Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A04W0032

LANDING BESIDE THE RUNWAY

BRADLEY AIR SERVICES LTD. (FIRST AIR)
BOEING 737-210C C-GNWN
EDMONTON INTERNATIONAL AIRPORT, ALBERTA
25 FEBRUARY 2004

Canada

Aviation Investigation Report

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Report Number A04W0032

Summary

The Boeing 737–210C (C–GNWN, serial number 21067) was operating as Flight FAB 6501 from Lupin, Nunavut, to Edmonton, Alberta. The runway visual range (RVR) provided to the flight crew prior to commencing the approach to Runway 12 at Edmonton was 1200 RVR, with a runway light setting of 5. The crew flew the instrument landing system approach in darkness and touched down on the infield to the left of the runway surface, at 0544 mountain standard time. The aircraft travelled approximately 1600 feet before returning to the runway. After the aircraft was brought to a full stop, aircraft rescue and firefighting was requested by the flight crew. One runway light, four taxiway lights, and one hold sign were struck by the aircraft. There were no injuries and the passengers deplaned via the rear airstairs door.

Ce rapport est également disponible en français.

Other Factual Information

Records show that the aircraft was certified and equipped, and was maintained in accordance with existing regulations and approved procedures. C–GNWN is a Boeing 737–210C (combi) that was modified with a forward main cabin cargo compartment, a cargo door and a gravel kit. The aircraft's weight and centre of gravity were within limits. Testing of the aircraft's auto-flight and approach avionics revealed the equipment was operating within design tolerances.

The aerodrome forecast for the airport, issued on 25 February 2004 at 0439 mountain standard time (MST)[1] and valid from 0500 to 0500, was as follows: winds variable at 3 knots, visibility 0 statute miles (sm) in freezing fog, temporarily from 0500 to 0800, 2 sm in mist, and ceilings broken at 25 000 feet above sea level. The hourly weather report (METAR) issued at 0600, 15 minutes after the occurrence, was as follows: winds calm, visibility ⅛ sm, Runway 12 RVR 1000 feet, Runway 30 RVR 800 feet in freezing fog, vertical visibility 300 feet, temperature -14°C, dew point -15°C, altimeter setting 29.76, and remarks, fog 8/8 and frost on the indicator.

The flight crew members were certified and qualified for the flight in accordance with existing regulations. The captain had a total of 25 000 hours total time with about 6000 hours on B–737 aircraft. In the previous 30 days, the captain flew 21 hours. The first officer had approximately 6000 hours total time with about 3200 hours on B–737 aircraft. In the previous 30 days, the first officer flew 33 hours.

Both pilots woke at approximately 0530 on February 24, to start the schedule. They had obtained adequate rest before the start of the schedule and were not tired when they checked into the day-room in Yellowknife. Neither pilot slept for any significant amount of time in the day-room, having just wakened a few hours earlier. The First Air *Operations Manual*, Section 4.1.3.3, which is compliant with *Canadian Aviation Regulations*, allows flight crews to reset their duty day if they are provided an opportunity to obtain not less than eight consecutive hours of sleep in suitable accommodation, time for meals, personal hygiene, and time to travel to and from the rest facility. The flight crew arrived at the hotel in Yellowknife at about 1000 and left at about 1830.

The captain and first officer had been awake for almost all of the 24 hours before the occurrence. Studies show that long periods of wakefulness produce a significant degradation in human performance.[2] [3] Performance decrements are noted in reaction time, arithmetic, signal detection, meter reading accuracy, safety alarm alerts, random number addition speed, psychomotor and cognitive functioning, etc.[4] Rest taken during a person's normal waking period is not normally

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1 All times are MST (Coordinated Universal Time minus seven hours).

2 D. Dawson and K. Reid, "Fatigue, Alcohol and Performance Impairment," *Nature* (1997), pp. 388, 235.

3 R.G. Angus et al., "Sustained Operations Study: From the Field to the Laboratory," in C. Stampi (ed.), *Why We Nap: Evolution, Chronobiology and Functions of Polyphasic and Ultra-short Sleep* (Boston: 1992), pp. 217–241.

