Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A05C0153

LOSS OF SEPARATION

NAV CANADA
EDMONTON AREA CONTROL CENTRE,
NUNAVUT SECTOR
HALL BEACH, NUNAVUT, 135 nm NW
09 AUGUST 2005

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

Loss of Separation

NAV CANADA
Edmonton Area Control Centre, Nunavut Sector
Hall Beach, Nunavut, 135 nm NW
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Report Number A05C0153

Summary

Lufthansa Flight 492, a Boeing 747-400 with 19 crew and 364 passengers, en route from Frankfurt, Germany, to Vancouver, British Columbia, was at flight level 340 on a converging track with Air Canada Flight 015, an Airbus A340-500 with 8 crew and 204 passengers, en route from Toronto, Ontario, to Hong Kong, also at flight level 340. The two aircraft crossed tracks at about 1114 mountain daylight time, with a spacing of 10 minutes between the aircraft in an area where the minimum separation for aircraft on crossing tracks at the same altitude was 15 minutes.

Ce rapport est également disponible en français.

Other Factual Information

General

Although weather reports were not available for the vicinity of the route cross point, satellite imagery indicated that both flights would have been operating in clear skies with good visibility at the time of the occurrence.

All the air traffic controllers involved in this occurrence were licensed and qualified as required by applicable regulations. The occurrence took place within the Nunavut (NV)[1] sector of the North High specialty of the Edmonton Area Control Centre (ACC), during the period 0544 to 1134 mountain daylight time.[2] The airspace involved was controlled Class A airspace in the northern control area (NCA).

At the beginning of the occurrence period, NV sector was combined with Polar (PR) and Franklin (FN) sectors, and was operated by one air traffic controller. At the end of the period, NV and PR sectors remained combined, while FN sector had been transferred to another controller. NV, PR, and FN sectors do not have radar available to monitor aircraft, and procedural separation between aircraft is maintained by controllers assigning specific routes, altitudes, and speeds to aircraft.

The northern airspace display system (NADS) situational display (NSiT) is used by North High controllers to predict conflicts between aircraft based on the flight progress information entered into the system by the controllers. NSiT provides a graphical display of airspace, aircraft positions, and routing, but does not operate as a real-time system. Confirmation of aircraft separation is provided by flight crews making periodic position reports and by controllers updating the NSiT with that position report information.

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1 See Glossary at Appendix D for all abbreviations and acronyms..

2 All times are mountain daylight time (Coordinated Universal Time minus six hours) unless otherwise noted.

Flight Plan Setup and Activation

Figure 1. NSiT flight plan window at 0544, with fixes field selected (times shown are Coordinated Universal Time)

Flight plan information sent to the ACC is first received by the air traffic operations specialists section, where it is reviewed for proper format, and then distributed electronically to the appropriate sectors for set up in the NSiT by the sector controller. When the NSiT receives the flight plan, the route field is automatically populated with the route information applicable to the ACC. Flight plans must be prepared for operational use by controllers doing a manual setup. The flight plan setup requires that aircraft altitude, speed, fixes, and an estimated time of arrival (ETA) at the entry point be entered into associated fields in the flight plan window on the NSiT (see Figure 1).

The route field gives the controller a reference to the aircraft's flight planned route as filed by the operator, but it is not used by the NSiT for calculations. Instead, fixes that define the route are used by the NSiT for calculations. The fixes are entered either by typing data directly into the fixes field, or by entering a fix reference number (FRN) into the FRN field. Each FRN is a three-digit number associated with pre-determined fixes that define a specific route. When an FRN is entered, the fixes field is automatically populated with the pre-determined fixes associated with that FRN. The NSiT does not automatically verify that the fixes in the fixes field match the route in the route field (route conformance); instead, the controller must manually verify that they match.

On the day of the occurrence, the setup of pending flight plans was done by the controller on the night shift during periods of lower workload. Controller setup practices varied, with controllers sometimes entering fixes using an FRN and sometimes entering the fixes directly into the fixes field. Procedures did not require the controller setting up the flight plan to crosscheck the data entry for errors, and there was no crosscheck procedure specified.

The setup flight plan is later activated when the controller receives an ETA for the sector entry point from the adjacent sector. The North High specialty operations manual requires that the controller who activates a flight plan "check the first printed strip with the estimate-copying strip to ensure data accuracy," but does not specify any procedure for doing so. To compensate for the lack of a specified procedure, individual controllers had developed various personal practices to check setup accuracy when activating flight plans.

Flight Progress Strips

Although the NSiT is the controllers' primary tool, paper flight progress strips are used for recording position reports and also as a backup control system. The flight progress strips depict the aircraft route in the centre bottom box, reading from left to right (see Figure 2). This information derives from the route field in the NSiT flight plan. The strips also depict the fixes used by the NSiT on the centre of the strip, reading from right to left for westbound flights such as Lufthansa Flight 492 (DLH492). This information derives from the fixes field in the NSiT flight plan.

Figure 2. Flight progress strip printed to FN sector at 1055, used to receive 90 west position report at 1127 (times on strip are UTC)

The route box displays a mixture of latitude/longitude, alphanumeric fix designators such as MEDPA, and track designators to describe the route, while the fix boxes use only latitude/longitude or alphanumeric fix designators. When a controller receives a position report, the information is written on the strip, and when time permits, the controller updates the NSiT and prints a new strip with the updated information.

Communications

Depending on the location of the aircraft, Edmonton controllers receive position reports in one of two ways. The first is via very high frequency (VHF) remote transceivers that provide direct controller–pilot communication. These transceivers are limited in number and coverage. The second is for flight crews to communicate with Arctic Radio flight service specialists in North Bay via either VHF or high frequency radio. The information is then relayed to the Edmonton controllers via telephone hotlines. Using the North Bay communication relay can introduce a substantial delay. Edmonton controllers sometimes receive aircraft position reports more than 10 minutes after an aircraft has passed a reporting point.[3] The NSiT provides a warning message to the controller if a position report has not been received within a specified time after the aircraft was predicted to pass the reporting point. Flight crews occasionally use aircraft satellite telephones to contact controllers when normal radio communications are not possible. Other means of communication such as controller–pilot datalink communications (CPDLC) and automatic dependent surveillance (ADS) waypoint position reporting (WPR) were not in operation within the Edmonton ACC at the time of the occurrence. NAV CANADA is planning to implement ADS and CPDLC, and ADS WPR is expected to be operational by January 2007.

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3 See TSB Report A01C0115 regarding the effect of communications delays.

Position Reports

At specified reporting points, flight crews are required to make position reports to controllers. The North High speciality receives two types of position reports. The first type is a standard position report, which specifies aircraft identification, position, time over reporting point, flight level (FL), name of next reporting point and ETA over that point, and name only of the subsequent reporting point along the route of flight. In the standard position report, latitude and longitude are used to identify a point if there is no reporting point designator. The second type is an abbreviated position report, which is applicable for flights operating within the NCA structured track system. It identifies reporting points either by a reporting point designator or by the code name of the NCA track and the reporting point longitude. For example, the same position would be reported as 70° N, 90° W (70N 90W) in a standard position report and as Hotel 90 in an abbreviated position report.

