Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A11F0012

PITCH EXCURSION

AIR CANADA
BOEING 767-333, C-GHLQ
NORTH ATLANTIC OCEAN, 55°00'N 029°00'W
14 JANUARY 2011

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

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Synopsis

The Air Canada Boeing 767-333 (registration C-GHLQ, serial number 30846) was operating as flight ACA878 from Toronto, Ontario, to Zurich, Switzerland. Approximately halfway across the Atlantic, during the hours of darkness, the aircraft experienced a 46-second pitch excursion. This resulted in an altitude deviation of minus 400 feet to plus 400 feet from the assigned altitude of 35 000 feet above sea level. Fourteen passengers and 2 flight attendants were injured. The seatbelt sign had been selected "on" approximately 40 minutes prior to the pitch excursion. The flight continued to destination whereupon 7 passengers were sent to hospital and were later released.

Ce rapport est également disponible en français.

Other Factual Information

History of Flight

Air Canada flight 878 (ACA878) departed Toronto / Lester B. Pearson International Airport, Ontario (CYYZ), on 13 January 2011 at 2138 [1] with 95 passengers, 6 flight attendants and 2 flight crew. The planned routing was north of the North Atlantic Organized Track System (OTS) on a random track [2] in order to avoid forecast turbulence associated with the jet stream. The captain had elected to use the centre line option as per the strategic lateral offset procedures [3] (SLOP) in the Air Canada Flight Operations Manual (FOM).

At 0040, the first officer (FO) expressed the need for a rest. The captain agreed and the FO commenced a controlled rest. The in-charge flight attendant (IC) was not advised.

Shortly after the start of the controlled rest, the captain increased the lighting on the flight deck to review aircraft manuals in preparation for upcoming training. This type of reading was in accordance with Air Canada standard operating procedures.

At 0118, the captain turned on the seatbelt sign in anticipation of the turbulence forecast for the area. An announcement by the IC was made to remind passengers that the seatbelt sign was now on and that they were to remain seated with their seatbelts secured. [4] Up to this point, there had been no

Controlled Rest—Air Canada FOM, Section *2.9.10 —Alertness Management*, describes controlled rest as an operational fatigue countermeasure that improves on-the-job performance and alertness when compared to non-countermeasure conditions. Controlled rest uses strategic napping on the flight deck to improve crew alertness during critical phases of flight. The rest periods are a maximum of 40 minutes in length (periods to be reviewed prior to resting) and must be completed 30 minutes prior to the top of descent. The In-Charge Flight Attendant must be advised that controlled rest will be taking place and instructed to call the flight deck at a specific time. Upon conclusion of the rest period, unless required due to an abnormal or emergency situation, the awakened pilot should be provided at least 15 minutes without any flight duties to become fully awake before resuming normal duties. An operational briefing shall follow.

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1 All times Eastern Standard Time (Coordinated Universal Time minus 5 hours).

2 Transport Canada, *Aeronautical Information Manual*, section RAC 11.6.1 advises that non-OTS tracks be great circle tracks joining successive significant points. For flights south of 70°N, such as for flight ACA878, the significant points are defined by the intersection of half or a whole degree of latitude at each 10 degrees of longitude. The distance between significant points shall not exceed 1 hour of flight time.

3 SLOP is recommended to reduce the exposure to turbulence from aircraft on the same track and to increase safety margins should another aircraft deviate from its assigned altitude. There are 3 options: centre line, 1 nautical mile (nm) right and 2 nm right. An ATC clearance is not required to SLOP when flying in the Gander or Shanwick Oceanic sectors.

4 This was in addition to the initial safety briefing where passengers are advised to keep their seatbelts fastened whenever seated.

turbulence; after the event, it was light to nil.

In response to the seatbelt sign being turned on, the flight attendants made a visual inspection of the passengers for compliance; the majority were asleep. Many of the passengers in economy were lying down across the centre 3 seats. Business class featured the lay-flat seats with seatbelts equipped with air bags, and the majority of those passengers were also lying down and appeared to be asleep.

At 0155, the captain made a mandatory position report with the Shanwick Oceanic control centre. This aroused the FO. The FO had rested for 75 minutes but reported not feeling altogether well. Coincidentally, an opposite-direction United States Air Force Boeing C-17 at 34 000 feet appeared as a traffic alert and collision avoidance system (TCAS) target on the navigational display (ND). The captain apprised the FO of this traffic.

Over the next minute or so, the captain adjusted the map scale on the ND in order to view the TCAS target [5] and occasionally looked out the forward windscreen to acquire the aircraft visually. The FO initially mistook the planet Venus for an aircraft but the captain advised again that the target was at the 12 o'clock position and 1000 feet below. The captain of ACA878 and the oncoming aircraft crew flashed their landing lights. The FO continued to scan visually for the aircraft. When the FO saw the oncoming aircraft, the FO interpreted its position as being above and descending towards them. The FO reacted to the perceived imminent collision by pushing forward on the control column. The captain, who was monitoring TCAS target on the ND, observed the control column moving forward and the altimeter beginning to show a decrease in altitude. The captain immediately disconnected the autopilot and pulled back on the control column to regain altitude. It was at this time the oncoming aircraft passed beneath ACA878. The TCAS did not produce a traffic or resolution advisory.