4 S. Sonnentag and M. Frese, "Stress in Organizations," in W.C. Borman, D.R. Ilgen and R.J. Klimoski (eds.), *Handbook of Psychology, Volume 12, Industrial and Organizational*

of sufficient quality to be fully restorative.[5] These rests may reduce fatigue, but not all of the performance decrements associated with residual fatigue.[6] However, even a full eight hours of sleep would not be sufficient to re-set the crew's circadian rhythm for a flight planned late at night.[7]

FAB 6501 was the return flight from Lupin (CYWO) on a charter that started in Edmonton (CYEG) the previous evening. This was a relatively new charter contract for a mining company, and this was the third time First Air had conducted the trip. The schedule for the charter required the flight crew to fly four legs over a 20-hour period with a 10-hour rest period during the daytime stopover in Yellowknife, Northwest Territories (CYZF). The scheduled arrival and departure times for the flights were planned as follows, starting on 24 February 2004:

FAB 951	CYEG – CYZF	depart 0725 arrive 0912 (day room provided in YZF)
FAB 956	CYZF – CYEG	depart 2045 arrive 2226
FAB 6500	CYEG – CYWO	depart 2345 arrive 0145
FAB 6501	CYWO – CYEG	depart 0305 arrive 0505

The aircraft's actual arrival and departure times were fairly close to the scheduled times until the departure from Lupin. The flight crew was advised by First Air dispatch of low visibilities due to fog in Edmonton, and they delayed the departure for approximately 40 minutes to assess the weather and plan for contingencies. FAB 6501 departed Lupin at 0340 MST with Calgary, Alberta, as the alternate airport.

When FAB 6501 contacted Edmonton arrival at 0519, the visibility for Runway 30 was 1200 RVR, the approach ban limit, and the flight crew briefed for an approach to that runway. During the next 14 minutes, the visibility for Runway 30 increased to 3000 RVR but then decreased to 900 RVR with the other runways, 12 and 02, reporting 800 RVR. The flight crew planned to hold for approximately 30 minutes at an initial approach fix for Runway 30 and wait for the visibility

Psychology (Hoboken, New Jersey: John Wiley & Sons, 2003), pp. 453–491. Studies have shown that fatigue in stressful situations can impair basic cognitive processes such as attention and working memory. The fatigued and stressed individual may not be able to retain as much information in working memory while making a decision, nor will he or she be able to simultaneously pay attention to as many pieces of information. The combination of stress and fatigue can also result in further impairing working memory and narrowing attention span.

5 E.D. Weitzman and D.F. Kripke, "Experimental 12-hour Shift of the Sleep-Wake Cycle in Man: Effects on Sleep and Physiological Rhythms," in L.C. Johnson, D.I. Tepas, W.P. Colquhoun and M.J. Colligan (eds.), *Biological Rhythms, Sleep and Shift Work* (New York: Spectrum Publishing, 1981),pp. 93–110.

6 P. Naitoh, "Circadian Cycles and Restorative Power of Naps," in L. C. Johnson, D.I. Tepas, W.P. Colquhoun and M.J. Colligan (eds.), *Biological Rhythms, Sleep and Shift Work* (New York: Spectrum Publishing, 1981), pp. 553–580.

7 K.E Klein and H.M. Wegmann, *Significance of Circadian Rhythms in Aerospace Operations* (Neuilly sur Seine, France: NATO AGARD, NATO AGARDograph no. 247, 1981).

to increase. Before entering the hold, the visibility for Runway 12 increased to 1200 RVR with a light setting of 5, so the crew requested the instrument landing system (ILS) approach to Runway 12 and briefed for that approach.

During radar vectors for the approach, the visibility for Runway 12 remained at 1200 RVR, while Runway 30 averaged 600 RVR. At 0541, FAB 6501 switched to tower frequency and was given the following information: wind 220° Magnetic (M) at 3 knots, altimeter setting 29.76, and 1200 RVR with a light setting of 5. Less than one minute later, FAB 6501 crossed the final approach fix (Devon beacon) established on the ILS glide path and localizer for Runway 12.