Sequence of Events

At 0346, the Edmonton ACC received a flight plan from Lufthansa dispatch for DLH492. ACC air traffic operations specialists processed this flight plan and, at 0357, sent it electronically to the NV NSiT. At 0447, Controller A[4] did the NSiT setup on the DLH492 flight plan, correctly entering 322[5] into the FRN field.

At 0440, the ACC received a revised flight plan from Lufthansa dispatch for DLH492. The only significant change in the flight plan was the addition of STS/HOSP to the remarks section of the flight plan, indicating that the flight was a hospital aircraft.[6] When the air traffic operations specialists processed this flight plan, they understood STS/HOSP to mean that the flight was a medical evacuation flight. Consequently, the suffix "M" was added, and the aircraft identification became DLH492M, signifying a medevac flight.[7] A revised flight plan for DLH492M was sent electronically to the NV NSiT at 0543, replacing the original DLH492 flight plan, which NSiT marked as cancelled.

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4 Because there were a number of controllers working in the same area, they are identified as Controller A, Controller B, and Controller C.

5 The flight planned route of DLH492 was MEDPA NCAH 7130N08000W LAT50 6830N09000W NCAN YQU. The fixes MEDPA, 7230N 70W, 7130N 80W, 6830N 90W, SEDAG, NADEB, LIBUG correspond to this route, and were associated with FRN 322 (see Appendix B).

6 DLH492 did not have any patients on board, but did have a patient transport unit installed for a patient traveling to Germany on the return flight. Lufthansa dispatch had added the STS/HOSP remark to the flight plan to ensure that DLH492 arrived in Vancouver on time to avoid delaying the return flight.

7 An international flight with a medevac call sign was considered very unusual by all the controllers involved in the occurrence.

At 0543, Controller A acknowledged the cancellation and manually deleted the original DLH492 flight plan. At 0544, Controller A did the setup on the revised DLH492M flight plan, incorrectly entering 324[8] in the FRN field instead of 322. Although the route field information remained unchanged, the fixes field was automatically populated with the fixes associated with the incorrect FRN 324. A flight progress strip for DLH492M was then printed and slotted into the pending flight plan bay.

At 0601, Controller A handed over the NV sector to another controller who was not involved in the occurrence. At 0858, Controller B took over the NV sector, which was still combined with PR and FN sectors. At 0930, the FN sector was transferred to another controller at an adjacent console.

At 0936, Controller B received an ETA for DLH492 at MEDPA from the Reykjavik ACC in Iceland. During this communication, Controller B queried Reykjavik about the "M" call sign suffix. Reykjavik advised Controller B that the flight had been using the call sign DLH492, without an "M." At 0946, Controller B activated the NSiT flight plan for DLH492M, entering the ETA at MEDPA, altitude, and speed into the flight plan window, and leaving the call sign DLH492M unchanged. During the activation, Controller B used the NSiT conflict probe function to check for conflicts with other aircraft; no conflicts were identified. Some of the fixes on the flight progress strip used by Controller B differed from the route described on the bottom of the strip, but the controller did not detect the differences. At 0959, Controller B handed over the NV sector to Controller C.

At 1025, Controller C received via Arctic Radio an abbreviated position report from DLH492 at MEDPA at FL 340. The controller instructed Arctic Radio to query the flight regarding the "M" call sign suffix.

At 1029, Controller C did a conflict probe on Air Canada Flight 015 (ACA015), and no conflicts were identified.[9]

At 1031, Controller C received via Arctic Radio an abbreviated position report from DLH492 at 70° west longitude. The position report included the information that the aircraft call sign was DLH492 rather than DLH492M. The next position in the position report (November 90) differed from the next position on the flight progress strip (70N 90W), but Controller C did not detect the difference. At 1033, the controller changed the aircraft identifier from DLH492M to DLH492, and probed the flight plan for conflicts; no conflicts were identified.

At 1034, Controller C assessed a request for ACA015 to climb from FL 330 to FL 340. The controller displayed the DLH492 route on the NSiT, and selected a route intercept feature for DLH492 and ACA015. This NSiT feature projects a straight line from the currently calculated position of the aircraft and does not take into account track changes at waypoints. The route

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8 The fixes associated with FRN 324 were MEDPA, 7230N 70W, 7130N 80W, 70N 90W, LENOT, GABRO, LIBUG (see Appendix B).

9 The flight planned route of ACA015 was 60N 81W, 65N 83W, 70N 88W, 75N 95W (see Appendix B).

intercept result indicated that the first of the two flights would reach the route cross point at 1108, and the second aircraft would reach the cross point 24 minutes later with more than 100 miles of spacing between the aircraft. At 1035, Controller C cleared ACA015 to climb to FL 340. At 1037, ACA015 reported level at FL 340, and the controller entered the new altitude into the NSiT.

At 1043, Controller C probed the ACA015 flight plan for potential conflicts at FL 340 by temporarily changing the 60 north arrival time from 1011 to 1008. The conflict probe produced a cross alarm for ACA015 and DLH492 at 70°18′ N, 88°19′ W (7018N 8819W), indicating that a conflict would occur if ACA015 reached its next reporting point earlier than expected. Because this cross alarm was based on hypothetical information, no action was taken. At 1044, Controller C probed DLH492 for conflicts at FL 360 in preparation for a climb to a higher altitude; no conflicts were identified.

At 1053, Controller C received via Arctic Radio an abbreviated position report from DLH492 at 80 west. The next positions in the position report (November 90 and SEDAG) differed from the next positions on the strip (70N 90W and LENOT), but Controller C did not detect the differences. Immediately after receiving the position report, Controller C instructed Arctic Radio to query DLH492 about when the flight would be able to climb to FL 350 and FL 360, and then updated the NSiT with the 80 west arrival time for DLH492.

At 1054, Arctic Radio reported to Controller C that DLH492 would be able to climb to FL 350 in 20 minutes and to FL 360 in 40 minutes. At 1055, Controller C entered into the NSiT flight plan remarks field the times at which DLH492 would be able to climb to higher altitudes. At the same time, the controller also probed the DLH492 flight plan for conflicts at FL 340; no conflicts were identified. Controller C then sent a strip for DLH492 to the printer at the FN sector and set up the handoff of the flight to the FN sector. Controller B, now working in the FN sector, accepted control of DLH492 at 1104.

At 1127, Controller B received via Arctic Radio an abbreviated position report from DLH492 at 90 west. The reported position and next positions in the position report (November 90, SEDAG, and NADEB) differed from the reported position and next positions on the strip (70N 90W, LENOT, and GABRO), but the controller did not detect the differences. The controller noted that the 1124 arrival time at 90 west was substantially later than the expected arrival time of 1116 and instructed Arctic Radio to confirm the time with the flight crew.

