Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A11Q0028

RISK OF COLLISION

AIR INUIT LTD.
BETWEEN DHC-8-314 C-GUAI
AND DHC-8-102 C-FCJD
PUVIRNITUQ, QUEBEC, 117 NM SOUTH
07 FEBRUARY 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

Risk of Collision

Air Inuit Ltd.
between DHC-8-314 C-GUAI
and DHC-8-102 C-FCJD
Puvirnituq, Quebec, 117 nm South
07 February 2011

Report Number A11Q0028

Synopsis

The DHC-8-314 (registration C-GUAI, serial number 423), operated by Air Inuit Ltd. as flight AIE880, was flying in accordance with instrument flight rules between Puvirnituq and La Grande-Rivière, Quebec, at flight level 220. Another aircraft operated by Air Inuit Ltd., a DHC-8-102 (registration C-FCJD, serial number 158), flight AIE304, was flying in the opposite direction at flight level 230, in accordance with instrument flight rules. Approximately 117 nautical miles south of Puvirnituq, the 2 aircraft received a traffic advisory, followed by a resolution advisory from the traffic alert and collision avoidance system. Avoidance manoeuvres were performed, and the 2 aircraft passed each other with a separation of approximately 1500 feet in the vertical plane and 0.8 nautical miles in the horizontal plane. They continued toward their respective destinations, where they landed without problem. The event occurred at 1436 Eastern Standard Time, in daylight. No one was injured.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

At 1328, [1] the DHC-8-102 operating as AIE304, with 3 crew members and 28 passengers aboard, took off from La Grande-Rivière for Puvirnituq, Québec. The first officer was acting as pilot flying (PF) while the aircraft captain was acting as pilot not flying (PNF). The instrument flight rules (IFR) clearance received prior to departure authorized AIE304 to follow a direct route toward Puvirnituq and to climb to flight level (FL) 250. [2] However, during the climb, upon request by the flight crew, the aircraft was authorized to maintain FL230, an altitude reached at 1349.

At 1357, upon request by the flight crew, AIE304 was authorized to switch from the Montréal Area Control Centre frequency to the en route frequency. [3] The aircraft left radar coverage [4] at 1416, approximately 175 nautical miles (nm) north of the Chisasibi radar facility located 55 nm northwest of La Grande-Rivière airport. Ten minutes earlier, at 1406, another Air Inuit Ltd. aircraft, a DHC-8-314 operating as AIE880, with only a 3-member flight crew, took off from Puvirnituq for La Grande-Rivière. Flight AIE880 was also authorized to pursue a direct route to its destination. The flight had been planned for FL220, but once en route, the flight crew asked to climb to FL250. However, because of AIE304 heading in the opposite direction, at FL230, AIE880 was authorized to maintain FL220 until it had passed AIE304.

Due to recurring aircraft pitch oscillations when the autopilot's altitude-hold mode was selected, the flight crew of AIE304 opted to engage vertical speed (VS) mode [5] on the flight guidance mode selector in order to maintain the altitude of 23 000 feet selected on the altitude alerting system. During the flight, the PF had to leave the cockpit for physiological reasons. The controls were transferred to the aircraft captain, who became the PF during the first officer's absence. At this time, the aircraft was flying at FL230 toward Puvirnituq.

At 1421:35, without the captain noticing, AIE304 began a slow descent (Appendix A). The aircraft lost just over 700 feet of altitude over a 14-minute period, [6] which corresponds to an average rate of descent of approximately 50 feet per minute. When the descent began, the aircraft were separated by a distance of 131 nm on opposing tracks (Appendix B). AIE304 was maintaining a heading of 7° magnetic (M) and AIE880 was maintaining 210°M. Although the captain of AIE304 visually scanned the instruments sporadically, his attention was largely focused outside as he contemplated the landscape of the eastern coast of Hudson Bay.

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1 Times are expressed in Eastern Standard Time (Coordinated Universal Time minus 5 hours).

2 Altitude expressed in hundreds of feet, indicated on an altimeter set to 29.92 inches of mercury.

3 Since the aircraft was flying under IFR in controlled airspace but without radar coverage, no en route frequency was designated. However, frequency 122.75 MHz can be used for air-to-air communications between pilots for flights within Canadian Southern Domestic Airspace, as in this case.

4 The maximum range of radar is 161 nautical miles at this altitude.

5 This mode is used to maintain the desired rate of climb or descent.

6 Between 1421 and 1435

Upon return, the first officer of AIE304 was standing in the cockpit entrance and observed the vertical speed indicator screen, which serves as the traffic alert and collision avoidance system (TCAS) display, indicating the presence of a target straight ahead and slightly to the right. A traffic advisory (TA) was heard followed by a resolution advisory (RA) requesting climb. Before the first officer could sit, the captain disconnected the autopilot and turned right, banking up to 38°. During this turn, the aircraft lost just over 50 feet in altitude before beginning to climb. The turn, which was started at 1435:37—that is, 5 seconds after the captain had disengaged the autopilot—was stopped on 045°M.

At 1435:26, 2 seconds after receiving a TA, the first officer of AIE880, who was acting as PF, disconnected the autopilot. He made a shallow turn to the right with a minor loss of altitude. At 1435:38, he made a shallow left-climbing turn before being warned by the PNF to halt the turn, and began descending as requested by the RA. The PF believed that the visual indication on the vertical speed indicator was recommending the turn. Following the actions taken by the 2 PFs, the aircraft passed each other at 1436:12, with a separation of approximately 1500 feet[7] in the vertical plane and 0.8 nm in the horizontal plane. AIE880 and AIE304 returned to their authorized altitude at 1437 and 1437:46, respectively. They continued toward their destination, where they landed without incident.

1.2 Personnel Information

The 2 flight crews were certified and qualified for the flight, in accordance with existing regulations. Also, the duty and rest time of both flight crews were within prescribed limits. There is no evidence to indicate that fatigue played a role in this occurrence. The flying experience of the pilots is summarized in the following table.

Table 1. Pilots' flying experience

Types of aircraft and position title	AIE304 captain	AIE304 co-pilot	AIE880 captain	AIE880 co-pilot
	Hours of flight			
DHC-8 captain	4500	0	300	12
DHC-8 co-pilot	0	700	0	350
Other types	16 500	4100	8200	6638
Total	21 000	4800	8500	7000

1.3 Aircraft Information

1.3.1 Autopilot Information

Appropriate use of an autopilot reduces the workload of the pilot and increases safety. The standard operating procedures (SOP) stipulate that with autopilot engaged, it is essential to monitor the aircraft to prevent an inadvertent deviation in the track or altitude.