The first officer was flying the approach and briefed for a pilot-monitored approach (PMA). The generic industry PMA technique used by some companies is one where the first officer flies the aircraft on to the approach minimums while the captain monitors the instruments. Approaching minimums, the captain begins to look outside for the appropriate visual cues. At decision height, if the captain has the appropriate visual cues to land, he would take control, or have the first officer continue on instruments until the appearance of more visual cues and then take control, and complete the visual landing. When control is transferred, the first officer continues to monitor the flight instruments until touchdown. If visual references are lost at any time, the captain would command a missed approach, and the first officer would fly the missed approach procedure.

Both flight crew members of FAB 6501 had worked for another employer flying Boeing 737s with a PMA procedure similar to the generic industry PMA standard operating procedure (SOP). The flight crew used the PMA SOPs from their previous employer rather than the First Air PMA SOPs, as they felt they were more complete and were better suited to the conditions in which they were flying.

The First Air PMA SOP says that the captain shall monitor the flight instruments and ensure that the procedure is being flown as briefed. The first officer shall fly the aircraft and published approach as briefed, until the captain assumes control. At decision height, if the captain has sufficient visual references to land the aircraft, he shall announce, “minimums – my controls, landing.” The first officer will respond “your controls” and assume pilot-not-flying duties. When the captain has assumed control, the first officer shall continue to monitor the flight instruments until the aircraft has landed and reverse thrust has been initiated.

When FAB 6501 intercepted the final approach course, the autopilot was set in VOR/LOC mode. The First Air Boeing 737 *Operations Manual* stated that if glide slope signals were erratic, only LOC mode was to be used on the autopilot. This was the preferred method used by First Air flight crews to avoid excessive pitch movements by the autopilot when coupled to the glide path in AUTO APP mode. These movements could be

Autopilot Approach Modes
VOR/LOC mode is used to automatically intercept and track the selected radio course. Crosswind compensation occurs after the course is engaged. AUTO APP mode is used to automatically capture ILS localizer and glide slope. After glide path capture at 1500 feet RAD ALT or below, localizer sensitivity is reduced from 100% to 50% as altitude decreases to 100 feet. Glide path sensitivity is reduced to 0% as altitude decreases to 50 feet. This attenuation feature is incorporated to prevent the aircraft from making any large pitch or roll changes low to the ground. There is no localizer sensitivity attenuation while in VOR/LOC mode.

the result of obstacles interfering with the glide path, autopilot anomalies, or configuration changes requiring a lot of trim adjustment – lowering flaps and landing gear. During the approach, just prior to crossing the final approach fix, the aircraft configuration was changed, in about 30 seconds, from flaps 5 and landing gear up to flaps 30 and gear down.

While in VOR/LOC mode, the glide path was being followed in control wheel steering mode, where the first officer manually controlled the pitch of the aircraft through the autopilot to maintain the glide path profile. After crossing the final approach fix, with aircraft configured for landing, the first officer elected to leave the autopilot in VOR/LOC mode.

The aircraft was in clear air until approximately 500 feet above ground level (agl), when it entered the ground-based fog layer. The glow of the runway approach lighting was observed by both the load master, seated in the jump seat, and the captain. At minimums (200 feet agl) the captain saw the approach lighting strobes and commanded the first officer to continue. At approximately 65 feet agl, the captain observed the runway edge lighting, took control of the aircraft, disconnected the autopilot and reduced the rate of descent. The first officer continued to monitor the instruments and called out airspeeds and descent rates.

The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR). Both operated as expected and provided useable information.

The FDR data showed that the aircraft crossed the threshold at a height of approximately 45 feet at 129 KIAS (Vref +10), heading 120° M. Descending over the runway, manual control inputs resulted in the aircraft drifting slightly right of the runway centreline, with a maximum displacement of approximately 10 feet. At about 40 feet agl, the aircraft was turned to the left to regain the centreline; the maximum bank angle achieved was 16° left wing down during this manouevre before returning to a near wings level attitude. This would have placed the left wing tip 33 feet and left engine pod 31 feet above the runway surface. At 15 feet agl, the power was reduced to idle; the captain had difficulty seeing the runway edge lighting at that time. Approximately four seconds later, it became evident to the flight crew that the aircraft was going to touch down beside the runway. The first officer called for go-around thrust and started to advance the thrust levers. Recognizing the aircraft's low energy state and position relative to the runway, the captain immediately retarded the thrust levers, and the aircraft touched down with a vertical deceleration of 2.3*g*.