Controller B then entered 1124 into the NSiT for the 70N 90W arrival time. The DLH492 flight plan window opened, depicting a conflict between DLH492 and ACA015 at position 7018N 8819W. The NSiT also depicted the two aircraft tracks in red on the main display, showing the conflict between DLH492 and ACA015. At 1129, the controller cancelled the 70N 90W arrival time entry; the investigation did not determine why this was done.

At 1132, Controller B received via Arctic Radio confirmation that DLH492 had passed November 90 at 1124. During this communication, the controller realized that there was a problem with the fixes in the DLH492 NSiT flight plan. The controller then reconfigured the NSiT to depict the DLH492 fixes and track, NCA track Hotel, and NCA track November on the display. Controller B then revised the fixes in the DLH492 flight plan by entering the correct fixes directly into the fixes field of the flight plan window, and probed the corrected flight plan for conflicts; no conflicts were identified.

At 1134, the correct fixes for DLH492 were activated, and Controller B printed a new strip for DLH492 with the correct fixes. At 1136, Controller B handed over the FN sector to a replacement controller.

Route Cross Points and Times

The route of ACA015 crossed the NSiT FRN 324 route for DLH492 at 7018N 8819W; this is the route cross position at which NSiT conflict probes for ACA015 and DLH492 were based. In fact, the route of ACA015 crossed the actual route of DLH492 (FRN 322) at 6925N 8725W (see Appendix B). Calculations later determined that DLH492 passed this position at 1114 and that ACA015 passed this position 10 minutes later at 1124. The required separation, before and after the cross, was 15 minutes.

Area Control Centre Staffing

For an extended period before the occurrence, the Edmonton ACC, including the North High specialty, had experienced a shortage of available, qualified, and current controllers. Table 1 summarizes the extent of the staff shortage from May 2005 to the occurrence date.

	Entire ACC			North High Specialty		
	Available	**Required**	**Staffing Level (%)**	**Available**	**Required**	**Staffing Level (%)**
May 2005	159	194	82	28	34	82
June 2005	160	194	82	27	34	79
July 2005	161	194	83	27	34	79
09 August 2005				28	34	82

Table 1. Area Control Centre and North High speciality staffing levels

NAV CANADA had made a commitment to staff major operational facilities at 105 per cent of requirements; recruitment and training of new controllers is ongoing. However, other measures were needed to enable Edmonton ACC to continue operations with reduced staff levels until recruitment and training could bring staff levels to the corporate goal.

For example, when staffing is below 100 per cent, the North High speciality tactically changes its mode of operation, depending on time of day, traffic flows, and traffic levels. These changes include Air Traffic Flow Management techniques to manage the number of aircraft in a sector in order to manage controller workload.

Two other measures used are overtime and schedule changes to optimize employment of available controllers.

Hours of Work and Rest

Under the authority of the *Civil Air Navigation Services Commercialization Act*, NAV CANADA is given the right to plan and manage the provision of its air traffic control services, including hours of work, staff scheduling, and the use of overtime. The collective agreements between NAV CANADA and the Canadian Air Traffic Control Association (CATCA) set out the limits for controller hours of work and rest. These are not regulated by Transport Canada in the *Canadian Aviation Regulations* (CARs). However, controller duty time limits are also governed by the *Canada Labour Code* (CLC), which permits controllers to be scheduled for overtime up to a maximum of 384 regular and overtime hours of work in a 56-day period. The collective agreement specifies that controllers can be scheduled for up to 288 hours of regular shifts in a 56-day period, and permits rest periods of as little as eight hours between some shifts. This eight-hour period between shifts includes a controller's travel time to and from accommodation and time for personal hygiene and meals.

The collective agreement requires that NAV CANADA not schedule the start of a shift within 10 hours of the completion of the controller's previous shift, subject to the following exceptions:

- NAV CANADA may schedule a reduction in the minimum time off between shifts to not less than eight hours, no more than once during each employee's "work week."
- NAV CANADA may schedule a reduction in the minimum time off between shifts to not less than nine hours, no more than twice during each employee's "work week." Such reductions shall not occur consecutively.
- Where an employee's published schedule contains no reduction in time between shifts (as described above), employees, at their individual option, may elect to reduce time between shifts to less than 10 hours but not less than 8, once in a "work week."
- Notwithstanding the above, in no instance shall such reductions occur consecutively.

Overtime

To compensate for the staff shortage, available controllers were scheduled to work overtime shifts. Overtime was usually scheduled in full shifts, rather than short periods before or after regular shifts. Overtime was scheduled by first requesting volunteers to fill shifts. If an insufficient number of controllers volunteered, overtime shifts were involuntarily assigned within guidelines agreed to by local NAV CANADA management and CATCA union representatives.

During the period from 02 August 2004 to 03 July 2005, the average number of overtime hours worked per controller in a 56-day period was 58.1 hours in the ACC as a whole, and 60 hours in the North High specialty. During this period, the average amount of overtime worked per 56-day period was 66.5 hours for Controller A, 58.25 hours for Controller B, and 41.5 hours for Controller C.

During the 56-day period from 09 May to 03 July 2005, overtime worked by North High controllers ranged from a minimum of 24.75 hours to a maximum of 98.75 hours. In some cases, the overtime and normal shifts reached the CLC maximum permitted hours of work, 384 hours during a 56-day period, preventing the controller from being scheduled for additional overtime. During this period, the amount of overtime worked was 87.75 hours for Controller A, 62.5 hours for Controller B, and 87 hours for Controller C.

Table 2 summarizes the schedules of all three controllers during the 56-day period from 04 July to 28 August 2005. This period includes the occurrence date.

	Controller A			Controller B			Controller C		
	Hours	**Shifts**	**Days off**	**Hours**	**Shifts**	**Days off**	**Hours**	**Shifts**	**Days off**
Regular	296.12	35		288.30	35		287.87	34.0	
Overtime	74.75	9		83.25	10		11.25	1.2	
Totals	370.87	44	12	371.55	45	11	299.12	35.2	21

Table 2. Regular and overtime hours and shifts with days off for occurrence controllers between 04 July and 28 August 2005

Controller Scheduling

During 2004, NAV CANADA and CATCA agreed to conduct trials of modified shift schedules within the Edmonton ACC, to reduce the effect of staffing shortages. CATCA conducted a vote within each specialty of the ACC to permit the controllers to select the shift schedule option they preferred. In the North High specialty, the majority of controllers preferred a condensed schedule. In the condensed schedule, the shift begins progressively earlier each day, producing a counter-clockwise shift rotation (see Table 3). The rest period between the day shift and midnight shift is eight hours. At the time of the occurrence, most North High controllers, including Controllers B and C, were on a modified condensed schedule (see Table 4) with repeat days and a counter-clockwise shift rotation. The remaining North High controllers had medical or other reasons for which they were on other work schedules such as a block schedule; Controller A was on a block schedule of midnight shifts.

