- ILS using the autopilot to minimums and hand flying for landing.
- ILS using the HGS and hand flying from glide slope intercept to landing.

Two volunteer Air Canada Jazz crews, matched in age and time within the company to the occurrence crew, participated in the trials. The volunteers each wore an ambulatory electrocardiography device known as a Holter monitor during the trials, in order to capture workload data. Each team of two pilots flew one autopilot approach and one HGS approach. All simulations approximated the Whitehorse conditions including an unfamiliar, atypical hold sequence and a long glide path approach to an airport without radar. Simulated weather conditions were similar to those on the occurrence approach.

Simulation test data identified that the approach to Whitehorse in instrument meteorological conditions (IMC) can place flight crews in moderate to high mental workload states. Moreover, the workload associated with hand-flying the aircraft with HGS from glide slope intercept to landing is likely to be crew dependent.

The data also provided examples of typical mental workload management strategies; crews consolidate and prioritize information based on its perceived salience for the given context. In the moderate to high mental workload conditions, PF workload management behaviour resulted in inaccurate sequence recall of tower communications and incomplete recall of the details of complex ATC communications.

The TSB simulator data also suggest that crew members are sensitive to their crew-mate's awareness of their operational conditions. It was not clear from these data how this knowledge might or should impact the crew's communications strategies.

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16 TSB Report HF118/2009, Assessment of Crew Workload, Canadair CL-600-2D15 (RJ 705), C-FDJZ

## *Additional Information: Alternatives to Radar Surveillance*

Air Canada Jazz operates into approximately 27 Canadian airports where radar coverage to the ground is not available and where separation between IFR aircraft is maintained by procedural methods.

Radar is a long-established air traffic surveillance technology. NAV CANADA is currently introducing two new aircraft surveillance technologies to enhance safe and efficient movement of air traffic in areas of Canada that do not currently have low-level radar surveillance coverage. [17] These systems cost less to install and maintain than traditional radar. NAV CANADA advised that both systems are primarily used for airborne surveillance; however with properly equipped aircraft and ground vehicles the systems can be used for ground surveillance as well. NAV CANADA has vigorously explored possible areas in Canadian airspace where this technology could enhance service, and Transport Canada supports this exploration.

Automatic Dependent Surveillance-Broadcast (ADS-B) is a satellite-based position reporting technology in which ADS-B ground stations receive reports from appropriately equipped aircraft which convey their GPS position, identification, and altitude, as well as other information about the aircraft. The information is processed and presented to air traffic controllers with a display of all reporting aircraft. ADS-B technology requires minimal ground support infrastructure compared to what is typically required for a radar system, which results in significantly lower operating costs. One limitation of this technology is that it requires aircraft to be fitted with suitable ADS-B broadcast equipment. ADS-B is currently approved for en route surveillance. The first phase of ADS-B implementation in Canada is underway over Hudson's Bay. Both NAV CANADA and Transport Canada will apply lessons learned from this project to future similar projects. The next phase of this implementation is the utilization of ADS-B in the eastern Arctic for flights utilizing the high northern Atlantic airspace en route to/from Europe.

Wide Area Multilateration (MLAT) senses an aircraft position by triangulation using at least three ground receivers that acquire transponder signals from an aircraft. This technology is compatible with transponder equipped aircraft. Compared to radar systems, the initial and operating costs are low. One disadvantage is that performance can be negatively affected by mountainous terrain. MLAT was approved on 02 July 2009 by Transport Canada for use where secondary surveillance radar could currently be used, and is saw initial use at Fort St. John, British Columbia, and the Olympic Sea to Sky corridor.

Prior to approving the installation of either of these surveillance systems in any area of Canada, NAV CANADA is required to conduct an aeronautical study using the Canadian Standard Q850 process for risk management to determine the feasibility. At the time of the incident, alternative surveillance technology was not being considered for installation at Whitehorse.