At touchdown the aircraft's heading was 117° M. The right main landing gear touched down first, approximately 8 feet off the left edge of the runway and 2700 feet from the threshold. The initial track of the main gear through the snow was approximately 109° M. Reverse thrust and a large input of right rudder were applied shortly after touchdown. The marks left by the aircraft through the snow were consistent with the aircraft sliding sideways, up to 23° nose-right of the aircraft's track. These corrective actions by the flight crew resulted in the aircraft regaining the runway after travelling 1600 feet beside it and crossing Taxiway A2. The aircraft was brought to a stop on the runway centreline, 4550 feet from the threshold (see Figure 1). At the time of touchdown, the RVR was 1200 for Runway 12 and 800 for Runway 30.

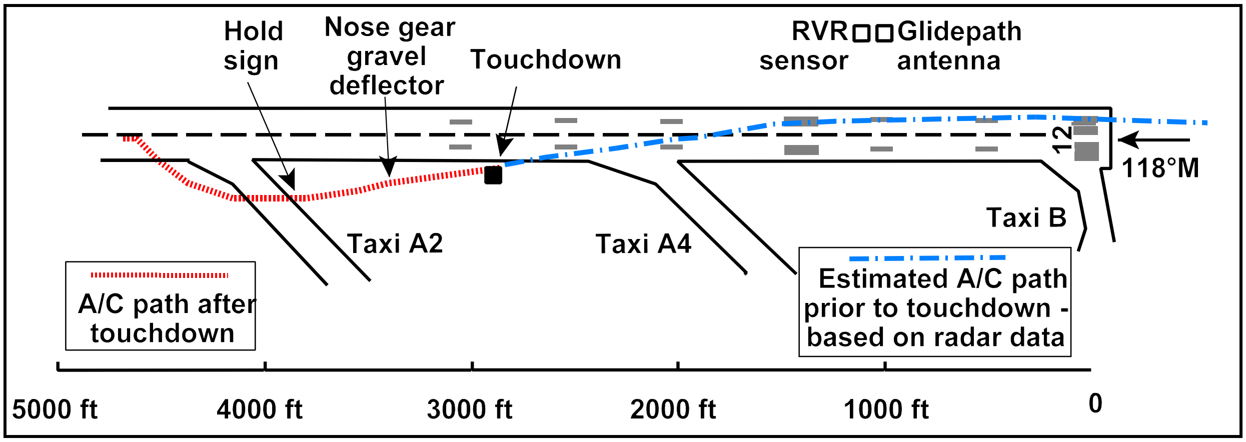

Figure 1. Overhead view of Runway 12 at CYEG

During the aircraft's rollout beside the runway, the nose gear gravel deflector detached, damaging the electrical/avionics bay doors and structure directly behind it. In addition, there were numerous areas of puncture and denting damage to the underside fuselage skin surface and a large puncture on the keel beam area of the belly just aft of the main gear. The left engine contacted and partially ingested a HOLD sign located on the west side of Taxiway A2 and both engines ingested grass and dirt.

Aircraft rescue and firefighting (ARFF) personnel responded to the crash alarm from the tower and began making their way out to the aircraft at 0545. Visibility was described as anywhere from 100 to 300 feet, and their progress was impeded by the fog. The first ARFF vehicle arrived at the aircraft with the assistance of forward-looking infrared camera equipment, four minutes after the alarm was activated.

Runway 12 at CYEG is 10 200 feet long and equipped with the required lighting and markings for a Category 1 ILS runway, in accordance with Transport Canada TP 312E. The lighting system comprised white parallel runway edge lights, green threshold lights, red runway end lights, 1000 feet of sequenced flashing approach lights, and 1400 feet of white runway alignment indicator lights. This system was described as a simplified short approach lighting system with runway alignment lights (SSALR). It has five intensity settings.