Shift	Start Time	End Time	Post-Shift Rest Period
Day 1 – Evening Shift	1415	2243	11 h 17 m
Day 2 – Swing Shift	1000	1828	11 h 32 m
Day 3 – Day Shift	0600	1428	8 h 00 m
Day 4 – Midnight Shift	2228 (day 3)	0656	Day off

Table 3. North High condensed schedule (counter-clockwise shift rotation)

Date	Controller		
	A	B	C
1 August	**2228 – 0643**	Off	0600 – 1428
2 August	**2228 – 0643**	Off	2228 – 0656
3 August	Off	1415 – 2243	2228 – 0656
4 August	2228 – 0656	1415 – 2243	Off
5 August	2228 – 0656	1000 – 1828	Off
6 August	2228 – 0643	0600 – 1428	**Sick Overtime**
7 August	2228 – 0643	0600 – 1428	1415 – 2243
8 August	2228 – 0656	2228 – 0656	1000 – 1828
9 August	2228 – 0656	**0600 – 1430**	0600 – 1428
10 August	**2228 – 0643**	Off	0600 – 1428
11 August	**2228 – 0643**	0600 – 1428	2228 – 0643
Occurrence date is shaded. Overtime shifts are shown in bold. Shifts starting at 2228 began the evening before date shown.			

Table 4. North High controllers' modified condensed schedule

Controller A started his shift at 2228 the evening before the occurrence. At the time the DLH492M flight plan was set up, he had been on duty for about 7¼ hours, and had been working at the NV sector for 29 minutes since his last break. During his shift, Controller A was working between 55 and 60 per cent of the time, with rest periods of more than 45 minutes.

Controller B started his shift at 0600. At the time the DLH492 flight plan was activated, he had been on duty about 3½ hours, and had been working at the NV sector for 37 minutes since his last break. Controller B was working a scheduled overtime shift on 09 August 2005. During his shift, Controller B was working about 50 per cent of the time, with rest periods of more than 45 minutes.

Controller C started his shift at 0600. At the time he received the DLH492 70W position report, he had been on duty about 4½ hours and had been working at the NV sector for 28 minutes since his last break (see Table 4). During his shift, Controller C was working about 50 per cent of the time, with rest periods of more than 45 minutes.

NAV CANADA Fatigue Management Program

NAV CANADA acknowledges that there will be some degree of fatigue in any operation that must run 24 hours per day, seven days per week. The company has an established fatigue management policy to reduce fatigue to an ALARA (as low as reasonably achievable) level so that related safety risks are effectively managed. The company manages the operational safety impact of fatigue by examining scheduling practices, educating staff about managing fatigue/alertness, and implementing fatigue countermeasures. Controllers are taught both preventive and operational strategies. The first can be used before a shift to reduce the adverse effects of fatigue, sleep loss, and circadian disruption. The later can be used during a shift to maintain alertness and performance levels.

All ACCs, including Edmonton, have countermeasures to mitigate the effects of fatigue. During their shifts, controllers have breaks, with exercise workout rooms and quiet rooms for naps readily available. Food and beverages are also readily available.

Normally Rested Person

A normally rested person is considered to be an average, healthy person, between 25 and 45 years old, who works a consistent day shift that starts between 0800 and 0900, and finishes between 1600 and 1700. A normally rested person is considered to be one who sleeps on average about 7½ to 8 hours per night usually between 2100 and 0600.

Human Performance and Fatigue

The human body functions optimally when it follows a predictable routine. Any change to the routine, including to the sleep–wake routine, requires time to adjust. During the adjustment period, the body functions at sub-optimal levels and continues to function at sub-optimal levels until the sleep–wake routine stabilizes.

Reversal of a person's sleep–wake routine, from sleeping at night to sleeping during the day, can result in cerebral hormone disruption with subsequent reductions in mental efficiency, and in psychomotor impairment, anxiety, depression, somatic complaints, daytime sleepiness, and fatigue.[10] Reversal of the sleep–wake routine is seldom fully successful.[11]

The human body takes longer to adjust to counter-clockwise shift rotations than to clockwise shift rotations.[12] The adjustment effects of a counter-clockwise shift rotation are the same as those listed above for a reversed sleep–wake schedule.

Many people experience difficulty sleeping during the afternoon and early night, usually around 2100, when the human body is predisposed to being awake.[13] Shift workers will often attempt to start sleeping during this period to be properly rested for an early morning shift;

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10 See for example: A. K. Pati, A. Chandrawanshi, and A. Reinberg, "Shift work: Consequences and Management," *Current Science,* 81.1 (2001): 32–52 and A. Kales and J. Kales, *Evaluation and Treatment of Insomnia* (New York: Oxford University Press, 1984).

11 J. M. Harrington, "Shift Work and Health: A Critical Review of the Literature on Working Hours," *Annals of the Academy of Medicine,* Singapore, 23.5 (1994), 699–705.

12 See for example: J. Aschoff, et al., "Re-entrainment of Circadian Rhythms After Phase Shifts of the Zeitgeber," *Chronobiologia,* 2 (1975), 23–78; K. E. Klein and H. M. Wegmann, "Significance of Circadian Rhythms in Aerospace Operations," NATO AGARDograph 247 (Neuilly sur Seine, France: NATAO AGARD, 1980); and D. I. Tepas and T. H. Monk "Work Schedules," *Handbook of Human Factors*, ed. G. Salvendy (New York: John Wiley & Sons, 1987), 819–843.

13 P. Lavie, "Ultrashort Sleep-waking Schedule III 'Gates' and 'Forbidden Zones' for Sleep," *Electroencephalography and Clinical Neurophysiology,* 63.5 (1986), 414–425.

however, the difficulty they have falling asleep results in less sleep than desired.[14] Shortening a person's total sleep time results in fatigue.[15, 16] Analysis of Controller C's sleep–wake history revealed short sleep periods before the 0600 day shift on 09 August.

Vigilance is the ability to stay attentive in order to perceive and react to stimuli, and is exercised constantly by air traffic controllers in their work. Vigilance is only one aspect of human performance that is negatively affected by fatigue. It is more difficult for fatigued individuals to maintain vigilance because they may not perceive important information, or they may become distracted by erroneous or extraneous information. As a result, accurate detection of problems decreases if the speed with which a task must be performed is held constant. In other words, if fatigued individuals must complete a task requiring them to perceive and react to relevant information, and are given the same time to complete the task as when they are rested, they will make more errors than when they are rested.

Controller schedules were analyzed, in part, using the Fatigue Avoidance Scheduling Tool (FAST).[17] FAST is a software decision aid designed to assess and forecast performance changes induced by sleep restriction and time of day. No planning software, including FAST, can predict fatigue or fatigue-induced errors in all cases or for all individuals. The tool can only forecast the effects of sleep and circadian rhythms on performance and cannot account for other factors that alter performance such as training, experience, stress, illness, or any of a variety of variables besides fatigue that are known to affect performance. Fatigue can be the result of factors other than restricted sleep or circadian disruption. For example, fatigue can result from sleep disorders, excessive workload, medications, chronic fatigue syndrome, exercise, temperature, or infection. These factors are not currently considered in FAST predictions. Furthermore, FAST does not take into account fatigue countermeasures employed by NAV CANADA such as naps, breaks, and physical activity.