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17 http://www.navcanada.ca/NavCanada.asp?Language=en&Content=ContentDefinitionFiles\Newsroom\NewsReleases\2007\nr0212.xml

## Analysis

Other than the HGS combiner glitch that occurred while the flight was holding at ELTAG there were no reported problems with the aircraft. As well, there were no reported unserviceable navaids. Therefore the analysis will address the human factors elements that contributed to the incident.

Aviation depends on an integrated system of multiple checks and balances to reduce risks associated with flight operations. Whenever the aviation system relies on a single layer of defence, such as a requirement for one individual to relay critical information at a later time, a lapse in memory or a deviation from standard practice can increase the risk of an incident or accident. In this incident, reduced flight crew and controller awareness and performance increased the risks associated with concurrent runway sweeping and aircraft landing operations at Whitehorse, and secondary defences that could have mitigated the primary defence were either not available or were not used.

### The Flight Crew

JZA447 was advised radar service was terminated after the flight passed the DUXAR reporting point. ATC services, including the frequent requests by Edmonton ACC for altitude and DME updates and recurring changes to the JZA447 clearances during the descent, were procedural in nature from then on. However, the flight crew appears to have not internalized the impact of Whitehorse being a controlled, non-radar airport. This influenced their communications strategy. They believed the relieving tower controller knew their location when tower communication was established, and consequently did not offer a position report.This belief was reinforced when the relieving tower controller did not request the flight's position at initial contact.

The flight simulation test data indicated that some crew members may perceive higher workload while conducting the ILS Runway 31L instrument approach to Whitehorse in IMC conditions. The degree of perception of this increased workload would be affected by such things as personal preparation, familiarity with the approach and airport surroundings and any other operational conditions that cause a disruption to familiar procedures such as use of a HGS system.

During the approach the captain became fully engaged with hand flying the ILS approach and maintaining flight stability using the HGS. The captain prioritized the ATC communications that provided weather and runway conditions. While the dual FMS CDUs would have provided a countdown of the distance to the runway threshold after the aircraft passed ELTAG, the HGS combiner, with the HGS in A1 mode, provided no-distance-to-runway navigation information. The first officer handled all JZA447 ATC communications following the decision to conduct an HGS approach, and several communication errors subsequently occurred. The pattern of communication errors was consistent with a perceived high workload and task saturation on the part of the first officer.

While it may have been perceived that the workload during the ILS approach was high, it is probable the actual workload was normal. The approach from glide slope intercept to touchdown was notably longer than many other approaches, which would have allowed more time to trim the aircraft and firmly establish the aircraft on the glide slope.

Following initial contact with Whitehorse tower, the relieving tower controller provided JZA447 with wind and altimeter setting information, followed by the 10-mile call instruction and an advisory that sweeping was in progress. The 10-mile call instruction was embedded between important pieces of runway information. There were three features of the 10-mile call instruction that characterized it as a prospective memory task:

- the first officer demonstrated intention to comply by acknowledging the instruction;
- thedelay between forming and executing the intention; and
- the absence of an explicit prompt to indicate when it was time to retrieve the intention from memory.

The first officer was relatively unfamiliar with the Whitehorse airport; therefore the first officer would not have routinely associated the 10-mile call instruction with the approach. As a prospective memory task with poor cue parameters the first officer had to rely entirely on memory to ensure that the 10-mile call was made. In addition, the first officer's performance and situational awareness may have been negatively impacted by the first officer's unfamiliarity with ATC procedures in a non-radar environment, by a lack of understanding of the importance of informing Whitehorse tower of the flight's proximity to the airport, by the HGS fail warnings, and by the possibility of an unwanted overshoot.

As well, the flight crew appears to have categorized the instruction differently than previous instructions from Edmonton ACC, many of which were associated with clearance changes and compliances. The crew did not recognize that the 10 nm call would be the trigger for the relieving tower controller to remove the sweepers from the runway, and then issue a landing clearance. The first officer forgot the call and, as there was little or no HGS distance information that would facilitate error trapping of radio transmissions not completed, the captain did not realize the call had been missed. The risk created by the first officer not reporting 10 miles back from landing could have been offset, in part, had the a request to call passing a published fix on the approach chart been made.