Appendix A shows the differences between Category l and Category ll approaches and runway lighting systems. The only difference in the approach phase is the lower decision height for a Category ll approach. The main difference between the two is the approach and runway lighting requirements. It is clear from Appendix A that the lighting required for a Category ll approach is far superior to that required for a Category l approach. In particular, the approach lighting is massive and two-dimensional, allowing a pilot to more easily keep the aircraft wings level and clearly determine the centre of the approach path. As well, the first 3000 feet of the runway has a two-dimensional lighting system, with centreline and touchdown zone lighting in addition to the runway edge lights.

Canadian regulations permit Category l approaches to be conducted in weather conditions equivalent to or lower than Category ll landing minima. However, the air and ground equipment requirements, procedural requirements and crew requirements for conducting Category ll approaches are much more stringent.[8]

To the flight crew, after the aircraft stopped on the runway, the runway edge lighting did not appear bright enough for light setting 5. The light setting for a given runway is not recorded; however, information gathered during the investigation supports the conclusion that most probably the lights were on setting 5 for the approach and landing, and for a time after the occurrence to facilitate ARFF and airport vehicle movements to and from the aircraft.

Maintaining airport lighting brightness or conspicuousness is achieved by ensuring that the power generating equipment is producing the necessary power, that the circuit that delivers the power is in good condition, and that the lights are operable and clear of contamination. The runway lighting system is maintained by the Edmonton Regional Airport Authority (ERAA). Inspection records showed that the visual aid facilities were being monitored and maintained on a scheduled basis. These facilities included the actual lights and support structures, as well as lighting circuits and power generation equipment. A Transport Canada inspection of the approach and runway edge lighting for Runway 12 was completed on 15 January 2004, and the lighting conformed to the applicable standards in TP 312; however, there were no Transport Canada standards with which to compare the lighting circuit and power generation measurements. The investigation used *Federal Aviation Administration Advisory Circular 150/5340–26* to obtain examples of suggested maintenance practices and equipment tolerances for comparison.

An independent audit organized by the ERAA determined that the visual aid facilities were being maintained to industry standards. A TSB Engineering Branch test, performed on 15 June 2004, showed that the runway edge lights for Runway 12 were producing the required lighting intensity for light setting 5. Two runway edge lights tested were not aligned to within ½° of the runway direction as stipulated in TP 312. The effect on overall luminosity caused by this misalignment is unknown.

Post-occurrence inspection of the glide path and localizer antennas and equipment rooms indicated that all systems were operational with no faults found or indicated at any time during the approach or after touchdown. TSB investigators viewed the antennas and equipment rooms approximately two hours after the occurrence and no anomalies were noted.

On 27 February 2004, NAV CANADA conducted a flight inspection for the ILS Runway 12 at CYEG. The report concluded that the ILS (both localizer and glide path) was within tolerances as described by International Civil Aviation Organization standards. The maximum localizer deviation recorded at minimums (200 feet agl, 0.55 nautical miles from the threshold) was 7uA (micro amps), which equated to 21.3 feet to the left of centreline.

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8 Details on Category ll requirements are contained in *Canadian Aviation Regulations*, Subsection 602.128, Landing Minima, and the *Manual of All Weather Operations* (categories ll and lll) (TP 1490E).

Analysis

All aircraft systems, airport equipment and NAV CANADA facilities were operating as designed and fully functional at the time of the occurrence. The analysis will focus on reasons why visual references were lost at a critical time in the approach and the risks associated with conducting approaches in 1200 RVR visibility to a Category I runway.

The exact position of the aircraft relative to the runway centreline after crossing the threshold could not be determined. The derived position from the TSB Engineering Laboratory report indicates that the aircraft was displaced to the right of centreline to some degree, most likely as a result of pilot input after autopilot disconnect. The use of the VOR/LOC mode for the approach did not have an effect on the stability of the approach or the eventual location of the aircraft while over the runway. However, the VOR/LOC mode does not have some of the safety enhancements that the autopilot can provide in AUTO APP mode while the aircraft is operated in close proximity to the ground.