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14 P. Cabon, et al., "Fatigue of Short-haul Flight Aircrews in Civil Aviation: Effects of Work Schedules" *Shift Work in the 21st Century: Challenges for Research and Practice,* eds. S. Hornberger, et al. (Frankfurt: Peter Lang, 2000), 79–85.

15 A. M. Anch, et al., *Sleep: A Scientific Perspective* (New Jersey: Prentice-Hall, 1988).

16 P. Tucker, et al., "Shift Length as a Determinant of Retrospective On-shift Alertness," *Scandinavian Journal of Work, Environment and Health,* 24 (Suppl. 3) (1998), 49–54.

17 Fatigue Avoidance Scheduling Tool (FAST) is a product of U.S. Air Force SBIR Contract F41624-99-C-6041 awarded to NTI Inc., with additional funding from the U.S. Department of Transportation Agreement No. DTRS56-01-T-004 awarded to Science Application International Corporation (SAIC). FAST is distributed by Nova Scientific Corporation, www.novasci.com/index_files/Page420.htm.

Even if fatigue is not present, night shift performance is generally poorer than day shift performance. This appears to be due to a circadian rhythm that biologically predisposes humans to be more effective during the day.[18]

Air traffic controllers typically demonstrate high job performance motivation. Performance motivation is also negatively affected by fatigue.[19] Not only are fatigued individuals less motivated to perform well, this decrease in motivation is insidious because it occurs without the individual's awareness. Decreased motivation can result in individuals unintentionally placing more reliance on established processes to detect errors rather than depending on their own vigilance.

Other Occurrences and Reports

Controller fatigue is an issue of longstanding concern. The TSB has investigated other incidents in which controller fatigue was found to have contributed to the occurrence.[20]

In 1990, the Canadian Aviation Safety Board issued a *Report on a Special Investigation into Air Traffic Control Services in Canada* (90-SP001). The report concluded that "The most serious problem facing the ATC community today is the shortage of qualified controllers in most of the ACCs." The report also stated that "A controller's shift work cycle is highly disruptive to natural body rhythms." The report included the following recommendations:

> The Department of Transport make and enforce further restrictions on . . . the minimum number of rest hours between shifts (CASB 90-37).
>
> The Department of Transport, in cooperation with the Department of Health and Welfare and international authorities, initiate a program of research into the adverse effects of circadian disrhythmia and sleep deficits on air traffic controllers' job performance (CASB 90-38).

In October 1996, a report prepared for the Transportation Development Centre, *Impact of Shift Work and Overtime on Air Traffic Controllers* (TP 12816E), concluded that cognitive performance was significantly reduced toward the end of counter-clockwise shift rotation cycles and that circadian rhythm and a significant sleep debt play a major role in reduced cognitive performance during midnight shifts. The report made a number of recommendations to mitigate the negative effects of shift work and fatigue.

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18 See for example: T. H. Monk, S. Folkard, and A. I. Wedderburn, "Maintaining Safety and High Performance on Shift Work," *Applied Ergonomics,* 27.1 (1996), 17–23.

19 L. C. Johnson, et al., eds. *Biological Rhythms, Sleep, and Shift Work* (New York: Spectrum Publishing, 1981).

20 See TSB reports A96O0196, A97A0166, and A99H0001.

The TSB listed "adequacy of work/rest schedules" as a significant air safety issue in its Annual Report to Parliament in 1998 and again in 1999.

In July 1999, the TSB issued a safety information letter to Transport Canada and NAV CANADA regarding air traffic controller fatigue. In response to the letter, Transport Canada mentioned the establishment of a special committee of Transport Canada, CATCA, and NAV CANADA to review fatigue issues, and the compilation of a compendium of research literature on fatigue among air traffic controllers. Transport Canada's response also indicated that consideration was being given to adding other aviation disciplines to the legislation governing duty limits for aircraft crew members.

In July 2000, a report prepared for the Transportation Development Centre, *Fatigue in Air Traffic Controllers: Literature Review* (TP 13457) summarized the available research literature and concluded in part that "redesigning schedules to allow longer rest periods, 10 to 13 hours instead of 8 hours on the quick turnaround, would reduce sleep loss and improve performance."

In 2000, a Tripartite Working Group (TWG) comprised of representatives from Transport Canada, CATCA, and NAV CANADA was formed to study the issue of fatigue and air traffic control services. The TWG emphasized the importance of accepting fatigue management as a shared responsibility between the employer, individual employees, and the bargaining agent. In its final report, *Report to the Tripartite Steering Committee on ATC Fatigue* (TP 13742E), the TWG proposed the following four high-level recommendations:

- the adoption of a holistic approach to fatigue management by all parties represented in the TWG and Tripartite Steering Committee;
- the introduction by NAV CANADA of a formal fatigue management program;
- the integration of NAV CANADA's Fatigue Management Program into the corporation's Safety Management System to proactively, effectively, and transparently manage safety risks related to fatigue; and
- the development of a performance-based measurement system to evaluate the effectiveness of fatigue management within NAV CANADA.

Analysis

Area Control Centre Staffing

The Edmonton ACC and the North High specialty were operating with about 83 per cent of the required control staff, which was substantially less than NAV CANADA's corporate goal of 105 per cent staffing. To compensate for staff shortages, tactical adjustments to ACC operations were made, including using Air Traffic Flow Management techniques. Schedule changes optimized the employment of available controllers. These included implementing condensed schedules and assigning overtime, in accordance with the collective agreement and the CLC.

Controller Schedules and Fatigue

The work schedules of the controllers involved were analyzed to determine whether fatigue played a role in this occurrence. The level of fatigue experienced by each controller will be discussed and its effect on work performance compared to the work performance expected of a normally rested person.

Controller A had been on a block schedule of midnight shifts and had had one day off six days before the occurrence (see Table 4). Although he had likely developed a stable sleep–wake routine that would have allowed his body to adjust as well as it could to a nocturnal routine, he most likely was more fatigued, although not severely, than a normally rested person.

Controller B worked a counter-clockwise shift rotation during the days leading to the occurrence. After the last day shift on 07 August, Controller B had eight hours of rest and returned for a midnight shift from 2228 to 0656, then had 23 hours off and returned to work on the occurrence day at 0600 (see Table 4). Because of the counter-clockwise shift rotation and limited post-midnight shift recovery time, Controller B was most likely significantly more fatigued than a normally rested person on the day of the occurrence with performance impaired accordingly.

Controller C also worked a counter-clockwise shift rotation during the days leading to the occurrence day. Because of the counter-clockwise shift schedule and a short sleep period before the occurrence shift, Controller C was most likely significantly more fatigued than a normally rested person on the day of the occurrence, and his performance was most likely impaired.

The FAST (Fatigue Avoidance Scheduling Tool) software analysis of controller schedules revealed that the counter-clockwise shift rotation employed within the North High specialty can result in significant levels of fatigue and poor performance. FAST predicted that the short rest periods between the day shift and the midnight shift can result in effectiveness estimates as low as 68 per cent (see Appendix C).