During the pitch excursion, the aircraft pitch changed from the cruise attitude of 2 degrees nose up, to 6 degrees nose down followed by a return to 2 degrees nose up. The vertical acceleration forces (g) went to -0.5 g to +2.0 g in 5 seconds. Computed airspeed increased 7 knots then decreased 14 knots before recovering to cruise speed with the aircraft's altitude decreasing to 34 600 feet increasing to 35 400 feet and finally recovering to 35 000 feet.

No one in business class had been displaced and / or injured during the event. When the IC walked into economy, it became apparent that there were passengers and crew injured from contacting cabin fixtures and armrests and the IC began to arrange for first aid. Two medical professionals identified themselves and provided assistance to the cabin crew. Once an assessment of injuries had been made, the IC advised the captain and a satellite phone link was established with Air Canada flight operations to advise of the situation and to establish a phone link with a physician trained in assessing injuries and illnesses encountered during flight. After

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5 TCAS targets show at the 30 nm range. With the ND set at 320 nm, as it was in this case, the TCAS target would appear on top of the aircraft symbol at the bottom of the ND. It is Air Canada standard operating procedures (SOP) to reduce the range to ensure a clear depiction of the TCAS target relevant to the aircraft.

coordinating through Air Canada dispatch, and speaking directly to the physician, the captain directed the IC to speak directly with those injured. Based on the information received from the injured, the physician's assessment, the enroute weather and a number of other factors, the decision was made that it was acceptable to continue to destination. Medical services were readied in Zurich for the arrival of ACA878.

The total number of passengers who were not seated with their seatbelts fastened is unknown. None of the passengers in business class was injured. The 14 passengers who were seen for their injuries were all located in economy in various locations (Appendix A). One injured flight attendant was in the rear galley, the other in a lavatory. All injuries were of the soft tissue variety, and a few of the injured sustained lacerations.

A pilot dead-heading to Zurich (to serve as relief pilot for the return flight) was on the flight. After the captain was informed of the injuries, a request was made to have this pilot sit on the flight deck to monitor the flight and assist as required. The remainder of the flight was uneventful. The flight was met by medical help upon arrival at Zurich. Within 20 minutes, all injuries were assessed and passengers were either released or sent to hospital for further observation.

Flight Crew

Records indicate that the flight crew were certified and qualified for the flight in accordance with existing regulations. The captain had over 30 years of experience at Air Canada and 14 800 hours total flight time including just over 400 hours pilot-in-command on type since qualifying as captain on the Boeing 767 in the spring of 2010. The FO had 24 years in aviation, the last 14 years at Air Canada, with 12 000 hours total flight time including approximately 2 000 hours on the Boeing 767 in the previous 4 years.

It was normal for both the captain and the FO to sleep at night. During the days leading up to the occurrence, the captain had not been working but had had a cold so slept longer than usual (12 hours instead of 10 hours). On the day of departure, the captain rose at approximately 0800 feeling recovered. The captain then performed a 6.5-hour commute from Florida to Toronto via aircraft. The captain obtained approximately 90 minutes of prone rest in the flight operations pilot rest facility before reporting for duty feeling well rested. This facility is a quiet room equipped with beds to permit prone rest.

Before he had children, the FO normally slept 8 hours per night. After having children, the FO normally slept approximately 6 to 7 hours per night, between 2300 and 0600, which could often be interrupted when the children required care. Often, the FO would take a nap early in the afternoon for an hour in an attempt to make up for lost sleep. The FO followed a normal sleep pattern during the 2 non-working days prior to the occurrence. The night before the occurrence, the FO was able to obtain nearly 8 hours of rest with some child care interruptions before waking at approximately 0600. The FO took a 2-hour nap in the afternoon before reporting for duty feeling well rested.

Both crew members checked in at the required time of 1935 and the aircraft pushed back at 2109. ACA878 landed in Zurich at 0505 and was at the gate at 0509 for a total flight time of 8 hours and 4 minutes, which was 9 minutes longer than scheduled.

Evening-departure Flights to European Destinations: Fatigue Issues

Fatigue reduces performance levels and increases the desire to obtain sleep. This effect is magnified during circadian lows [6], which are encountered by people who normally sleep at night and work during the day (diurnal). For example, North American pilots flying eastward at night across the Atlantic experience circadian lows that magnify performance decrements and increase desire to sleep.

Night flights from North America to Europe have an inherent risk of fatigue for North American-based pilots. Most of these pilots fly a small number of night-time legs per month and revert to sleeping at night when not working. The circadian system of pilots who fly only a small number of night-time legs will not adapt to working at night [7], and these pilots are likely to display performance decrements during the night-time legs [8] in spite of any countermeasures.

To counter fatigue, some pilots will try to nap before a night-time leg. While this can be helpful in some cases, it cannot prevent fatigue in all pilots. Moreover, it is not always possible to obtain

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6 Circadian lows are periods of high fatigue and poor performance. The highest levels of fatigue and worst performance occur when circadian rhythms dictate sleep. For a diurnal person this is during the night. See for examples: Härmä, M., Sallinen, M., Ranta, R., Mutanen, P., & Müller, K. (2002). The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. *Journal of Sleep Research*, *11*, 141 – 151; Ingre, M., Kecklund, G., Åkerstedt, T., & Kecklund, L. (2004). Variation in sleepiness during early morning shifts: A mixed model approach to an experimental field study of train drivers. *Chronobiology International, 21(6)*, 973-990; Gupta, S. & Pati, A. (1994). Desynchronization of circadian rhythms in a group of shift working nurses: Effects of pattern of shift rotation. *Journal of Human Ergology, 23(2)*, 121-131; Tilley, A., Wilkinson, R., Warren, P., Watson, B., & Drud, M. (1982). The sleep and performance of shift workers. *Human Factors, 24(6)*, 629-641

7 In general, researchers have found that the adjustment of the human circadian system resulting from changes to sleep-wake pattern occurs at a rate of 1 to 1.5 hours per day. Adjusting from being awake during the day to being awake at night, a 12 hour difference, could take between 12 and 18 days for complete adjustment to take place and optimum performance to return. Flying one night shift will not result in adequate circadian adjustment and pilot performance will continue to be affected by circadian lows during night flying (Klein, K. & Wegmann, H. (1980). *Significance of circadian rhythms in aerospace operations*, (NATO AGARDograph, 247). Neuilly sur Seine, France: NATO AGARD).