The captain visually acquired the runway environment and continued the approach. Initially, the high intensity strobes of the approach lighting were observed, prior to and at minimums, followed by the runway edge lighting. During the flare, the aircraft travelled toward an area of decreasing visibility with only runway edge lights for reference, and the lights did not provide enough visual guidance. Another indication of the quality of the visual reference was the large 16° left bank angle established by the captain while the aircraft was only 40 feet above the runway and the hard 2.3*g* touchdown.

The flight crew found the runway lights hard to see and dimly lit after the aircraft was brought to a stop. Given that the power generation equipment and the lighting circuit met industry and manufacturer standards, it is most likely that the runway edge lights and the approach lights were producing the required amount of luminance. The dimness observed by the flight crew could be attributed to the thickness of the fog, which the ARFF personnel responding to the scene described as giving a visibility of only 100 to 300 feet.

The crew members had been awake for almost all of the 24 hours before the time of the occurrence, and these long periods of wakefulness could have produced some degradation in their performance. It could not be determined to what degree fatigue played a role in the occurrence; however, degradation of a commercial flight crew's performance is a significant risk to the safety of flight operations.

The First Air *Operations Manual*, Section 4.1.3.3, allowed the flight crew to reset their duty day if they were provided an opportunity to obtain not less than eight consecutive hours of sleep. This policy did not address the requirement that the flight crew get sufficient restorative sleep. Moreover, it did not address the requirement that the flight crew get the amount of sleep needed to shift circadian rhythms enough to allow effective performance during a night shift. Transport Canada regulations concerning flight duty time limitations and rest periods do not address these requirements for effective performance.

The crew members did not use the First Air SOP for the PMA approach. However, they did use a SOP that they were both familiar with, and crew coordination was maintained throughout the approach. The non-adherence to their company's SOPs could not be shown as contributing to the incident. When the unexpected runway excursion occurred, the first officer reacted instinctively, calling for a go-around and to start to advance the thrust levers, contrary to the First Air SOPs. This breakdown in crew coordination did not contribute to the incident when the captain, who had control of the aircraft, promptly retarded the thrust levers.

The following TSB Engineering Branch reports were completed.

LP 026/2004 – FDR/CVR Analysis
LP 043/2004 – Autopilot/Navigation Instruments
LP 054/2004 – Runway Edge Lighting

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

Finding as to Causes and Contributing Factors

1. With deteriorating visibility and only runway edge lighting for guidance, the captain was unable to manoeuvre the aircraft to stay within the confines of the runway.

Findings as to Risk

1. Canadian regulations permit Category I approaches to be conducted in weather conditions equivalent to or lower than Category II landing minima without the benefit of the operating requirements applicable to Category II approaches – in this occurrence, the lack of adequate runway lighting.

2. The approach was conducted in the VOR/LOC mode rather than the AUTO/APP mode, which disabled the desensitizing feature of the autopilot while tracking the localizer.

3. Neither the *Canadian Aviation Regulations* nor the First Air *Operations Manual* provides sufficient defences concerning the scheduling of crew duty periods so that extended periods of wakefulness, lack of restorative sleep and rapid changes in crew shift times do not unduly affect crew performance.

Other Finding

1. The flight crew members were not using the First Air SOP for PMA approaches.

Safety Action Taken

Transport Canada

In the past, the TSB has identified the safety deficiencies associated with conducting approaches in low visibilities. The TSB investigated a landing accident in Fredericton, where the weather at the time of the accident was as follows: vertical visibility 100 feet obscured, horizontal visibility ⅛ mile in fog, and runway visual range 1200 feet. On 20 May 1999, the TSB issued report A97H0011. The following is an excerpt from that report:

As demonstrated by this accident, however, Canadian regulations permit Category I approaches to be conducted in weather conditions equivalent to or lower than Category II landing minima without the benefit of the operating requirements applicable to Category II approaches. Therefore, to reduce the risk of accidents in poor weather during the approach and landing phases of flight, the Board recommends that:

The Department of Transport reassess Category I approach and landing criteria (re-aligning weather minima with operating requirements) to ensure a level of safety consistent with Category II criteria.