The first officer realized prior to touchdown that the flight did not have a landing clearance and attempted to communicate this to the captain; however, the captain did not assimilate this information. The flight crew's perception was that there were no vehicles or obstructions in the touchdown zone. The captain, believing that the trucks were holding until the flight landed, elected to land without the flight receiving a landing clearance. Although a landing clearance will normally be issued without a specific request from the crew, the onus is on the crew to request such a clearance if it is not provided. If a clearance has not been received, the pilot shall pull up and go around. The crew had no assurance that other maintenance vehicles were not on the runway beyond its field of view. Had there been another vehicle on the unseen portion of the runway, the decision to continue the landing would have exacerbated the risk of collision.

Detailed analysis of the effectiveness of CRM employed by the JZA447 flight crew was compromised by the loss of the CVR evidence. ATC recordings revealed what communications had taken place between the aircraft and ATC; however, the interactions between the flight crew members themselves, and between the crew members and the tower controller, would have been better understood had the CVR data been recovered.

## *The Controller*

The relieved tower controller had been advised by Edmonton ACC that JZA447 would be arriving at the Whitehorse VOR at 1331; the ETA had been entered on the flight progress strip in accordance with ATC MANOPS, without reference to a fix. The relieved tower controller had also been advised by Edmonton ACC that JZA447 would have to hold prior to commencing the approach. That information was not recorded on the flight progress strip and was not communicated to the relieving tower controller during the position transfer briefing, and was therefore not available to the relieving tower controller to establish initial situational awareness. JZA447 contacted Whitehorse tower approximately one minute after the relieving tower controller assumed the control position, and it is likely that the relieving tower controller focused during the next few minutes on establishing situational awareness of the equipment operating on the runway and organizing the work station.

The transfer of communication between Edmonton ACC and Whitehorse tower often occurred when inbound IFR aircraft were 40 to 45 miles from Whitehorse. The relieving tower controller assumed the aircraft was 40 to 45 miles out, as opposed to in the hold at ELTAG, when the transfer of communication took place. The relieving tower controller's mental model was strongly dominated by that incorrect assumption, to the point that consideration of all other data that could have or should have been available appears to have been excluded. Because the approach was conducted in a non-radar environment, the only way for the relieving tower controller to accurately establish the position of the flight at any time after the transfer of communication took place was through radio communication with the aircraft. While this was a primary defence to avoid a risk of collision, ATC MANOPS did not require airport controllers to solicit a position report on initial contact. A position report was not provided voluntarily by the flight at first contact and was not requested by the relieving tower controller. The relieving tower controller's instruction to the flight to report 10 miles final suggests it was the relieving tower controller's intention to fully establish situational awareness of the flight when the flight was five miles outside of the Whitehorse control zone, rather than at first contact. This plan met all ATC MANOPS requirements.

The relieving tower controller relied on his internal clock to estimate 10 minutes elapsed time and was expecting the aircraft to call 10 miles final within 10 minutes of initial contact. However, the relieving tower controller's internal clock was not a defence that could have prevented this incident, as the aircraft was over 20 miles closer to the airport than the relieving tower controller realized when the controller's internal clock was started.

## *ATC Operations in Whitehorse*

There were several ATC operating procedures and anomalies that contributed to the occurrence:

- Communication transfers between Edmonton ACC and Whitehorse tower were not taking place in accordance with the Inter Unit Arrangement between the two facilities, resulting in a wide variation in aircraft position and situational ambiguity at the time of the communication transfer.

- The relieving tower controller did not establish the position of JZA447 on initial contact, and was not required to by ATC MANOPS. The relieving tower controller assumed that JZA447 was 45 nm from the airport and this resulted in an inaccurate assessment of the flight time left prior to the aircraft's arrival.

- Information that JZA447 would have to hold was not communicated to the relieving tower controller during the position transfer briefing.

- The flight progress strip did not contain holding information, a fix reference or an airport ETA for JZA447. This reduced the opportunity for the relieving tower controller to establish accurate initial situational awareness and allowed the 45 nm from airport assumption to persist.