8 See for examples: Gupta, S. & Pati, A. (1994). Desynchronization of circadian rhythms in a group of shift working nurses: Effects of pattern of shift rotation. *Journal of Human Ergology, 23(2)*, 121-131; Tilley, A., Wilkinson, R., Warren, P., Wastson, B., & Drud, M. (1982). The sleep and performance of shiftworkers. *Human Factors, 24, 629-641*; Tepas, D., Walsh, J., & Armstrong, D. (1981). In L. C. Johnson, D. I. Tepas, W. P. Colquhoun, & M. J. Colligan (Eds.). *Biological rhythms, sleep and shift work* (pp. 347-356). New York: Spectrum Publishing; Duffy, J., Dijk, D., Klerman, E., Czeisler, C. (1998). Later endogenous circadian temperature nadir relative to an earlier wake time in older people. *American Journal of Physiology, 275*, R1478-R1487.

an adequate amount of good quality sleep during the day [9] and, coupled with a small number of night-time legs, performance decrements will persist.

In addition, these types of flights are characterized by long periods of darkness with few operational demands while mid-Atlantic, creating inherently soporific conditions [10]. It is not until the flight approaches the coast of Europe at dawn that pilots experience reduced sleepiness as the daylight and circadian rhythms start to alleviate some of the fatigue. Nonetheless, the high workload requirements of approach and landing have to be borne at a time when there is a significant risk of pilot fatigue.

Pilots must develop strategies in advance to manage their fatigue effectively. Planning related to trans-Atlantic flights typically takes place during the early evening when diurnal pilots experience a circadian high. In such cases it may be difficult for pilots to assess their readiness to undertake the entire flight based on their subjective assessment of their alertness or sleepiness immediately prior to the flight and instead rely on their personal assessment of the adequacy of their pre-flight sleep regime.

Fatigue Risk Management

Transport Canada outlines a series of defences in its Fatigue Risk Management System (FRMS) for the Canadian aviation industry. [11] While not targeted specifically to flight operations, it provides a useful benchmark from which a review of fatigue management at Air Canada can be made. This is similar to the FRMS framework that was under development at the time of the occurrence by ICAO for flight operations. [12] The defences include

- creating sufficient opportunity for sleep (*Canadian Aviation Regulations*, crew scheduling, etc.);
- obtaining sufficient sleep (employee actions, on-going assessment);
- monitoring for fatigue while on duty (symptom checklists, self-reporting);
- fatigue based error mitigation (for instance caffeine, controlled rest, relief pilots, error reporting);
- fatigue based occurrence analysis (safety management system [SMS]–based incident and accident analysis); and

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9 See for examples: Lavie, P. (1986). Ultrashort sleep-waking schedule III. ‘Gates’ and ‘forbidden zones’ for sleep. *Electroencephalography and Clinical Neurophysiology, 63(5)*, 414–425; Cabon, P., Bourgeois-Bougrine, S., Mollard, R., Coblentz, A., & Speyer, J. (2000). Fatigue of short-haul flight aircrews in civil aviation: Effects of work schedules. In S. Hornberger, P. Knauth, G. Costa, & S. Folkard (Eds.), *Shiftwork in the 21st century: Challenges for research and practice* (pp.79-85). Frankfurt: Peter Lang.

10 Conditions that cause or tend to cause sleep, such as low lighting, few task requirements and / or little to observe outside the aircraft.

11 TP 14575E, *Developing and Implementing a Fatigue Risk Management System*, April 2007.

12 In June 2011, ICAO released DOC 9966 FRMS for Regulators. In July 2011, IATA, ICAO and IFALPA jointly announce the FRMS Implementation Guide for Operators.

- fatigue training and awareness program.

Some of these are explored below.

In an effort to address fatigue risks, the Canadian Aviation Regulation Advisory Council formed a Flight Crew Fatigue Management Working Group in September 2010 to make recommendations regarding the flight time and duty time limitations and rest period regulations based on the science that underpins the FRMS. Fourteen meetings were held; the last was in December 2011. Transport Canada summarized the process so far:

> The Co-chairs have begun the process of writing the report of the working group. The report will summarize the science, harmonization, and operational experience associated with each issue discussed. It will include recommendations from the working group, where consensus was found, and recommendations from the Co-chairs where there was no consensus of the working group. One area of consensus was the effect of circadian rhythms on the length of the flight duty period. The longest duration flight duty period available would start from between 0700 and 1200, and the shortest duration flight duty period available would start from between 2300 and 0430 am [sic] – accounting for the window of circadian low and the generally reduced performance during this period.

Crew Scheduling at Air Canada

From a carrier’s point of view, crew scheduling involves the need to ensure that all flights have qualified crews while minimizing labour costs and complying with a wide variety of constraints governed by safety regulations and labour contracts. For crews under bid systems such as those at Air Canada, earnings and convenience also play a role in crew scheduling.