A99–05

[See Appendix A to this report for differences between Category I and category II approaches.]

Changes to the *Canadian Aviation Regulations*, as proposed by Transport Canada, to improve the safety of runway approaches in poor visibility, were published in the *Canada Gazette*, Part l, on 20 November 2004, with a 30-day public comment period. After consideration of the comments, the regulations will be finalized and published in the *Canada Gazette*, Part ll. The regulations will help harmonize Canadian regulations with international standards and will respond to recommendations from the TSB.

On 18 May 2004, the TSB issued Safety Information Letter (A040029) to Transport Canada, informing the department that an appropriate standard for ongoing preventative maintenance practices of airport visual aid facilities is not in place. Transport Canada responded to the information letter on 06 July 2004, stating that the current TP 312 standard provides sufficient direction to airport operators on maintenance standards.

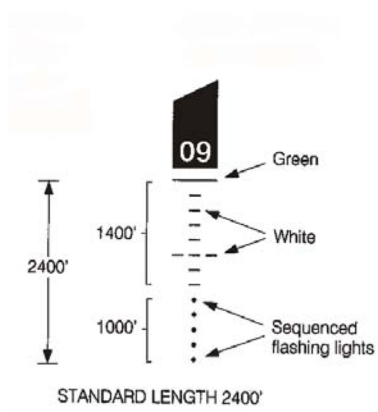
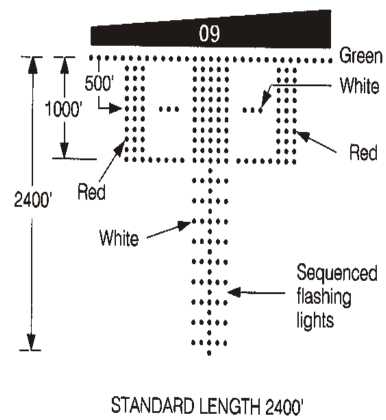
Bradley Air Services Ltd. (First Air)

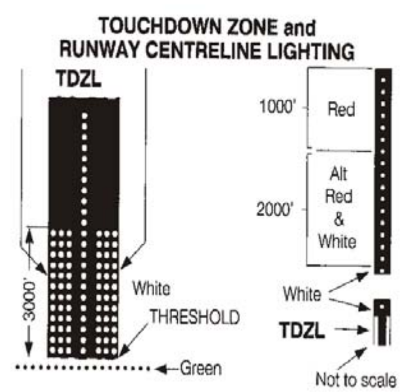
First Air has changed the schedule for the mining charter, and it is now conducted during the day, eliminating the requirement for flight crews to switch from day flying to night flying within the schedule.

First Air has promulgated changes to the low visibility SOPs and PMA SOPs for B–737 aircraft operations. Within these changes is the requirement that the autopilot, if it is to be engaged below decision height, must be in AUTO/APP mode.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 17 May 2005.

Appendix A – Differences Between Category I and Category II Approaches

<table>
<tr><th></th><th>Category I</th><th>Category II</th></tr>
<tr><td>Visibility</td><td>1200 RVR A, 600 RVR B</td><td>1200 RVR A, 600 RVR B</td></tr>
<tr><td>Decision Height</td><td>≥200'</td><td>≥ 100'</td></tr>
<tr><td>Lighting</td><td>Simplified Short Approach Lighting System With Runway Alignment Indicator Lights (SSALR):

</td><td>Approach Lighting System – High Intensity (ALSF–2):



</td></tr>
<tr><td>Equipment</td><td>As per CAR 605.18</td><td>As stated in the aircraft Minimum Equipment List and as approved by Transport Canada in addition to the items listed in CAR 605.18. The Manual of All Weather Operations (TP 1490) and the authority to conduct CAT II/III approaches in CAR 705.38</td></tr>
<tr><td>Training</td><td>A rating shall be issued upon completion of the rating requirements as stated in CAR 401.46.</td><td></td></tr>
</table>