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7 AIE304 was at FL228, and AIE880 was at FL213

Among other things, the flight guidance mode selector located on the glare shield panel enables the pilot to select several different guidance modes, including VS mode (Photo 1). When selected, this mode maintains the current vertical speed of the aircraft at the time of activation. The vertical speed can be changed using the "NOSE DN / NOSE UP" pitch trim wheel located on the selector. The new vertical speed to be maintained appears on the advisory display unit and remains there until a new mode is activated. Since VS mode is used primarily to maintain a desired rate of descent or climb, its ability to maintain precisely a set altitude, such as VS-0, has not been evaluated for certification purposes. However, the autopilot manufacturer indicated that VS mode should be capable of maintaining the desired rate ± 300 feet when used for descents and climbs.

Photo 1. Flight guidance mode selector

In this occurrence, the aircraft used for flight AIE304 was oscillating in pitch when the autopilot was engaged in altitude-hold mode. For this reason, the crew chose to use VS mode to halt the oscillation, by displaying "0" as the vertical speed. The use of VS mode, in such a case, was customary and also used by other pilots in the company. Nothing prohibited it. Furthermore, the minimum equipment list (MEL) allows flight, with certain restrictions, despite an autopilot defect. Among other things, the MEL indicates that any mode that functions can be used. According to the Pilot's Manual, [8] vertical plane oscillation is a typical issue that can arise in various modes of use. [9]

Pitch oscillations when the autopilot was engaged had been observed in the past, not only by this crew or on this particular aircraft, but on other DHC-8s of the company. Nothing indicates that this situation had been formally pointed out to the company's maintenance personnel, such as by means of an entry in the aircraft logbook.

In this occurrence, the cause(s) of the pitch oscillations could not be determined. In the autopilot manufacturer's experience, there are 2 likely causes for the problem: poor tension of the flight control cables or a malfunction of the air data computer.

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8 SPZ-8000 Digital Integrated Flight Control System Pilot's Manual for the De Havilland Dash 8.

9 ALT mode (maintain altitude), VS mode (maintain vertical speed), IAS mode (maintain indicated airspeed) and MACH mode (maintain MACH speed)

1.3.2 Altitude Alerting System

The altitude alerting system controller, located to the left of the engine instrument panel, consists of a set knob and a 5-figure digital display. As soon as the aircraft deviates more than 250 feet from the altitude selected, the altitude warning light located on each of the pressure altimeters lights up as a visual alarm[10] (Photo 2). It does not flash.

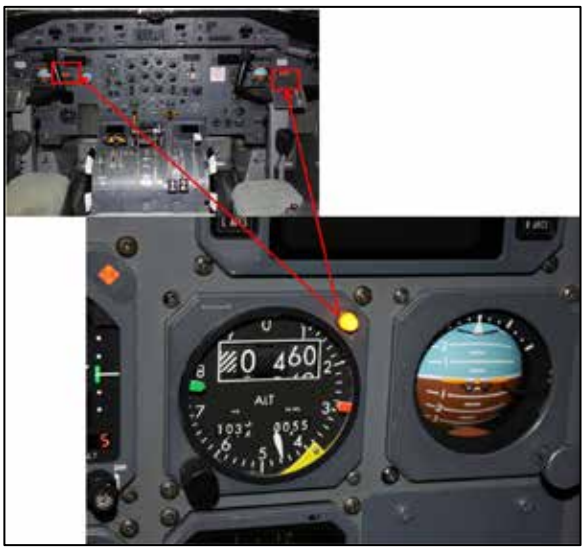

Photo 2. Altitude warning light

In this occurrence, the light would have illuminated when AIE304 descended below 22 750 feet, and would have remained lit until the aircraft returned to the altitude selected. The PF, alone in the cockpit at that time, did not observe the warning light. Following the occurrence, no anomaly in the warning light was reported by the flight crew in question, or by subsequent flight crews. All indications are that it operated correctly.

1.3.3 Traffic Alert and Collision Avoidance System

The 2 aircraft were equipped with a TCAS II manufactured by Collins. [11] TCAS II provides 2 types of traffic alert warnings: a traffic advisory (TA) warns the flight crew of a potential conflict, and if the system determines that the possibility of conflict escalates to the point where action is required to correct the situation safely, the system issues a resolution advisory (RA) to the flight crew. The advisories consist of audio announcements as well as a symbolic depiction on the vertical speed indicator (VSI), which serves as the display (Appendix C).

Although the display allows visualization of aircraft intruding within a radius of 6 nm and 12 nm, the conflict surveillance area extends to a radius of roughly 40 nm. [12] All audio announcements consist of actions required in the vertical plane. As designed, the system does not issue any commands to perform a turn.

The logic behind effective operation of the TCAS calls for a compromise between the required protection and unnecessary advisories by controlling the sensitivity level (SL). [13] The SL varies according to the altitude at which the aircraft is flying. In other words, the higher the altitude, the higher the SL, which results in greater protection. Since the aircraft were travelling at an altitude over 20 000 feet, their SL was level 7. At

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10 An audible alarm is available as an option on some DHC-8 series 100s. AIE304 was not equipped with this option.

11 AIE304 was equipped with model TTR-920 while AIE880 was equipped with model TTR-921. However, both had version 7.0 processors.

12 The manufacturer of the display system may offer different selectable ranges.

13 The SL ranges from 1 to 7.

this level, a TA is issued when the aircraft is 48 seconds from the closest point of approach (CPA). A TA consists of a visual indication on the VSI indicator of the relative position of the intruding aircraft as well as an audible announcement of "TRAFFIC, TRAFFIC", which affords the flight crew the opportunity to visually identify the intruder and prepare to perform a possible avoidance manoeuvre.

Since the CPA occurred at about 1436:12, a TA should have sounded at 1435:24. Following the TA, the captain of AIE880 spotted the vapour trail behind AIE304, which indicated that the aircraft was on its right and approaching.