While crew scheduling aims to address the employer’s role to provide work conditions that allow employees to accrue sufficient rest, employees are obligated to make appropriate use of that rest time and report fit for duty. [13]

Neither the *Canadian Aviation Regulations* nor Air Canada makes specific accommodations to account for the particular risks associated with operating overnight flights during a circadian low.

Air Canada, with its pilot association, has a mechanism to review crew pairings (flights) that pilots may consider to be onerous. The occurrence flight, at the time of the occurrence, had not been brought forward as a concern under this mechanism.

Monitoring for Fatigue

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13 CAR 602.02 and Air Canada Flight Operations Manual 2.9.4.

The aim of fatigue monitoring is to identify a pilot who appears to be in a fatigued state and take appropriate actions before an error occurs. While Air Canada provides information concerning the causes and effects of fatigue, it does not provide procedures or information concerning the identification of fatigued colleagues through observation of symptoms. Currently there is no "fit to fly" checklist [14] to enable employees to self-monitor or monitor others in order to identify effectively crew members who may not be sufficiently alert to perform their duties.

Fatigue-based Error Mitigation

Air Canada training on fatigue management outlines several strategies for mitigating fatigue in order to reduce the likelihood of errors, such as exercise, social interaction and caffeine. Two specific strategies— controlled rest and the use of relief pilots—are described in more detail below.

Controlled Rest

Controlled rest is the strategic use of short naps on the flight deck to improve crew alertness during critical phases of flight. Research has shown that this improves on-the-job performance compared with non-countermeasure conditions. [15] This approach has been adopted by 17 air carriers in Canada and several airlines around the world such as British Airways, Qantas, Air New Zealand and Emirates. The approach was adopted by Transport Canada in 1996 and is specified in CAR 700.23 and Commercial Air Services Standards (CASS) 720.23. Authorization for Air Canada to conduct controlled rest was granted by Transport Canada on 13 June 2005.

At Air Canada, the in-charge flight attendant must be advised that controlled rest will be taking place and must be instructed to call the flight deck at a specific time [16]. The rest periods are a maximum of 40 minutes in length and must be completed 30 minutes prior to the commencement of descent.

Upon conclusion of the rest period, the awakened pilot should be provided at least 15 minutes without any flight duties to become fully awake before resuming normal duties, unless required

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14 Checklist challenges user to consider pre-duty workload, pre-duty sleep, actual fitness and actual flight duty period. See for example: Valk, P.J.L. and Simmons, M. (1997). Pros and Cons of Strategic Napping in Long Haul Flights. *AGARD-CP-599 Aeromedical Support Issues in Contingency Operations,* The AMP Symposium, held in Rotterdam, The Netherlands, 29 September - 1 October 1997.

15 For example: Rosekind, M.R. et al. (1994*). Crew Factors in Flight Operations IZ: Effects of Planned Cockpit Rest on Crew Performance and Alertness in Long-Haul Operations*, NASA Technical Memorandum 108839; Speyer, J.J. et al. (2004). *Getting to Grips with Fatigue and Alertness Management*, Airbus STL 945.2796 / 04; Simons M., and Valk PJL. (1997). *Effects of controlled rest on the flight deck on crew performance and alertness.* Netherlands Aerospace Medical Centre Report No. NLRGC 1997-B3.

16 Controlled Rest – Air Canada FOM, Section *2.9.10 – Alertness Management*.

to do so due to an abnormal or emergency situation. Following the 15-minute wakening period, an operational briefing must be given.

This is designed to ensure that the rest is taken in a manner that minimizes risks to the flight. This includes

- ensuring that rest is only undertaken during portions of the flight that are anticipated to be low risk and do not require actions by the resting pilot;
- the period of sleep is not so long that the pilot is likely to suffer from sleep inertia;
- the cabin attendant enters the cockpit after the rest period to ensure that both pilots are not asleep; and
- sufficient time is provided for the wakening pilot to recover from the sleep.

Relief Pilot

Transport Canada recognizes a relief pilot as a pilot who is fully trained to the successful completion of a pilot proficiency check on the aircraft type and utilized solely for the purpose of providing flight relief for the captain or FO in order to extend flight deck duty times. Transport Canada issues individual type ratings for relief pilots for aircraft that require a minimum of 2 flight crew. These type ratings come with a restriction indicating that a relief pilot may relieve a member of the flight crew only while the aircraft is in cruise. The relief pilot must have a Commercial or Airline Transport Pilot Licence with a Group 1 instrument rating.

At Air Canada, relief pilots are trained to the FO standard and possess Airline Transport Pilot Licences. They are issued the aircraft type rating without the relief pilot restriction.

Relief pilots are used at Air Canada according to the terms of the collective agreement. In the case of ACA878, a relief pilot is not required where the maximum flight time is 9 hours and the duty day maximum is 11 hours. In this occurrence, the scheduled flight time for ACA878 was 7 hours 55 minutes and a duty day of 9 hours 25 minutes. For the return flight, ACA879, the scheduled flight time was 9 hours 5 minutes and a duty day of 10 hours 35 minutes. In that instance the flight time exceeded 9 hours and a relief pilot was required to work the flight. To comply with this agreement, a relief pilot dead-headed on flight ACA878 in order to work the return flight ACA879.