- While techniques for obtaining and maintaining controller situational awareness are taught during basic training, and during the onsite qualification phase of training, there were differences in how the relieving tower controller, compared to other Whitehorse tower controllers, routinely handled IFR arrivals in IFR weather. The risks of errors occurring due to missing or ambiguous information were greatest following position transfers.

The relieving tower controller relied entirely on the instruction for JZA447 to report 10 nm final to establish situational awareness prior to the aircraft entering the Whitehorse control zone. When the crew of JZA447 did not make the 10 nm call the relieving tower controller did not receive the necessary trigger to issue a landing clearance.

## *Prospective Memory*

Prospective memory tasks with inadequate cues and decision-making based on uncoordinated mental models between Whitehorse Tower and JZA447 were factors in the incident. There were two ATC instructions that required the flight crew to carry out a prospective memory task. The first was the instruction from Edmonton centre for JZA447 to report reaching 9000 feet asl, using the second radio, after the communications transfer took place. The associated cue for the call back request was expressed as 9000 feet. The second was the instruction from the relieving tower controller for JZA447 to call 10 miles final. As the requests had no visible or audible associated cue for either the captain or the first officer, the first officer missed both calls and the captain did not detect that the calls had not been made.

### *Mental Models*

Flight crew and relieving tower controller mental models for flight location were not aligned. When the communication transfer from Edmonton centre to Whitehorse tower took place, the flight crew assumed that the tower knew their position and ETA, and, as they had already received their approach clearance, that there was no equipment on the runway. This demonstrated the flight crew's misunderstanding of the differences between an approach clearance and a landing clearance relative to the status of the active runway.

In some respects the flight crew were treating the approach to Whitehorse as if they were operating in a radar environment, where flight crews do not normally provide position and ETA information to controllers unless asked to do so. Therefore, the significance of the instruction to report 10 miles final as a cue for the relieving tower controller to remove the trucks from the runway and issue the landing clearance was not recognized by the flight crew.

The relieving tower controller's instruction for the flight to report 10 nm final suggests it was the relieving tower controller's intention to fully establish situational awareness of the flight when the flight was five miles outside of the Whitehorse control zone, which would have provided sufficient time to ensure safe removal of the sweepers from the active runway. Without clear communications, it was not possible for the flight crew and the relieving tower controller to establish a common view of what was going on.

### *NAV CANADA OSIs*

The NAV CANADA OSIs that were completed following the previous incidents involving the controller appeared to focus on the performance of the individual controller, without apparent consideration for deficiencies in unit operations and procedures.

### *Technological Alternatives for ATC*

Lower cost alternatives to radar, such as wide area multilateration and ADS-B technology may be useful tools to enhance tower controller situational awareness of traffic and reduce the risk of collision between arriving aircraft and ground vehicles in non-radar environments such as Whitehorse.

The following TSB Human Factors Report was completed as part of this investigation:

Crew Workload, Mental Models and Prospective Memory

This report is available from the Transportation Safety Board of Canada upon request.

## *Findings as to Causes and Contributing Factors*

1. Communication transfers between Edmonton ACC and Whitehorse tower did not take place in accordance with the Inter Unit Arrangement between the two facilities, resulting in a wide variation in aircraft position at the time of the communication transfer.

2. The relieving tower controller did not establish the position of JZA447 on initial contact. The relieving tower controller assumed that JZA447 was 45 nm from the airport and this resulted in an inaccurate assessment of the flight time left prior to the aircraft's arrival.

3. Information that JZA447 would have to hold was not communicated to the relieving tower controller during the position transfer briefing and the flight progress strip did not contain holding information, a fix reference or an airport ETA for JZA447. This reduced the opportunity for the relieving tower controller to establish accurate initial situational awareness and allowed the 45 mile from airport assumption to persist.

4. The mental models of the flight crew and the Whitehorse tower controller were not aligned; the flight crew believed the Whitehorse controller knew their location when tower communication was established and their current position was not requested.

5. The first officer handled all JZA447 ATC communications following the decision to conduct an HGS approach, and several communication errors subsequently occurred. The pattern of communication errors was consistent with task saturation.