In the event of a level-7 SL, an RA is activated when the aircraft is 35 seconds from the CPA. It consists of an audible announcement commanding the vertical-plane manoeuvre that the PF must make to avoid collision, as well as a visual depiction on the VSI (Appendix C). The visual depiction consists of a green band recommending a target vertical speed range that will provide an adequate vertical separation, if heeded. A red band also appears indicating the vertical speed range to be avoided.

Also, on the indicator are symbols representing the relative position of aircraft intruding in the horizontal plane accompanied by 3 other symbols: a numeric value indicating the difference in altitude with the intruder(s), accompanied by a +/- symbol to indicate the relative altitude, as well as an adjacent arrow indicating whether the intruder is climbing or descending.

According to the aircraft flight manual, TCAS warnings are based on the precision of the pilot in performing the RA manoeuvre within 5 seconds, and within approximately 2 seconds if another corrective RA is issued. The manual also indicates that when an RA predicts an intersecting trajectory, all efforts should be made to visually locate the intruder in order to ensure adequate separation. In this case, it was not possible to determine the accuracy of the TCAS warnings generated, since neither the TCAS nor the DFDR recorded this data.

The investigation determined that AIE304 received an advisory to climb, while AIE880 received an advisory to descend. In this case, an RA should therefore have been issued at around 1435:37. All indications are that the 2 TCAS operated correctly during the occurrence.

1.4 Meteorological Information

At the time of the occurrence, the 2 aircraft were travelling under visual flight conditions with a cloudless sky. There was no turbulence forecast at the altitude at which the aircraft were flying, and none was reported. Meteorological conditions did not play a role in this occurrence.

1.5 Airspace Information

Flights AIE304 and AIE880 were flying in class A airspace [14]. Although this airspace is controlled, radar coverage is limited depending on the distance and altitude of aircraft. In this occurrence, the 2 aircraft were outside the radar range. However, NAV

[14] Airspace from 18 000 feet above sea level to FL600 inclusive, in which all flights must be made according to instrument flight rules and the aircraft equipped with a transponder and automatic pressure-altitude transmission equipment.

CANADA ensures air control and aircraft separation using procedural methods, i.e., without radar identification and, in this case, without direct communication.

Using the Canadian Automated Air Traffic System (CAATS), the controller can obtain projections of aircraft positions. Aircraft are graphically depicted on a screen, which allows the controller to maintain greater awareness of the situation. When positions are reported, the controller updates the positions in CAATS, which makes it possible to update the projections. Use of CAATS does not provide a controller with real-time altitude information.

Upon request by the flight crew, the controller authorized AIE304 to leave the radio frequency and switch to the en route frequency. However, no specific frequency is assigned in the area flown over by the 2 aircraft. Although the 126.7 MHz frequency is normally used for IFR flights in uncontrolled airspace or for VFR flights in controlled airspace, nothing requires a flight crew to monitor 126.7 MHz. Furthermore, 122.75 MHz can be used for air-to-air communications between pilots during flights within Canadian Southern Domestic Airspace, as in this case. Pilots are not required to report their positions except when specifically asked to do so by the controller.

When required, position reports are transmitted by the pilot by means of a remote communications outlet (RCO) or a dial-up remote communications outlet (DRCO), whichever is closer to his position. The flight service specialist who receives the message will relay it to the controller in the Montréal Area Control Centre (ACC). Exceptionally, the controller can use a frequency that enables direct communication with aircraft flying in the region, but this frequency is assigned to another control sector.

1.6 Telecommunications

Both AIE304 and AIE880 were equipped with 2 very high frequency (VHF) radios capable of transmitting and receiving. According to the company's standard operating procedures, VHF 1 is generally used for the en route frequency while VHF 2 is used for the company frequency. In the case of this occurrence, AIE304 was authorized to use the en route frequency at 1357. As indicated earlier, no specific frequency was assigned. It was determined that AIE304 had VHF 1 selected on the frequency 123.27 MHz, the Puvirnituq (CYPX) DRCO, and VHF 2 on 121.5 MHz, the emergency frequency. Until the 2 aircraft crossed paths at 1436, the AIE304 flight crew had not transmitted its position or its intentions on either VHF 1 or 2, nor was it required.

To accommodate the request of AIE880 to climb to FL240, the flight service specialist (FSS) at the Québec flight information centre (FIC) attempted unsuccessfully to reach AIE304 4 times [15] on 126.7 MHz in order to determine its exact position. Since 126.7 MHz is generally used as the en route frequency, it is possible that the FSS expected the flight crew to be monitoring it. This transmission was issued on the Inukjuak (CYPH) DRCO and the Puvirnituq (CYPX) DRCO as well, among others. Since AIE304 was not set to 126.7 MHz, it would not have been able to hear these broadcasts.

After the 2 flights crossed paths, AIE880 returned to FL220 and notified the FIC that it had just passed AIE304 and repeated its request to climb to FL240. To authorize this request, the FIC

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15 Between 1430 and 1432

again attempted without success to reach AIE304. It was not until 1445—9 minutes after the 2 aircraft passed each other—that AIE304 communicated with the FIC on 126.7 MHz. Neither flight crew mentioned to the FIC the deviation in altitude to comply with the RA.

Both the aeronautical information manual (AIM) [16] and the company flight operations manual indicate that the pilots must inform the appropriate ATC as soon as possible after a deviation in altitude resulting from an RA. Their report must include the direction of their flight and the time they were back on track and at their assigned altitude. The occurrence was reported later in the day to the company and to NAV CANADA.

1.7 Flight Recorders

The flight data recorders (FDR) of the 2 aircraft were sent to the TSB Laboratory for examination. Although the recorded data parameters were limited, they did make it possible to determine the proximity of the 2 aircraft to each other. [17]

Each of the aircraft was equipped with a cockpit voice recorder (CVR) capable of recording and saving the last 30 minutes of sounds heard in the cockpit. The 2 CVRs were sent to the BST Laboratory. However, since each of the flights continued for more than 30 minutes after the occurrence, the audio recordings were overwritten.

The 2 CVRs met the requirements of the existing regulations. The majority of new CVRs equipped with semiconductor memories offer a recording capacity of 2 hours. Conversations and RAs heard by the pilots in the cockpit during the risk of collision would have been very useful to the investigation.