By using a relief pilot, flight crews may obtain a higher quality of rest by removing themselves from the flight deck and obtaining longer periods of rest time.

Reporting and Analysing Fatigue-based Errors

At Air Canada, there are several methods through which flight crew can communicate various concerns during flight operations. For safety of flight issues, the Aviation Safety Report (ASR) is used to capture occurrences for analysis by the flight safety department under Air Canada’s SMS; the ASR does not specifically identify fatigue on the form. A Flight Crew Report (FCR) is used to address administrative and contractual issues. In addition to these reporting streams, the Air Canada Pilots Association (ACPA) has a form specific to capturing fatigue-related issues.

In the calendar year 2010, the Air Canada SMS database system contained no ASRs related to fatigue; in particular, there were none for the eastbound European flights that departed in the evening. Conversely, the FCR system contained 5 reports pertaining to the fatigue issues on these types of flights and 4 of those reports questioned the rationale for not having a relief pilot on the eastbound flights.

In November 2009 Air Canada's SMS was assessed by Transport Canada. In that assessment Transport Canada had moderate findings [17] for the SMS elements of reactive and proactive reporting processes for safety oversight. Air Canada's corrective action plan was filed in September 2010. Transport Canada accepted that plan on 20 July 2011 with implementation to be completed by 31 July 2012.

Fatigue Risk Management Training at Air Canada

Fatigue risk management training is a foundation for many of the defences against fatigue. It provides employees with knowledge of how to avoid, mitigate and report fatigue issues. CASS 720.23 – Controlled Rest on the Flight Deck requires that every crew member who participates in the controlled rest on the flight deck program shall have received training in the program as well as training in the general principles of fatigue and fatigue countermeasures. In the Air Canada Flight Operations Manual, the training requirement associated with controlled rest is that: "prior to practising controlled rest the pilots shall be familiar with the contents of the relevant Flight Operations Manual Bulletin."[18]

All pilots at Air Canada are required to attend annual recurrent training (ART) as part of the Air Canada Continuing Qualification program. The requirements of CASS 725.124 are met by a 6-year training matrix that is reviewed by Air Canada and approved by Transport Canada on an annual basis. Requirements under CASS 725.124 do not include the requirements of CASS 720.23 and as such, Air Canada had included a separate module on controlled rest in 2005, 2006 and 2010. Controlled rest is also covered in initial training for newly hired pilots.

Both the captain and FO were on year 3 of the ART program which featured the module on fatigue risk management. The captain attended ART on 25 June 2010 and the FO on 15 September 2010. This unit was approximately 30 minutes in length and reviewed the science behind fatigue, fatigue mitigation options for flight crew while away from work and at work. The training briefly covered the stages of sleep and the effects of sleep inertia.

The approach taken to training for controlled rest was to read the controlled rest procedure to the trainees. Transport Canada's expectation concerning training for controlled rest was based on Guidance Material S740.23 which refers to the NASA Ames Fatigue Countermeasures Program. This program provides a module in alertness management in flight operations. In this module's introduction it states that the information is intended to be offered as a live

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17 A finding is considered moderate where a surveillance activity has identified that a SMS component and / or element has not been fully maintained and non-conformance findings indicate that the component is not fully effective, but where no immediate safety issues were detected.

18 Air Canada Flight Operations Manual, 01 Jun 2010, *Health and Medical Considerations, Practicing Controlled Rest*, p19.

presentation by a trained individual to ensure an interactive format that would promote discussion.

When new material is provided on a topic that differs only slightly from what is known but is critical, the difference must be emphasized so that it will be retained. [19] In addition, unless they are told why the procedures are taught, it is common for workers either to default to what they know or to exceed the limits set in the procedures until they encounter actual safety problems. [20]

Air Canada's internal flight safety magazine, Flight Line, featured an article on sleep inertia in the fall / winter 2010 issue. Neither the captain nor FO had read the article prior to the occurrence.

Pilot Knowledge of Fatigue and Controlled Rest

The occurrence pilots and several line pilots at Air Canada were interviewed in order to assess their knowledge of fatigue mitigation measures and in particular their knowledge of controlled rest. General knowledge about how to manage their rest for flights was good but there were specific gaps including their knowledge of how disturbances to sleep, such as those caused by caring for children, waking periods during the night or snoring can affect the quality of sleep and subsequently increase the risk of fatigue. They were unsure how to assess whether symptoms of fatigue in themselves or a colleague might indicate being unfit to fly, but they did have a good understanding of methods they could use to mitigate fatigue during flight.

All of the pilots understood that they were required to call cabin crew prior to taking a controlled rest, but they tended to rely on their own assessment of the sleepiness of the non-resting pilot in order to decide whether the cabin crew needed to be told that rest was being taken. Since pilots take controlled rest at times when they are most sleepy, which is likely to be at a similar time to the other pilot due to the circadian rhythm of fatigue, there is a high risk of night-time controlled rest resulting in both pilots falling asleep. [21] One of the reasons they were reluctant to inform cabin crew was that they knew cabin crew were not entitled to controlled rest themselves. They did not realize that by not informing the cabin crew of the controlled rest they were creating the possibility of the resting pilot being disturbed.

There was considerable misunderstanding about the reason why controlled rest was limited to 40 minutes. Some pilots believed that 20-40 minutes could not provide appreciable benefits and believed that what was really required was a significant sleeping period—90 to 120 minutes. Some were unaware that by sleeping longer than 40 minutes there was a high risk of entering slow-wave sleep and increasing the severity of sleep inertia.