6. Whitehorse Tower's instruction to call 10 miles final became a prospective memory task with no relevant memory reminder cue for the first officer. As well the significance of the instruction to report 10 miles final as a cue for the relieving tower controller to remove the trucks from the runway and issue the landing clearance was not recognized by the flight crew; thus the call was missed.

7. The relieving tower controller relied entirely on the instruction for JZA447 to report 10 miles final to establish situational awareness prior to the aircraft entering the Whitehorse control zone. When the crew of JZA447 did not comply with the instruction to report 10 miles final the relieving tower controller did not receive the necessary trigger to issue a landing clearance.

8. The flight crew's perception that the approach clearance meant there was no equipment on the runway demonstrated a misunderstanding of the difference between an approach clearance and a landing clearance relative to the status of the active runway.

9. The flight crew's perception was that there were no vehicles or obstructions in the touchdown zone. The captain, believing that the trucks were holding until the flight landed, elected to land without the flight receiving a landing clearance.

## *Findings as to Risk*

1. There were differences in how the relieving tower controller, compared to other Whitehorse tower controllers, routinely handled IFR arrivals which created the potential for situational ambiguity between controllers, especially during position transfers.

2. A PF's attention resources may be fully occupied, due to moderate to high perceived workload, when hand-flying an approach using the HGS under IMC, resulting in a significantly reduced capacity to monitor radio communications and provide PNF support.

3. To properly assess applicants for pilot positions, operators need access to information on experience and performance that is factual, objective, and (preferably) standardized. Transport Canada pilot records are not available to employers—this may lead to the appointment of pilots to positions for which they are unsuited, thereby compromising safety.

4. The crew had no assurance that other maintenance vehicles were not on the runway beyond its field of view. Had there been another vehicle on the unseen portion of the runway, the decision to continue the landing would have exacerbated the risk of collision.

# *Other Findings*

1. The CVR was not secured following the incident and the incident was not reported to the TSB by the quickest available means, which resulted in the loss of beneficial investigative evidence.

2. Wide area multilateration and ADS-B technology may be useful tools to enhance tower controller situational awareness of traffic and reduce the risk of collision between arriving aircraft and ground vehicles in non-radar environments.

# *Safety Action Taken*

## *NAV CANADA*

On 15 May 2009, as a result of this incident, NAV CANADA issued Whitehorse Control Tower Operations Letter 09-04. The letter stated that the following procedure will be in effect:

> On initial contact and in addition to the usual information (e.g. aircraft identity, type and altitude) the following must also be obtained from pilots:
>
> - Position report from VFR and IFR aircraft which might include a VFR reporting point, an IFR navigation aid or distance (DME or GPS) back from an IFR navigation aid and,
> - from IFR aircraft the pilot's ETA for the airport.

## *Transport Canada*

Transport Canada has undertaken, through its National Operations branch oversight plan, to monitor Whitehorse Tower and other units within uncontrolled or non-radar environments, in order to identify possible systemic issues related to communication protocols and the adherence to those protocols by all air traffic controllers.

## *Air Canada Jazz*

Air Canada Jazz has taken the following safety actions:

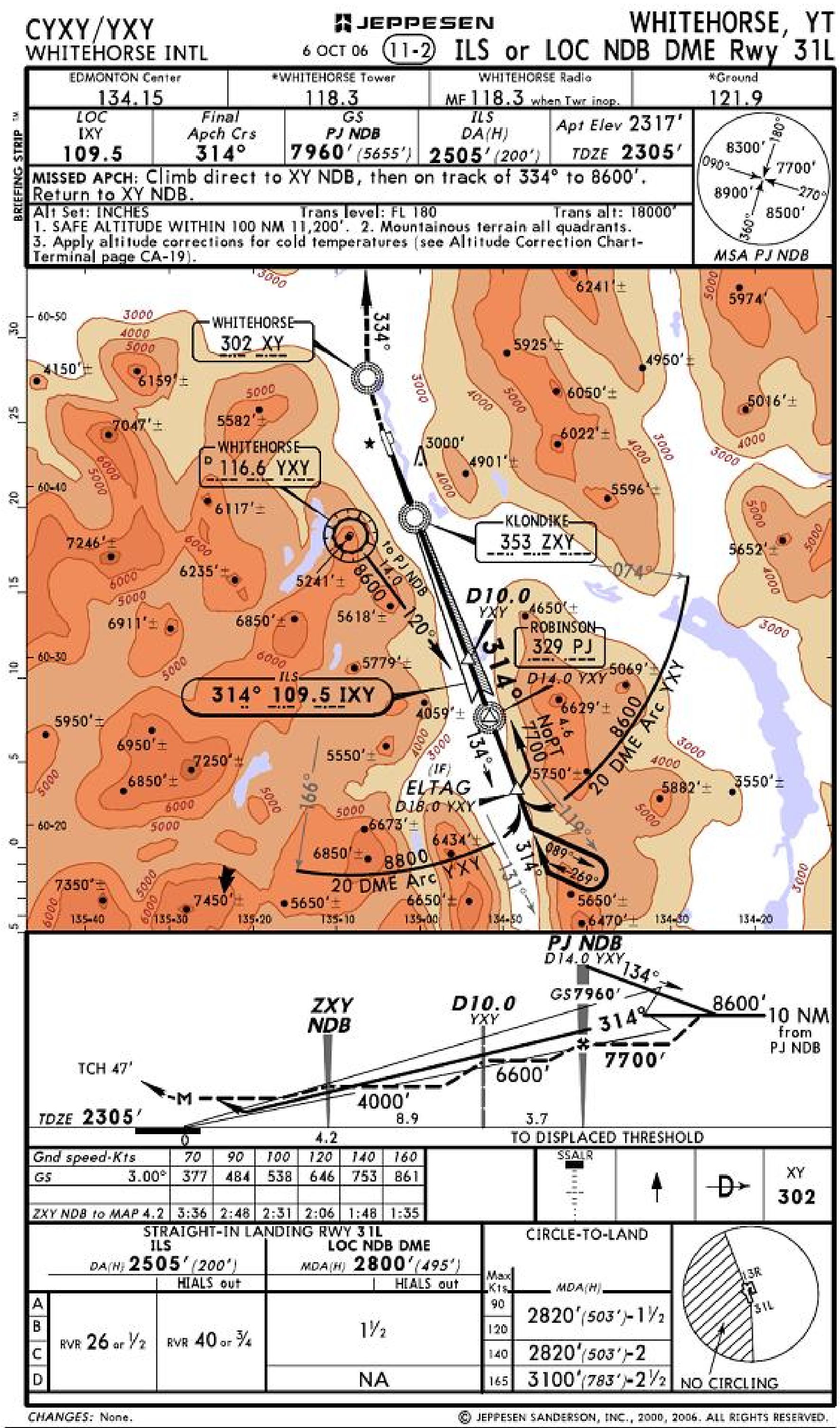
- Increased emphasis on HGS usage for the CRJ fleet. On 01 November 2009, the CRJ aircraft operating manual was modified to state that the captain shall utilize the HGS, when serviceable, for all phases of flight as both the PF and PNF.
- On 11 June 2010, the new Section 7.3.6 of the Flight Operations Control Manual (New Hire-Line Pilot Employment Follow up procedure) was published. This procedure describes the process to evaluate the performance of new pilots and validate the effectiveness of training.
- Recurrent training on uncontrolled airport operations has been added as a pre-briefing item. The training will include procedures published in the AIM and will also include reference to the forthcoming language in the COM with respect to supplemental information that must be communicated to ATS.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 20 July 2010.*