On 09 March, 1999, the TSB recommended [18] to Transport Canada (TC) and the European Joint Aviation Authorities that "as of 01 January, 2005, all aircraft that require both an FDR and a CVR be required to be fitted with a CVR having a recording capacity of at least 2 hours." TC supported this recommendation, provided that harmonization was maintained between the requirements of the United States Federal Aviation Administration (FAA) and those of Canadian authorities. Since its first response, dated 07 June 1999, TC has indicated its intention to present a notice of proposed amendment (NPA) to the regulation to rectify the deficiency described in recommendation A99-02.

Since April 2008, the FAA requires aircraft manufactured prior to 07 April 2010 to be equipped with a CVR with a recording capacity of at least 2 hours. The modernization of these aircraft must have been completed before 07 April 2012. Nearly 12 years after its initial response to recommendation A99-02, an NPA (2011-010) was prepared by TC and submitted to a CARAC Technical Committee meeting [19] in September 2011.

The Technical Committee accepted the NPA as presented, provided that it would be subject to a risk evaluation. TC stressed that the elements of the NPA could be altered following

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16 Aeronautical Information Manual TP1437

17 The error between the 2 flight trajectories determined using the FDR and radar data can be up to 1 nm.

18 Recommendation A99-02

19 Canadian Aviation Regulation Advisory Council

consultations, and based on the results of the risk evaluation, the cost/benefit analysis and other instruments that could be used to verify the proposed regulatory approach.

1.8 Company Information

1.8.1 General

Air Inuit Ltd. holds a valid operations certificate. At the time of the occurrence, the company operated a fleet of 28 aircraft: 1 Boeing 737, 1 Turbo Otter, 1 DHC-2 and 2 helicopters, 3 Beechcraft 100s, 3 HS-748s, 7 DHC-6s and 10 DHC-8s. Only the company's Boeing 737 and DHC-8s are equipped with a TCAS. Operation of its DHC-8s began in 1995, and at that time, these aircraft were already equipped with a TCAS. Depending on the type of aircraft used, the TCAS are operated in compliance with subparts 2, 3, 4 and 5 of Part VII of the *Canadian Aviation Regulations* (CARs). In this occurrence, the 2 aircraft were used in compliance with CAR subpart 5. [20]

Flight AIE304 is a regularly scheduled flight normally made with a Boeing 737. For operational reasons on the day of the occurrence, this flight was made using a DHC-8. The captain of the AIE304 was nonetheless familiar with the route, having made the flight a number of times before. However, he did not know that he would be crossing paths with flight AIE880, which is an on-demand cargo flight.

1.8.2 Cruise Flight-Task Information

The SOPs indicate the various tasks that flight crews must perform once the aircraft is in cruise. Most of these tasks are performed as soon as the aircraft reaches cruising altitude. These include:

- Cruise power shall be set and maintained according to the maximum cruise power tables.
- The 2 pilots shall verify the engine instrumentation, lights, pressurization, igniters and de-icing equipment to confirm the correct operation of these systems; external monitoring shall also be performed.
- Engine parameters shall be noted during the first flight of each day, if flight conditions and workload permit.
- Awareness of the situation shall be maintained at all times.

Prior to beginning descent:

- The PNF shall obtain the latest weather observations for the destination. The standby altimeter and pressurization shall be set, take-off and landing data displayed, and the planned approach chart prepared.
- The approach briefing may be given prior to beginning descent.

Discipline is to be maintained in the cockpit, as is indicated in the company flight operations manual. Among other things, it indicates that a pilot may leave the cockpit for physiological reasons or for any other overriding concern related to flight safety.

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20 Airline operations

1.8.3 Training Information

The AIM [21] stipulates that in order to satisfy regulatory requirements, Canadian operators must cover the following with respect to flight crew TCAS training, inspection and maintenance:

- Initial ground training
- Initial flight training (except for those programs which do not require flight training, as permitted by FAA Advisory Circular AC120-55A, as amended)
- Initial training
- Recurrent training
- Maintain qualifications current.

According to the AIM, TC requires the same standards as those indicated in the modified FAA Advisory Circular AC120-55A, as amended. This circular covers several elements related to the qualification of flight crews and the use of TCAS. The circular also stipulates that, in addition to academic training on TCAS, specific training regarding manoeuvres is required to ensure that the procedures and responses to TCAS advisories are appropriate.

According to an FAA document published in November 2000, [22] experience has shown that it is essential that flight crews who are called on to use aircraft equipped with TCAS complete theoretical and practical training. Pilots must understand how TCAS works. This includes alert thresholds, the expected response to a TA and an RA, appropriate use of the information displayed on the TCAS, phraseology, and system limitations.

The investigation determined that training related to TCAS equipment is not provided during the initial 59-hour ground training or the 16-hour recurrent ground training sessions. According to the company training program, when the pilot is hired, ground training on the operation and use of TCAS is provided during the company's orientation training. The aircraft captain aboard AIE304 had been employed by the company since 1990 at which time none of the company's aircraft was equipped with TCAS. During recurrent ground training in 2010, a CD containing a self-paced study program was provided to pilots. Among other things, this program contained a PowerPoint presentation covering the following points:

- Basic principles of TCAS operation
- Description of symbols appearing in the TCAS display
- Types of TCAS advisories
- PF and PNF tasks in the event of a TCAS advisory.

There is no record that this self-paced study program was completed by the captain of AIE304 or the co-pilot of AIE880, who were the 2 PFs during this occurrence. In the case of the other pilots, the self-paced study program appears to have been completed in February 2010.

According to the self-paced study program, the following tasks should be performed during a TCAS advisory:

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21 AIM RAC 12.16.4 Operational Approval

22 Introduction to TCAS II version 7.0

Table 2. Tasks to be performed during a TCAS advisory

Type of TCAS advisory	PF tasks	PNF tasks
Traffic advisory (TA)	With the aid of information appearing on the TCAS display, begin a visual search for the intruder. If, and only if, the intruder is spotted, manoeuvre the aircraft in order to maintain separation.	With the aid of information on the TCAS display, announce the relative bearing, using the o'clock reference position, distance and relative altitude of the intruder for the pilot flying. Assist the PF in visually searching for the intruder.
Resolution advisory (RA)	Use all means available, and leave the space in which you were manoeuvring. If necessary, quickly and smoothly adjust the vertical speed of your aircraft so as to maintain the vertical speed indicator (VSI) needle just outside the red zone of the VSI. This should not require more than one manoeuvre equivalent to ¼ g. A deviation in the authorization assigned, for example, to climb or descend if you are in level flight, or to stabilize if you are climbing or descending, is authorized in order to comply with an RA.	Using the VSI information, confirm that the current PF action complies with the RA.
Once the traffic has passed	Quickly and smoothly return the aircraft to the previously assigned authorization.	At the discretion of the aircraft captain, inform the ATC that a situation occurred that caused an RA.