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19 Negative transfer is the detrimental effect of prior experience on the learning of a new task.

20 Rasmussen J., Pejtersen A. M. and Goodstein L. P. (1994) *Cognitive systems engineering*. Wiley, New York.

21 Valk, P. J. L. and Simmons, M. (1997). Pros and Cons of Strategic Napping in Long Haul Flights. *AGARD-CP-599 Aeromedical Support Issues in Contingency Operations*, The AMP Symposium, held in Rotterdam, The Netherlands, 29 September - 1 October 1997.

Their knowledge of sleep inertia was low. They were aware of the term but were not aware how significantly impaired a recently awakened pilot could be. They believed that the recuperation period after a rest was for the pilot to become apprised of the current state of the flight operations, rather than to come back to full alertness.

Sleep Inertia

Sleep inertia [22] refers to the post-sleep performance decrements that occur immediately after awakening. Sleep inertia is a transient physiological state characterized by confusion, disorientation, low arousal, and deficits in various types of cognitive and motor performance. [23] Although the duration of sleep inertia is usually short, from 1 to 15 minutes [24], some deleterious effects can last 30 minutes [25] or longer. [26]

Research indicates that the duration and severity of sleep inertia can be worse

- if naps are longer [27];
- if naps occur during the circadian core body temperature trough or circadian low [28] (normally in the middle of the night for a diurnally-oriented person);
- when the person is sleep deprived or has been awake for an extended period [29]; and the nap contains or ends with slow-wave sleep. [30]

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22 Lubin, A., Hord, D., Tracy, M., & Johnson, L. (1976). Effects of exercise, bedrest and napping on performance decrement during 40 hours. *Psychophysiology*, *13*, 334-339

23 Ferrara, M. & De Gennaro, L. (2000). The sleep inertia phenomenon during the sleep-wake transition: Theoretical operational issues. *Aviation, Space and Environmental Medicine, 71*, 843-848

24 See for examples: Webb, W. & Agnew, H. (1974). *The effects of a chronic limitation on sleep length. Psychophysiology*, *11*, 265-274;Wilkinson, R. & Stretton, M. (1971). Performance after awakening at different times of night. *Psychonomic Science*, *23*, 283-285

25 Dinges, D., Orne, M., Whitehouse, W., & Orne, E. (1987). Temporal placement of a nap for alertness: Contributions of circadian phase and prior wakefulness. *Sleep*, *10*, 313-329; Ferrara, M. & De Gennaro, L. (2000). The sleep inertia phenomenon during the sleep-wake transition: Theoretical operational issues. *Aviation, Space and Environmental Medicine, 71*, 843-848

26 For example: Jewitt, M., Wyatt, J., Ritz-De Cecco, A., Khalsa S., Djik D., & Czeisler, C. (1999). Time course of sleep inertia dissipation in human performance and alertness. *Journal of Sleep Research*, *8*, 1-8.

27 Matchock R. & Mordkoff (2007). Visual attention, reaction time, and self-reported alertness upon awakening from sleep bouts of varying lengths. *Experimental Brain Research, 178*, 228-239; Dinges, D., Orne, E., Evans, F., & Orne, M. (1981). Performance after naps in sleep-conducive and alerting environments. In L. Johnson, D. Tepas, W. Colquhoun, & M. Colligan, (Eds.), *Biological Rhythms, Sleep and Shift Work* (pp. 539-553). New York: Spectrum Publications

28 See for examples: Dinges, D., Orne, M., & Orne, E. (1985). Assessing performance upon abrupt awakening from naps during quasi-continuous operations. *Behavior Research Methods, Instruments, and Computers, 17*, 37-45; Lavie, P. & Weler, B. (1989). Timing of naps: effects on post-nap sleepiness levels. *Electroencephalography and Clinical Neurophysiology, 72*, 218-224;Dinges, D., Orne, M., Whitehouse, W., & Orne, E. (1987). Temporal placement of a nap for alertness: contributions of circadian phase and prior wakefulness. *Sleep, 10*, 313-329.

One of the detrimental effects of sleep inertia is a decrease in cognitive processing speed. [31] For example, it takes longer than normal for a person experiencing sleep inertia to filter out incongruous visual information. [32]

Given that a decrease in cognitive processing speed, confusion and disorientation are characteristic performance decrements of sleep inertia and that it also results in a propensity for visual distraction and reduced ability to filter out irrelevant visual information, [33] it is important to allow adequate recovery time after a nap to offset sleep inertia's effects.

It is also important to control the amount of sleep during controlled rest. One study [34] showed that the best reaction times were demonstrated after naps of only 20 minutes compared to naps of 50 and 80 minutes. This may be a direct result of awakening from slow-wave sleep in the longer nap condition. [35]

Assessing Flight Paths of Opposite-direction Aircraft at Night

The assessment of relative position at night is difficult: there are few external cues by which the position and motion of objects can be assessed. Visual cues are further reduced if the cockpit lights are turned on full. In the case of assessing whether an oncoming aircraft at similar altitude will pass above or below, there is no horizon by which to assess the relative motion.

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29 See for examples: Dinges, D., Orne, M., & Orne, E. (1985). Assessing performance upon abrupt awakening from naps during quasicontinuous operations. *Behavior Research Methods, Instruments, and Computers, 17*, 37-45; Ferrara, M., De Gennaro, L., & Bertini, M. (2000). Voluntary oculomotor performance upon awakening after total sleep deprivation. *Sleep, 23*, 801-811.