All three controllers most likely suffered from some decreased ability to maintain vigilance because of fatigue, potentially resulting in missed information and an increased risk of distraction. All three also may have suffered decreased motivation because of fatigue, unintentionally placing increased reliance on other controllers and on the control process to detect errors.

Eight-Hour Rest Period

Controller duty and rest times are not regulated by CARs, although they are scheduled in compliance with the NAV CANADA/CATCA collective agreement and the CLC. The schedule worked by Controllers B and C provided only eight hours off-duty between the day shift and the subsequent midnight shift. Controller sleep opportunity during off-duty periods is reduced by travel time to and from accommodations and time for meals and personal hygiene. Consequently, while permitted by legislation and the collective agreement, this eight-hour period between shifts reduces controllers' total sleep time to less than that required by a normally rested person. Because shortened total sleep time causes fatigue, the risk that controllers will suffer from fatigue resulting from this eight-hour off-duty period is higher than the risk for normally rested persons. In this instance, FAST predicted a significant performance reduction during the midnight shift following the eight-hour off-duty period (see Appendix C).

Overtime Shifts

Overtime was usually scheduled in entire shifts, rather than in short periods before or after regular shifts. Because overtime shifts occurred at times when controllers would otherwise be off duty, the effect of overtime was not only to increase the total number of hours worked, but also to reduce the number of days off (see Table 2). This reduced the number of opportunities the controllers had to reduce their sleep debt or stabilize their sleep–wake routine. In fact, Controller B was working an overtime shift on the day of the occurrence.

Position Reports and Flight Progress Strips

Controllers received one of two types of verbal position reports. The standard position report used either an alphanumeric designator or latitude and longitude to identify a position. The abbreviated position report used either an alphanumeric designator or the code name of the track and the reporting point longitude to identify a position. The flight progress strip fixes used either an alphanumeric designator or latitude and longitude. It is more difficult to reconcile flight progress strip fixes that use latitude and longitude with the abbreviated position report that uses a code name and longitude than with a standard position report that uses latitude and longitude.

Conflict Probes

Checking for conflicts is a routine part of the control process. The controllers in this occurrence repeatedly probed for conflicts, indicating that they were aware of the potential for conflicts. However, none of the controller probes detected the loss of separation because the NSiT was programmed with incorrect fixes for the DLH492 route, and the spacing calculated by the NSiT using the incorrect fixes was greater than the minimum separation required. The incorrect FRN entry meant that the actual track to be flown by DLH492 no longer matched the fixes used by the NSiT to display the aircraft track or detect conflicts with other aircraft.

Controller Actions

All three controllers were most likely fatigued, and fatigue degrades performance characteristics such as vigilance and motivation. These degradations are the insidious effects of fatigue and are not associated with the character or personality of the individual. This analysis focuses on vigilance and motivation.

Controller A set up both the original DLH492 and the amended DLH492M flight plans while his performance was negatively affected by fatigue. Fatigue could have reduced his vigilance, resulting in a greater likelihood of distraction or of missing important information. Fatigue could have also insidiously reduced his motivation, causing him to unconsciously place increased reliance on others. The investigation did not determine why Controller A entered an incorrect FRN; however, it is likely that a distraction, such as the unusual medevac call sign, drew his attention away from the flight plan setup task. When he returned to the setup task, decreased vigilance, coupled with an unintentionally increased reliance on others, likely made it more difficult for him to perceive and react to the incorrect FRN entry. Additionally, the NSiT does not provide automated route conformance checking. Consequently, the FRN error went undetected.

Controller B's performance was most likely impaired by fatigue when he activated the DLH492M flight plan. The flight plan activation task required Controller B to check the data accuracy for the flight. However, there was no specific procedure for data crosscheck, and he did not detect the incorrect FRN and fixes. This is consistent with a fatigue-related vigilance problem, that is, he did not perceive the information that would have highlighted the error. The combination of impaired vigilance and the absence of a crosscheck procedure most likely prevented Controller B from detecting the error and acting upon it during the flight plan activation.

Controller C's performance was most likely impaired by fatigue during the three opportunities he had to detect the discrepancies in position reports at 1025, 1031, and 1053. Vigilance impairment from fatigue most likely made him more susceptible to distraction and less able to detect important information. Controller C was likely distracted at 1025 and 1031 by the unusual "M" suffix on the call sign, and again at 1053 by the request for information regarding the time when DLH492 would be able to climb to a higher altitude. Impaired vigilance, resulting from his fatigue, most likely made it more difficult for him to perceive and react to subtle differences between the positions in the position reports and the fixes on the flight progress strips, which were presented in different formats. Impaired performance resulting from fatigue most likely prevented Controller C from detecting the error and acting upon it.

At 1127, Controller B received an abbreviated position report for DLH492 at 90 west. The controller was sufficiently vigilant to identify that the arrival time at 90° west longitude was eight minutes later than expected, but did not identify that the positions in the report differed from the NSiT strip fixes. The time discrepancy occurred because the NSiT was programmed incorrectly with the fixes associated with FRN 324. The distance from 7130N 80W to November 90, the correct fix, is greater than the distance to Hotel 90, the incorrect fix (see Appendix B). Consequently, the time required for DLH492 to transit from 80W to November 90 was greater than the time the NSiT calculated for the distance between 80W to Hotel 90. When the controller obtained confirmation from DLH492 of the arrival time at 90 west, he then searched further for an explanation of the time discrepancy and determined that the FRN and fixes for DLH492 were incorrect and that a loss of separation had occurred.

Findings as to Causes and Contributing Factors

1. A shortage of controllers in the Edmonton Area Control Centre led to scheduling practices that were detrimental to effective rest recovery. The three occurrence controllers were most likely impaired by fatigue because of the scheduling practices.

2. The controllers' fatigue was likely a factor that prevented them from detecting the errors in flight plans, and the incorrect fix reference number (FRN) and fixes.

3. The fixes and route on the flight progress strips were presented in different formats and reading sequence. This, combined with the different formats for position reports, made identification of the incorrect FRN and fixes more difficult.

4. The assignment of the "M" call sign suffix for DLH492 was likely a distraction for the controllers during the flight plan setup task and subsequent position reports. This distraction reduced the controllers' ability to detect the FRN and fix errors.

5. Because there were no data accuracy crosscheck procedures specified for the flight plan activation, the controllers were more likely to rely on the normal vigilance of subsequent controllers to detect errors.

Findings as to Risk

1. The lack of continuous, direct controller–pilot communications in procedurally controlled Canadian northern airspace results in communications delays.

2. Controller minimum off-duty periods are governed by collective agreements and the *Canada Labour Code*; they permit occasional rest periods as short as eight hours without any additional time for travel, meals, and personal hygiene. This increases the risk of controller fatigue from shortened total sleep time.

Other Finding

1. The northern airspace display system situational display (NSiT) neither checks route conformance nor alerts controllers that an aircraft is following a route that has not been programmed into the NSiT.

Safety Action Taken

Transport Canada issued an amendment to Section RAC 12.7.1.3 of the *Aeronautical Information Manual* requiring that pilots use published latitude and longitude coordinates when making position reports when compulsory reporting points have not been named.