The AFM also provides the appropriate TCAS system limitations and procedures, as well as a comprehensive description of all normal modes of operation, including expected flight crew procedures.

Responding to an RA requires prompt and appropriate reactions on the part of the pilots. This is why the FAA document indicates that it is important to include an RA in routine simulator exercises, such that pilots are able to experience the circumstances surrounding an RA in a realistic environment. Company flight crews do their DHC-8 training in a flight simulator capable of simulating TCAS advisories. However, nothing in the training files of the crews involved indicates that RA scenarios were practised in the simulator during their initial training or during their recurrent training.

1.8.4 Safety Management System

Air Inuit Ltd. has had a TC-approved safety management system (SMS) since January 2009. Some elements of an SMS program, including occurrence reporting, were in place prior to approval of the program by TC. The Air Inuit Ltd. SMS covers all elements indicated in the guidance material regarding the TC SMS, which are as follows: event or hazard reporting either formally or confidentially, risk management, internal investigation processes, corrective action plans, safety issue trend tracking, performance analysis, employee safety training, and safety communication processes.

From 2007 to 2010, inclusive, several occurrences [23] were reported by company personnel under the company's SMS. Of these occurrences, 9 were related to a risk of collision or loss of separation, including 3 [24] which necessitated avoidance manoeuvres following a TCAS advisory. During these 3 events, the pilots at the controls executed a right turn. Two of these events occurred in uncontrolled airspace. Although the occurrence in question occurred in controlled airspace, it happened in an environment without radar surveillance.

Among the points raised following internal company investigations, communications appear to have been one of the predominant factors, involving

- incomplete communications;
- inadequate monitoring of the appropriate frequency;
- the absence of a position report;
- inaccurate position reports;
- congestion on the frequency used.

Following internal investigations of the first 2 occurrences, the company issued 2 interim operation bulletins to its pilots. The first bulletin[25] contained the following recommendations:

- Always tune in the appropriate frequency.
- Make clear and precise position reports in both languages, if necessary *[...]*.
- Have the "transponder" ON at all times.
- Verify, with another company aircraft, the proper functioning of mode C via their TCAS, principally up north, and report any snag to the company's maintenance department.
- For those who are equipped, keep the TCAS at 12 nm to check the traffic.

The second bulletin[26] contained the above recommendations, as well as the following ones:

- In uncontrolled airspace when using the global positioning system (GPS) or flight management system (FMS), why not do "DIRECT" once you are airborne instead of while on the ground, to ensure less converging routes, and then fly a 1.5 mile off-set to the right of the route.
- Adopt a company spacing requirement (to be included, very soon, in the SOP), always maintain a minimum of 1000 foot vertical spacing and 20 nm horizontal spacing during climbs and descents.
- Wait for 25 nm or more from the airport of departure before making company calls.

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23 150 occurrences in 2007, 211 in 2008, 219 in 2009, and 291 in 2010

24 19 June 2008
20 October 2009
07 February 2011, which is the occurrence in question

25 15 July 2008

26 26 November 2009

- Free up the frequency of 126.7; for weather or flight plans, use the appropriate frequency on the RCO or DRCO.

1.8.5 Risk Evaluation

The International Civil Aviation Organization (ICAO) defines risk as "the assessment, expressed in terms of predicted probability and severity, of the consequences of a hazard, taking as reference the worst foreseeable situation." [27] Since an in-flight collision involves serious damage, and generally loss of life, the severity of the occurrence is catastrophic, according to the ICAO definition (Appendix C).

Over the past decade, [28] 2168 occurrences related to a TCAS warning [29] were reported in Canada. Of this number, the Civil Aviation Daily Occurrence Reporting System (CADORS) reported 1864 losses of separation. However, not all losses of separation involve a risk of collision because, in some cases, the aircraft are not on converging trajectories. According to the TSB database, [30] 67 near-collisions occurred in the country during this same period. As a result, based on the ICAO definition, it can be concluded that the probability of a collision is either occasional [31] or remote. [32]

Considering the *remote* possibility and *catastrophic* severity, the ICAO safety risk assessment matrix shows that the risk of collision is unacceptable (Appendix D). As a result, according to the ICAO matrix, strategies to overcome or mitigate risks should be implemented to reduce the risk to as low a level as reasonably possible.

In the context of its SMS, Air Inuit Ltd. uses a risk assessment form. It determines the probability and severity of a hazard in order to determine the level of risk. Following its analysis of the risk of the occurrence of 20 October 2009, the index of probability indicated that the risk level associated with a risk of collision was undesirable and that risk mitigation was necessary. The risk analysis dated 12 November 2009 indicates that the following security measures were taken:

- Issue of an interim operational bulletin to all of its pilots
- Traffic conflict simulation during training flights
- Increased flight crew awareness of hazards associated with traffic conflict
- Special attention devoted to TCAS during theoretical training.

The following TSB laboratory report was completed:

LP016/2011 – FDR Analysis and Animation Analysis

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

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27 ICAO, *Safety Management Manual* (SMM), Doc 9859, AN/474, paragraph 5.2.8

28 01 January 2001 to 31 December 2010

29 Warnings reported involving RAs and TAs

30 Aviation Safety Information System (ASIS)

31 Likely to occur sometimes (has occurred infrequently)

32 Unlikely to occur, but possible (has occurred rarely)

2.0 Analysis

Nothing indicates that fatigue, weather conditions or the airworthiness of the aircraft played a role in this occurrence. This analysis will revolve around 3 points: the use of the autopilot; the factors that led the flight crew not to notice, during a 14-minute period, that the aircraft was losing altitude; and the reaction of the flight crews following the TCAS advisory.

For 14 minutes, until the traffic advisory (TA) was heard, the pilot flying AIE304 did not note that the aircraft was losing altitude. The aircraft had been cruising for 32 minutes when the descent began. It is therefore likely that the majority of tasks associated with cruise flight had been completed. The PF nonetheless should have maintained awareness of the situation at all times, even if the autopilot was engaged.