30 See for example: Feltin, M. & Broughton, R. (1968). Differential effects of arousal from slow wave sleep and REM sleep. *Psychophysiology*, *5*, 231

31 See for example: Tassi, P. & Muzet, A. (2000). Sleep inertia. *Sleep Medicine Reviews, 4(4)*, 341-353

32 Matchock R. & Mordkoff (2007). Visual attention, reaction time, and self-reported alertness upon awakening from sleep bouts of varying lengths. *Experimental Brain Research*, *178*, 228-239.

33 See for examples: Matchock R. & Mordkoff (2007). Visual attention, reaction time, and self-reported alertness upon awakening from sleep bouts of varying lengths. *Experimental Brain Research*, *178*, 228-239; Tassi, P & Muzet, A. (2000). Sleep inertia. *Sleep Medicine Reviews*, *4(4)*, 341-353.

34 Evans, F. & Orne, M. (1976). *Recovery from fatigue*. Annual Summary Report No. 60. Fort Derrick, MD: US Army Medical Research and Development Command

35 Stampi, C., Mullington, J., Rivers, M.,Campos, J., & Broughton, R. (1990). Ultrashort sleep schedules: Sleep architecture and the recuperative value of multiple 80- 50- and 20 –min naps. In J. Horne (Ed.) *Sleep '90* (71-74). Bochum, U.K.: Pontenagel Press.

When the aircraft is distant it appears as a single point of light with no motion relative to the observer. Based on tests conducted in an Air Canada B767 simulator, no distinct motion up or down the field of view of an oncoming aircraft was detectable until the aircraft was 15 seconds apart at a closure speed of 900 knots. An oncoming higher aircraft then moves up the visual field and an oncoming lower aircraft moves down the visual field. There are no known illusions where a person can perceive an oncoming object as moving contrary to the actual path.

C-GHLQ Boeing 767-333

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. Nothing was found to indicate that there was any system malfunction prior to or during the flight.

The aircraft was equipped with a cockpit voice recorder (CVR) that had a 2-hour recording capacity and a digital flight data recorder (DFDR) with a 25-hour recording capacity. The event was captured on the DFDR but not on the CVR. The aircraft was just over 3 hours from arrival in Zurich when the pitch excursion occurred; therefore, the event was overwritten on the CVR.

At the time of the occurrence, the aircraft's autopilot flight director system was engaged in the normal single-channel mode for cruise flight. A crew member can manipulate the controls when the autopilot is engaged: the engaged autopilot servo will cam-out and the flight crew will have direct control of the primary flight control surfaces. A push or pull force of 24 pounds is required for this action to occur on the elevator servo. A push force of 80 pounds was input by the FO during the event.

The following TSB laboratory report was completed:

LP009/2011 FDR Analysis

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

Analysis

Sleep Inertia

The FO felt fit for flight at the time of reporting for duty at 1935, which likely coincided with a circadian high. [36] However, the interrupted sleep obtained in the 24 hours immediately preceding the flight increased the likelihood the FO would feel fatigued and need rest during the overnight eastbound flight, particularly as a circadian low was reached. The FO fell

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36 A circadian high is a period of normal or optimal alertness and performance. Circadian highs occur during the daytime hours for the diurnal person.

completely asleep during the controlled rest period which also indicates the FO's level of fatigue.

With a view to providing a substantial rest, the captain allowed the FO to rest beyond the 40-minute maximum set as a defence against entering slow-wave sleep; the 75-minute rest that ensued increased the probability of entering slow-wave sleep. The severity and duration of sleep inertia are more likely to be worse if a person is awakened from slow-wave sleep, especially if the rest occurs at a circadian low and when the person is fatigued. Given the consistency between the conditions that worsen sleep inertia and the FO's sleep and controlled rest, and the observation that the FO felt unwell when awakened, it is likely that the FO was suffering from high levels of sleep inertia.

Action Taken Following Identification of the Oncoming Aircraft

The captain followed standard procedure after the identification of the oncoming aircraft as a TCAS target on the ND. The captain sought the aircraft visually—which, at this point, appeared as a single point of light approximately straight ahead of the aircraft—and verified the target. This task was made more difficult by the cockpit lights being on full, causing reflections in the cockpit glass and hindering the view outside the aircraft. At about this time the FO awoke. To avoid the FO being startled, the captain twice pointed out the relative position of the oncoming aircraft to the FO. This occurred approximately 1 minute after the FO had woken and was most likely suffering from the strong effects of sleep inertia. The FO was not in a state to effectively assimilate the information from both the instruments and from outside the aircraft or effectively provide an appropriate response. Despite having been trained to interpret TCAS targets and react to them, the FO was drawn to rely on immediate perceptual information. Under the effects of sleep inertia, the FO was likely confused and disoriented and perceived the aircraft on an imminent collision course. Consequently, the FO pushed forward on the control column to avoid the collision. The FO quickly realized the error because the traffic appeared to be moving down in the visual field, which did not make sense. By that time, the captain had reversed the control movement to return the aircraft to the previous altitude.

By identifying the oncoming aircraft, the captain engaged the FO before the effects of sleep inertia had worn off. As a consequence, the FO did not form an effective response to the situation.

Training for Controlled Rest Procedures at Air Canada

Several deviations from Air Canada controlled rest SOP occurred. They included:

- not advising the cabin crew of the intention to rest;
- not agreeing in advance on an end time of 40 minutes;
- not stopping the rest at 40 minutes; and
- not providing recovery time after the rest.