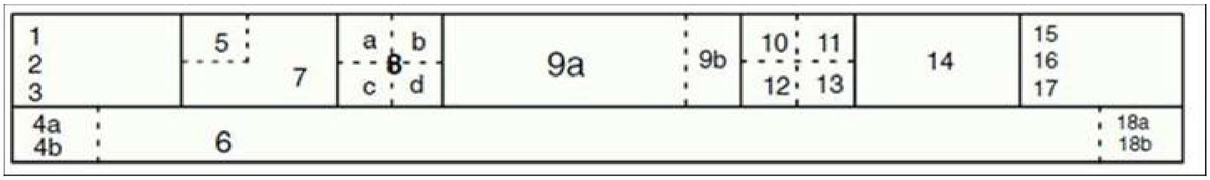
*Visit the Transportation Safety Board's Web site (**www.bst-tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*

# *Appendix A – Jeppesen ILS or LOC/NDB/ DME Rwy 31L*

NOT TO BE USED FOR NAVIGATION



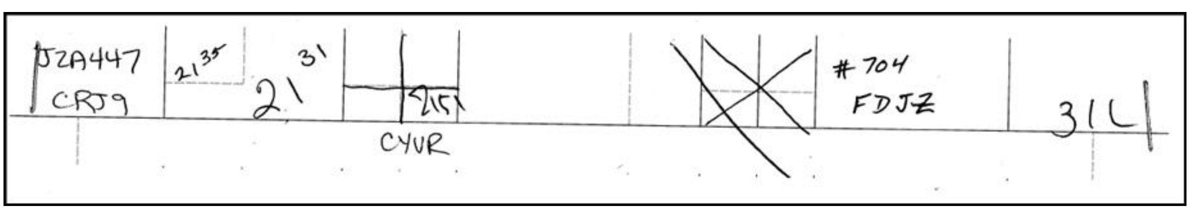
# *Appendix B - Flight Progress Strips Used by Tower*




*Reference Diagram for Tower Flight Data Strips in ATC MANOPS 912.1*

Legend (Reference ATC MANOPS 912 COMPLETION OF TOWER STRIPS):

Box 1 --- Aircraft identification
Box 2 --- Aircraft type
Box 3 --- Speed if required
Box 4a --- Secondary Surveillance Radar (SSR) Code
Box 4b --- Category of flight plan
Box 5 --- Proposed departure time for departure strip
Box 6 --- Other route information
Box 7 --- Inbound estimate for IFR arrival
Box 8 d --- Actual arrival time (for arrivals draw a cross over the dotted lines and enter the actual arrival time)
Box 9a --- IFR departure altitude
Box 9b --- VFR last reported altitude or assigned altitude
Boxes 10 to 13 --- Type of operation (touch-and-go, stop and go, flight plan, etc.)
Box 14 --- Control data and pertinent information
Boxes 15 to 17 --- runway number, code for type of aircraft operation, other information as specified in a unit directive
Box 18 --- ATIS code