When the co-pilot left the cockpit due to physiological needs, the captain was alone at the controls. As a result, monitoring of the flight instruments should have been increased, since any anomalies or loss of altitude not observed by the captain could not be detected and reported by the co-pilot. Since there was no turbulence, the pilot expected that autopilot would likely maintain the altitude correctly in VS mode. Also, the pilot did not pay attention to the instruments, more specifically to the altimeter and vertical speed indicator.

Several factors may have contributed to a certain relaxation on the part of the PF of AIE304, leading him to admire the coastal landscape of Hudson Bay:

- The prevailing visual flight conditions and visibility, which afforded a good general view of the eastern coast of Hudson Bay
- The routine of flying in this region for over 20 years
- The low level of traffic and radio communication in the sector at the time
- The low workload in the cockpit
- The fact that crossing another aircraft in the opposite direction was unexpected.

As a result, the frequency of visual scanning of the flight instruments was reduced to the point that he did not notice that the aircraft was descending. Since the rate of descent was very slow, the speed and attitude of the aircraft were very similar to those of cruise flight. It was therefore impossible to note the descent without reference to the flight instruments.

Although the use of VS mode was the precursor to this occurrence, nothing prohibited the AIE304 flight crew from using it to maintain altitude. Due to aircraft pitch oscillations when altitude-hold mode was selected, which could be uncomfortable for passengers and crew, VS mode proved to be an acceptable “work-around” for maintaining altitude. This had already been done on previous flights without causing problems. Since VS mode, when activated, maintains the current vertical speed of the aircraft, it is possible that it was descending imperceptibly on the VSI at the time VS mode was activated. Although “0” (zero) may have been selected, it is possible that an imperceptible initial descent coupled with the level of precision of the autopilot in this mode may have contributed to the slow rate of descent.

2.1 Altitude Alerting System

Although the aircraft was equipped with an altitude warning light, this light attracts less attention than it might because it does not flash. In addition, under daylight conditions, the contrast between the light when extinguished and lit is reduced. Although it is possible that the sunny day may have reduced the light's visibility, special attention to the altimeter should have made it possible to detect the loss of altitude and the illumination of the indicator light. The captain did not see that once he had deviated more than 250 feet from the altitude displayed, the altitude warning light was lit for approximately 9 minutes. The installation of an audible alarm, such as that found on the other DHC-8 belonging to the company, would have provided an additional defence against unexpected loss of altitude.

When a warning system is present on certain aircraft but not on others in the same fleet, it can create a hazard for flight crews who are regularly obliged to switch between different aircraft models, particularly when the aircraft are very similar in other respects. As a result, flight crews are forced to rely on their memory of the different configurations of each aircraft, and they have to anticipate the absence of a warning or alert. It is possible that the captain expected to hear an audible warning if the aircraft deviated in altitude for any reason.

2.2 Reaction to the Resolution Advisory

At an SL of 7, flight crews have 13 seconds between the TA and RA to visually locate the intruding aircraft. At this time, a distance of 7.4 nm separated the aircraft, which were to the right of each other on a converging trajectory. The sky was clear, and no visual restriction prevented the 2 aircraft crews from seeing each other. Following the TA, the PNF of AIE880 was able to see the vapour trail of the intruder approaching from its right.

The TCAS display superimposes several symbols as representations, the interpretation of which can be ambiguous if training is absent, poorly adapted or incomplete. Following the RA, the PF of AIE880 had the reflex to turn left following a misinterpretation of the RA display. It is possible that the appearance of the target in the upper right-hand corner of the display may have caused the PF to turn left. In the case of the PF of AIE304, the right turn remains unexplained considering that the intruder was to his right. It is unlikely that the PF of AIE304 had, using the TCAS display, visually identified the other aircraft considering that he initiated a right turn when the aircraft was on his right on a converging trajectory.

TCAS advisories are quite rare, especially in environments where air traffic is less dense. The actions flight crews must take following a TCAS advisory are always performed at a time when stress is heightened and time is short. Under the effect of stress, the possibility of misinterpreting ambiguous information is increased. For pilots with many years of flying experience or training on aircraft not equipped with TCAS, which was the case for the PF of the AIE304, their automatic reaction when faced with traffic coming from the opposite direction may be to turn right. It is possible that the PF of AIE304 perceived the intruder on the TCAS display as being in front on an opposing trajectory without observing that it was slightly to the right of its trajectory. In a stressful situation, and when the workload is high, behaviour may return to what was learned in the past or to what is done habitually. This type of behaviour

would have been learned at the skill-based level, [33] such as a well-learned automatic behaviour. Considering that aviation regulations require pilots to turn right when there is a risk of frontal collision, it is possible that the right turn performed by the PF of AIE304 may have been the result of a well-learned and well-entrenched reaction.

Taking into account the time at which the crew of AIE880 initiated the descent, probably following the RA, and the 5-second delay allowed for the pilot to perform the RA manoeuvre, it may be concluded that the PF reacted promptly to the RA, despite the fact that he initiated a left turn, which he halted at the request of the PNF.

The right turn made by AIE304 was inappropriate considering the relative position of the other aircraft. This type of manoeuvre in an environment with heavier traffic could have adverse consequences. Although a turn might increase the distance between the 2 aircraft, it might also reduce the separation with other neighbouring aircraft and lead to a collision. Furthermore, the loss of lift caused by the turn with a 38° bank was corrected late. The aircraft lost altitude, and this loss delayed the climb as announced by the RA. Roughly 9 seconds elapsed between the time of the RA and the halting of descent, which is 4 seconds longer than the delay allowed to perform the RA manoeuvre. The element of surprise, the required shift in attention, which was diverted outside, and the inexperience of the captain with TCAS equipment were all factors that may have reduced his ability to react quickly to the TCAS advisory.

During the 2 previous occurrences, which were subjected to a risk analysis by the company, the pilots had also performed an avoidance manoeuvre, namely a right turn following a TCAS advisory. It is known that pilots sometimes do not react correctly to TCAS advisories, but this is generally limited to the vertical plane, with pilots not correctly following the rate of climb or descent announced by the TCAS.

2.3 Telecommunications

Neither crew reported their deviation in altitude. The self-paced study program indicates that this task is at the "discretion" of the aircraft captain while the company flight operations manual and the AIM stipulate that aircraft captains must report all occurrences related to an RA to air traffic services (ATS). It could not be determined whether this difference might have played a role in the 2 flight crews not reporting the deviation in altitude to the ATS in a timely manner.