On 27 June 2006, the Edmonton Area Control Centre issued a directive to the North High and Shield specialties that included a requirement that the controller activating the northern airspace display system (NADS) flight plan verify the fix field against the flight plan route to ensure an accurate setup.

NAV CANADA has implemented the following initiatives to alleviate North High specialty staffing issues:

- The Bison sector was reallocated to another specialty to reduce the number of sectors in the North High specialty.

- Controllers have been deployed from adjacent specialties into the North High specialty to increase staff availability during peak periods.

- Training within the specialty is ongoing.

- A volunteer overtime list process has been implemented so that controllers can volunteer for vacant shifts. If there are no volunteers, then overtime shifts are assigned in accordance with the NAV CANADA/Canadian Air Traffic Control Association (CATCA) collective agreement.

- A scheduling team has been developed in the North High specialty to look at future schedules and take into consideration the interests of individual controllers in the scheduling process. The scheduling process must comply with the NAV CANADA/CATCA collective agreement and *Canada Labour Code* requirements, and consider the needs of operational staff.

Since the occurrence, direct controller–pilot communications have been enhanced in the North High and Shield specialties as follows:

- Twelve new frequencies are in operation.

- Two frequencies have been upgraded to long-range frequencies.

- Two new frequencies are scheduled to be operational on Baffin Island, which is in the vicinity of this occurrence, in July 2008.

NAV CANADA is presently considering re-hosting the Northern Airspace Flight Data Processing System to gain certain benefits.

- Flight progress strip formatting would account for pilot estimates, equipment suffixes, and only those fixes that are required for individual sectors.

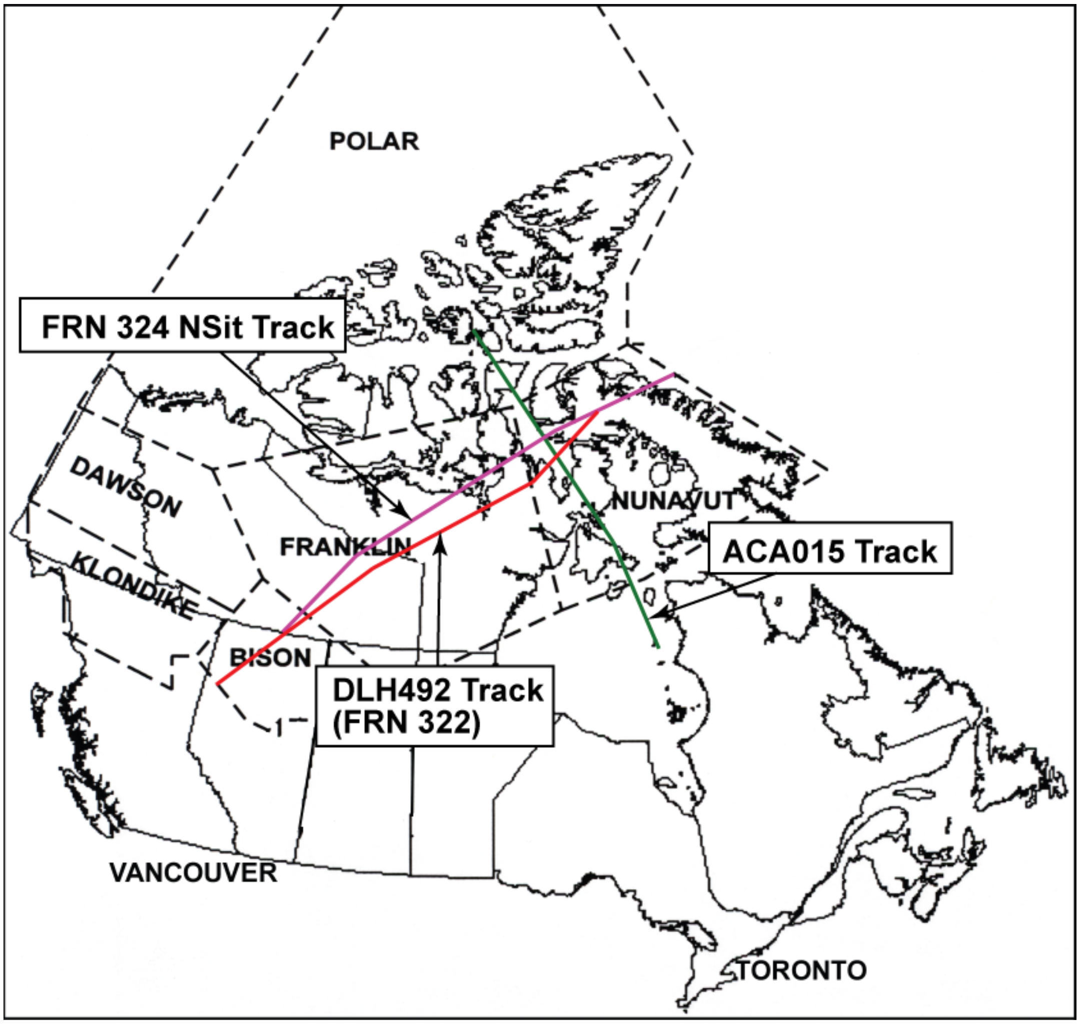
- There would be a reduced coordination workload between existing NADS specialties and reduced training time for new controllers because it enables combining NADS specialties.

- Information would be transferred from the flight plan to the system, thus reducing the risk of controller setup errors.