*Tower Data Strip for JZA447 Completed by Whitehorse Tower Controllers*

# *Appendix C – Excerpts from Jeppesen Airport Information*

## AIRPORT NOTES

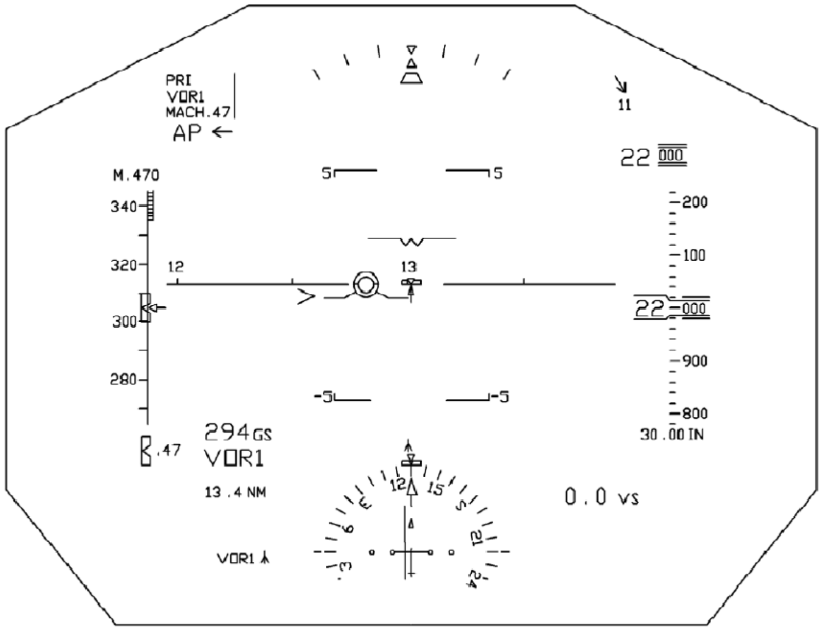
**4. OVERVIEW**

a. The Whitehorse airport is located just to the west of the city on a level plateau approximately 225 feet above and parallel to the Yukon River. The Yukon River Valley, itself, is oriented along a north-south axis with large lakes and low, densely treed hills extending along its broad relatively flat floor. Lake Laberge lies 20 NM to the north and Marsh Lake 20 NM to the southeast. Mountain ranges rise on either side of the valley, reaching heights of over 6000 ASL at 15 NM to the southwest, 7 NM to the east and 30 NM to the northwest of the airport.

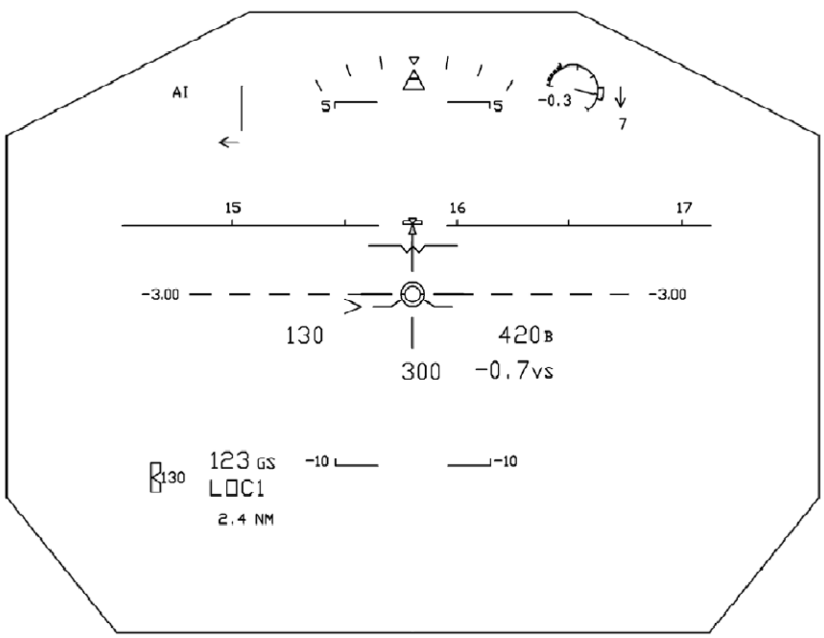
## ARRIVAL CONSIDERATIONS

1. **At the present time, Whitehorse is a non-radar environment. Position reporting at DUXAR on 126.7 is required. Provide an estimate for Whitehorse. Crews should be aware that the non-radar environment may result in arrival delays during poor weather conditions. Edmonton Center may require frequent DME information during your descent. Descent/approach clearance is issued by Edmonton Center. Contact is possible within about 150 NM of YXY. The ILS can be flown directly from the commonly used inbound tracks.**
2. **The preferred runway is 31L since it has the only ILS approach available at the airport. There is a LOC/BC approach to RWY 13R. Doing the ILS to RWY 31L with a visual downwind for 13R is the best approach if weather permits. RWY 13R has an upslope gradient of 0.42%. When on final approach to RWY 13R the upslope gradient as well as the lower terrain over the approach, gives the illusion of being high. Use the PAPI to verify the flight path. In moderate winds expect a momentary drop of 5 to 10 knots in airspeed when passing the gully which crosses the approach lights.**
3. **Due to high terrain surrounding the airport, it is critical that proper temperature corrections are applied to altitudes when the surface temperature is below 0 degrees C.**

# *Appendix D – Rockwell Collins HGS4200 Display Modes*




*HGS Primary (PRI) Mode, in-flight (typical)*




*HGS AI Mode – Approach (typical)*