Following earlier occurrences, the aviation company identified communications as a common factor in collision risks that arose, and issued recommendations in this respect, including one recommending that the appropriate frequency always be monitored. In the case of this occurrence, the aircraft was flying in airspace for which no en route frequency was designated. The absence of such a frequency may have led the flight crew of AIE304 to place little importance on radio communications once authorized to leave the frequency of the Montréal Area Control Centre. However, it was possible to maintain 2-way communications with ATS through the Québec FIC on the DRCO frequency.

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[33] Rasmussen, J. (1983). "*Skills, rules, knowledge; signals, signs, and symbols, and other distinctions in human performance models*". IEEE Transactions on Systems, Man and Cybernetics, 13, 257-266.

Although the controller can obtain projections of aircraft positions using CAATS, it is not possible for him to know if an aircraft has left the altitude it was authorized to maintain. Without direct radio contact, controllers have to submit their instructions to a flight service specialist who in turn relays them to the pilots. Therefore, delays in the transmission of important instructions to pilots flying over this region can arise.

2.4 Safety Management and Risk Assessment System

Safety culture is an important and considered factor within the company. Even before approval of its SMS in 2009, some elements of an SMS, such as occurrence reporting, were already in place, and occurrence reporting was on the rise. However, nothing indicates that the autopilot oscillation problems were reported in an official way, such as by means of an anomaly entry in the logbook. The oscillation problem of this model of autopilot is a typical and known problem. Since another option is possible, such as the use of VS mode, it is probable that the flight crews considered this to be a minor issue. As a result, informal reporting of the anomaly seemed to them to be adequate.

The company SMS made it possible to identify the risk of collision as an undesirable risk, and to establish that risk mitigation was necessary. Use of the risk assessment form employed by the company made it possible to come to the same assessment as use of the ICAO Safety Risk Assessment Matrix. However, the measures taken by the company did not prevent this particular occurrence. None of the risk analyses performed by the company took into consideration inappropriate actions taken by flight crews following an RA. All performed a right turn following an RA, although TCAS advisories provide instructions only in the vertical plane. The impact these manoeuvres could have under other circumstances was not taken into consideration. Also, nothing indicated that the company had questioned or attempted to understand why the crews had all turned right.

2.5 Training

Since 2010, an academic self-paced study program on the operation and use of TCAS has been available to flight crews. However, the training files of the flight crews concerned show that this training had been completed only by the 2 PNFs. Although the PNF of AIE304 had completed the self-paced study program, the PNF was not seated at the time of the occurrence, and therefore not able to provide the PF with assistance by performing the assigned tasks, specifically:

- Following the TA, with the aid of information on the TCAS display, announce the relative bearing using the o'clock reference position, as well as distance and relative altitude of the intruder.
- Assist the PF in visually searching for the intruder.
- Following the RA, using the VSI information, confirm that the PF's current action is in accordance with the RA.

Although the risk analysis performed by the company on 12 November 2009 indicated that safety measures were taken regarding training, including traffic-conflict simulation during training flights, several elements indicate that simulator training on manoeuvres is either nonexistent or incomplete:

- Training files did not indicate that RA scenarios were practised during initial training in the simulator or during recurrent training.

- The 2 PFs in this occurrence initiated a turn following the TCAS advisory.
- The reaction time of the captain of AIE304 following the RA was almost double that specified in the standards in the AFM.
- Neither flight crew involved in the occurrence in question reported their deviation in altitude to ATS.
- Other company pilots had also initiated turns following a TCAS advisory.

Such simulator training prepares flight crews better for this type of eventuality.

2.6 Flight Recorders

Since the aircraft was not equipped with a CVR with a 2-hour recording capacity, the investigators were deprived of information that might have made it possible for them to identify potential safety deficiencies in terms of flight crew coordination either before or after the TCAS advisory, as well as the appropriateness of the operation of TCAS.

Nearly 12 years after its first response following recommendation A99-02, a NPA (2011-010) was prepared by TC and submitted at a CARAC Technical Committee meeting in September 2011.

The Technical Committee accepted the NPA as presented, subject to a risk evaluation. All elements of the NPA could be altered following consultations based on the results of the risk evaluation, the cost/benefit analysis and other instruments that could be used to verify the proposed regulatory approach. This means that some time—possibly years—will pass before any change is made,. As a result, the safety deficiency identified by the recommendation and recognized by TC persists.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The AIE304 flight crew used the VS mode to maintain altitude as a work-around to the aircraft pitch oscillation when altitude-hold mode was engaged.

2. The use of VS mode is neither intended for nor evaluated for this function, but nothing prohibited the flight crew from using it to maintain altitude.

3. In VS mode, AIE304 began a gradual descent that was imperceptible without reference to flight instruments.

4. The captain of AIE304 did not monitor the flight instruments with a degree of attention that would have enabled him to be aware of the situation, contributing to the loss of altitude that led to the risk of collision.

5. The element of surprise, the required shift of attention, and the rarity of traffic alert and collision avoidance system (TCAS) warnings are all factors that may have reduced the AIE304 captain's ability to react quickly to the resolution advisory (RA).

6. The absence of simulator training on TCAS manoeuvres contributed to the crews' initial incorrect reaction to the RAs.

7. The PNF of AIE304 was not seated in the cockpit, and therefore unable to assist in responding to the TCAS warnings.

3.2 Findings as to Risks

1. The altitude warning light located on each barometric altimeter is less likely to draw attention than it might because it does not flash, and, in daylight, the contrast between extinguished and lit is reduced. These characteristics could reduce the time in which pilots are able to identify and initiate corrective measures.

2. The absence of an audible alarm, indicating that the aircraft had deviated from its altitude, available on some other DHC-8s operated by the company, reduced the likelihood of discovering the loss of altitude in a timely manner.

3. Different alarm systems within the same aircraft fleet can create a hazard for flight crews who are regularly obliged to switch between aircraft models. As a result, expectation of a warning that never comes can delay the measures necessary to avoid dangerous situations.

4. The TCAS display superimposes several symbols, the interpretation of which can be ambiguous when training is absent, poorly adapted or incomplete. As a result, the reaction to a TCAS advisory could be delayed or inappropriate.

5. The 2 PFs initiated turns following the TCAS advisory. This type of manoeuvre in an environment with heavier traffic could have reduced the separation with other neighbouring aircraft, resulting in a collision.