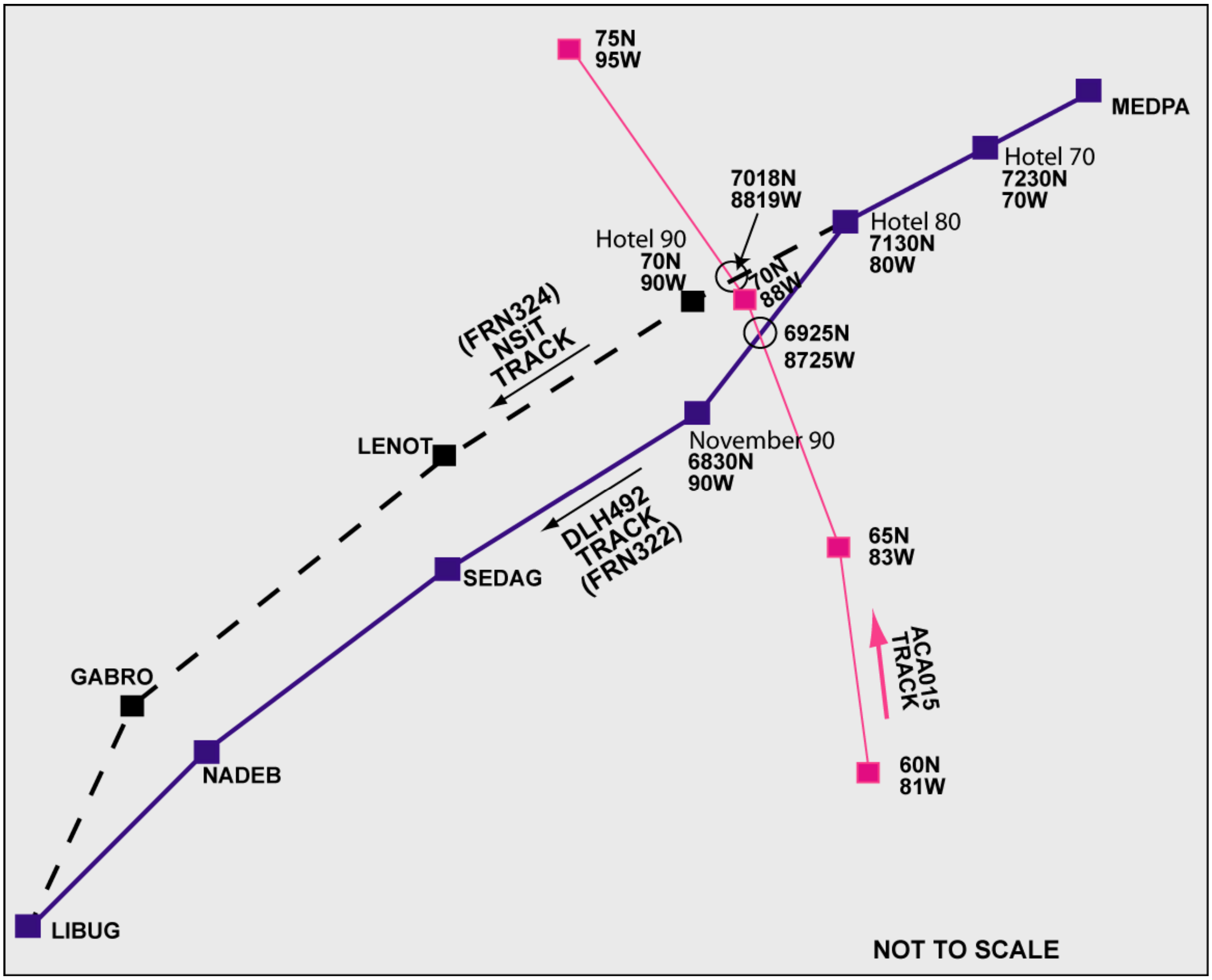
This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 08 December 2006.

*Visit the Transportation Safety Board's Web site (**www.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.*

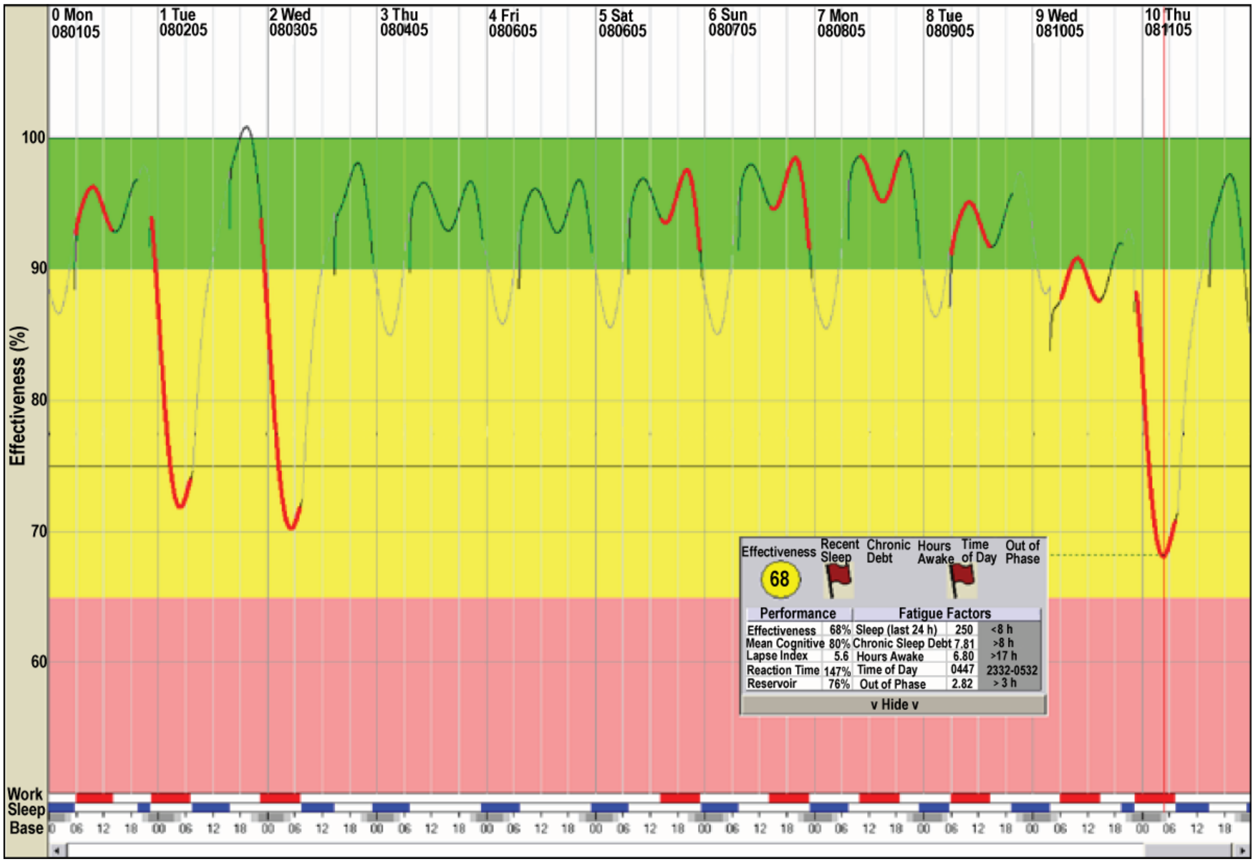
Appendix A – Sector Boundaries with Aircraft and Northern Airspace Display System Situational Display (NSiT) Tracks



Appendix B – Aircraft and Northern Airspace Display System Situational Display (NSiT) Tracks



Appendix C – Fatigue Avoidance Scheduling Tool (FAST) Effectiveness Graph



Appendix D – Glossary

ACC	Area Control Centre
ADS	automatic dependent surveillance
ALARA	as low as reasonably achievable
CARs	*Canadian Aviation Regulations*
CATCA	Canadian Air Traffic Control Association
CLC	*Canada Labour Code*
CPDLC	controller–pilot datalink communications
ETA	estimated time of arrival
FAST	Fatigue Avoidance Scheduling Tool
FL	flight level
FN	North High specialty–Franklin sector
FRN	fix reference number
h	hours
m	minutes
N	north
NADS	northern airspace display system
NCA	northern control area
nm	nautical miles
NSiT	northern airspace display system situational display
NV	North High specialty–Nunavut sector
NW	northwest
PR	North High specialty–Polar sector
SAIC	Science Application International Corporation
TWG	Tripartite Working Group
VHF	very high frequency
W	west
WPR	waypoint position reporting
%	per cent
'	minutes
"	seconds
°	degrees