Each of these actions was consistent with common misunderstandings among Air Canada pilots.

The procedure for controlled rest provides a means to manage rest and avoid unsafe consequences. For instance, if sleep goes beyond 40 minutes, there is an increased risk of slow-wave sleep, which will likely be followed by longer and more severe sleep inertia. Sleep inertia will happen after any nap. It is particularly important, however, that naps taken during the night on a flight from North America to Europe conform to the procedure because these are likely to occur when other factors, such as the circadian low, are likely to exacerbate any sleep inertia.

The training provided by Air Canada on controlled rest was limited to repeating the procedure in the FOM to the trainees, and did not explain or emphasize why the boundaries of the procedure are critical to safety. The safety publication did describe some of these issues but this form of training does not reliably lead to the level of training required.

Although training was provided on controlled rest and the topic was covered in a recent Air Canada flight safety magazine, this was insufficient to ensure that pilots fully understood and carried out the controlled rest procedures.

Air Canada Analysis of Fatigue Reports

At Air Canada there are several methods in which flight crew can identify fatigue-related issues during flight operations: Aviation Safety Reports, Flight Crew Reports (FCR) and specific fatigue reporting forms distributed by ACPA. Such a wide range of options allows a situation where safety issues related to fatigue may be reported in one system but not analyzed because it does not appear in Air Canada’s SMS. The TC-recognized SMS reporting system at Air Canada may not be effective as several reporting systems are being used to report fatigue-related safety issues.

Passenger Safety

Passengers had been briefed to always wear their seatbelts when seated. Although the seatbelt sign was on and an announcement was made regarding potential turbulence, several passengers were injured during the event because they were not wearing their seatbelt. Some passengers may not be aware of the inherent risks in not wearing a seatbelt at all times when seated.

Use of Relief Pilot

Night flights from North America to Europe have an inherent risk of fatigue for North American-based pilots. Research to date has not identified a level of alertness required in order to ensure the safety of operations at the end of such a flight, particularly during the heavy workload period of approach and landing. While controlled rest mitigates fatigue to some extent, studies have not been able to show whether it is sufficient in order to fully mitigate fatigue during this type of flight. More effective rest can be obtained with the use of a relief pilot on eastbound flights.

Findings as to Causes and Contributing Factors

1. The interrupted sleep obtained by the first officer prior to the flight increased the likelihood that rest would be needed during the overnight eastbound flight.

2. The first officer slept for approximately 75 minutes which likely placed the first officer into slow-wave sleep and induced longer and more severe sleep inertia.

3. The first officer was experiencing a circadian low due to the time of day and fatigue due to interrupted sleep which increased the propensity for sleep and subsequently worsened the sleep inertia.

4. By identifying the oncoming aircraft, the captain engaged the first officer (FO) before the effects of sleep inertia had worn off.

5. Under the effects of sleep inertia, the first officer perceived the oncoming aircraft to be on a collision course and pushed forward on the control column.

6. The frequency of training and depth of the training material on fatigue risk management to which the flight crew were exposed were such that the risks associated with fatigue were not adequately understood and procedures for conducting controlled rest were not followed by the flight crew.

7. Although the seatbelt sign was on and an announcement about potential turbulence was made, several passengers were injured during the event because they were not wearing their seatbelt.

Findings as to Risk

1. North American-based pilots flying eastbound at night towards Europe are at increased risk of fatigue-related performance decrements.

2. The use of multiple safety occurrence reporting systems may result in some safety issues not being properly identified and analyzed.

3. Some passengers may not be aware of the inherent risks in not wearing a seatbelt at all times when seated.

Other Finding

1. As the aircraft cockpit voice recorder (CVR) was only capable of recording for 2 hours, the event was overwritten.

Safety Action Taken

Air Canada

On 2 March 2011, Air Canada issued FOM Bulletin 13-11 emphasizing that flight crew must adhere to all components of the SOP in order for the controlled rest to be implemented safely. The bulletin emphasized the requirement to notify the applicable flight attendant and to arrange for a call from the flight attendant no later than 45 minutes from the time of briefing.

On 2 March 2011, Air Canada issued FOM Bulletin 14-11 which emphasized the benefits of using strategic lateral offset procedures (SLOP) and to offset by 1 or 2 nm at all times including random tracks unless the course places the aircraft on a less desirable track.

On 23 March 2011, Air Canada Flight Operations issued bulletin 28-11 identifying a Pairing Evaluation and Assessment Committee (PEAC) data collection exercise on the Toronto-Zurich route in an effort to understand the alertness levels of crews on these flights. This committee has both company and association representation.

Air Canada Cabin Safety issued a bulletin to all in-flight service personnel that cabin crew are an important part of the SOP for controlled rest on the flight deck and emphasized the flight deck briefing that is required and the call to the flight deck when 45 minutes have elapsed.

Air Canada Pilots Association (ACPA) – Technical and Safety Division

On 1 March 2011, ACPA issued newsletter No. 3, a Crew Flash Alert from the Technical and Safety Division, regarding the collection of data on flights that occur in the window of circadian low. This 60-day collection of data commenced with the Toronto-Zurich-Toronto operation but may expand to other similar routes. Pilots were asked to fill out the ACPA fatigue form prior to top of descent to capture the subjective rating of their alertness/fatigue. This survey is in addition to the data collection efforts of the Flight Standards and Quality department.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 07 March 2012. It was officially released on 16 April 2012.

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 – Seating Diagram and Location of the Injured