6. When cockpit or data recordings are not available to an investigation, this may preclude the identification and communication of safety deficiencies to advance transportation safety.

3.3 Other Findings

1. Risk analyses done by the company in the context of its SMS did not take into consideration previous non-compliant actions by flight crews following an RA. In this case, both PFs initiated a right turn following the RA, whereas TCAS advisories only provide directives in the vertical plane.

2. Neither crew reported their deviation in altitude to the ATS in a timely manner.

3. The absence of a direct radio-communication link can result in delays in the transmission of important instructions.

4.0 Safety Action

4.1 Safety Action Taken

4.1.1 Safety Action Taken by Air Inuit Ltd.

On 04 March 2011, the company issued a “safety alert” prohibiting pilots from using VS mode except when descending.

This report concludes the Transportation Safety Board’s investigation into this occurrence. Consequently, the Board authorized the release of this report on 04 July 2012. It was officially released on 21 August 2012.

Visit the Transportation Safety Board’s Web site (www.bst-tsb.gc.ca) for information about the Transportation Safety Board and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

Appendix A— Summary of the Sequence of Events

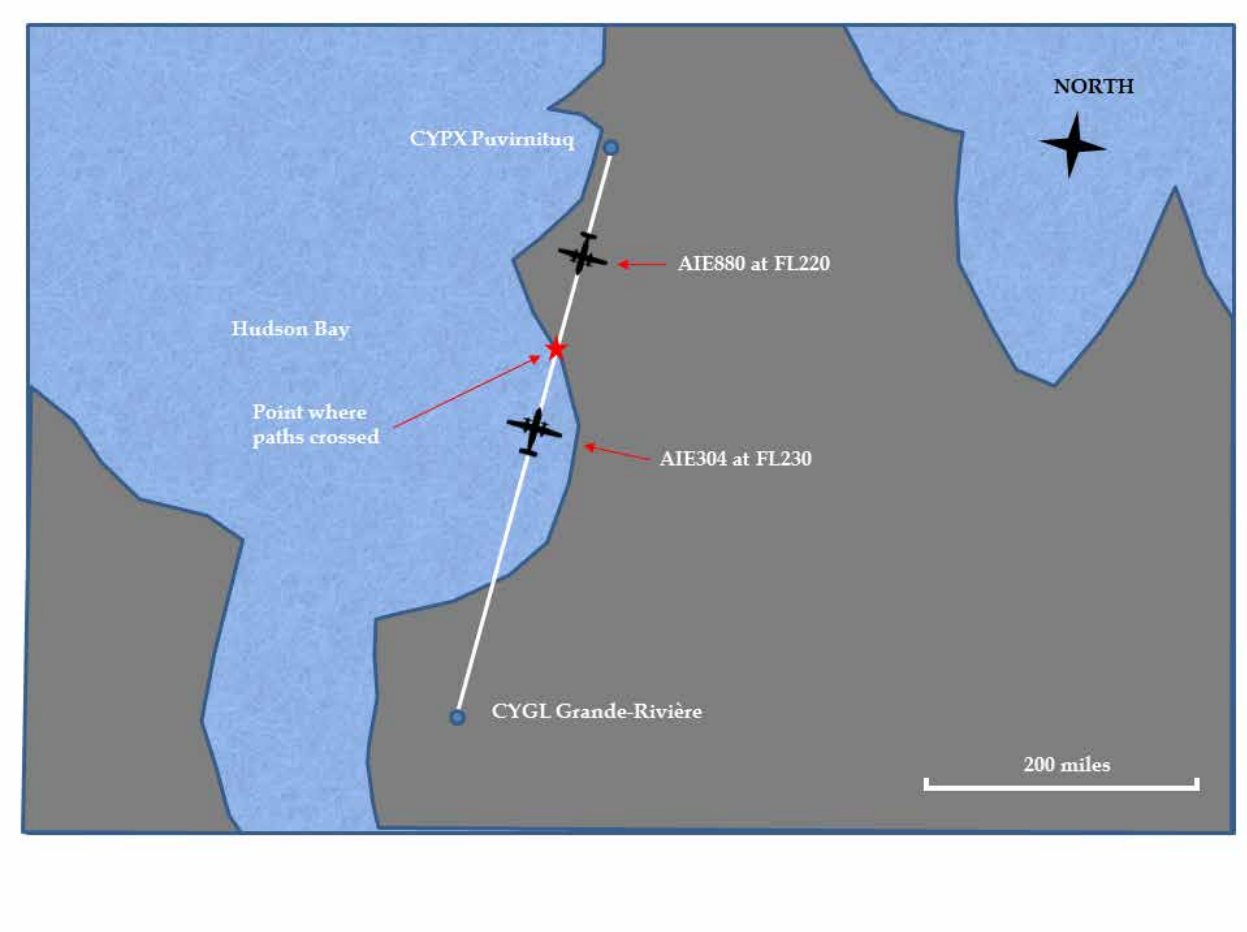
Time	AIE880	AIE304	Vertical / horizontal separation
14 21:35		Descent begins at a rate of roughly 50 ft. / min	1000 ft. / 131 nm
1435:24 (TA [34] = CPA [35] - 48 sec)	Audible announcement "TRAFFIC, TRAFFIC"	Audible announcement "TRAFFIC, TRAFFIC"	300 ft. / 7.4 nm
1435:26	Disconnection of autopilot		277 ft. / 6.6 nm
1435:32	Shallow turn to right with loss of altitude	Autopilot disconnected	284 ft. / 5.7 nm
1435:37 (RA [36] = CPA - 35 sec)	Audible announcement to descend	Audible announcement to climb; PF begins right turn, banking up to 38°	300 ft. / 5.5 nm
1435:38	PF initiates a left turn and begins to descend		360 ft. / 4.8 nm
1435:46		Pulls on flight stick to halt descent due to turn with a 38° bank	518 ft. / 3.7 nm
1436:12 (CPA)	At 21 300 ft.	At 22 800 ft.	1500 ft. / 0.8 nm
1436:58		Autopilot activated	800 ft. / 6.2 nm
1437	Level off at FL220		775 ft. / 6.5 nm
1437:11	Autopilot activated		675 ft. / 8.0 nm
1437:46		Level off at FL230	1000 ft. / 12 nm

[34] TA = traffic advisory

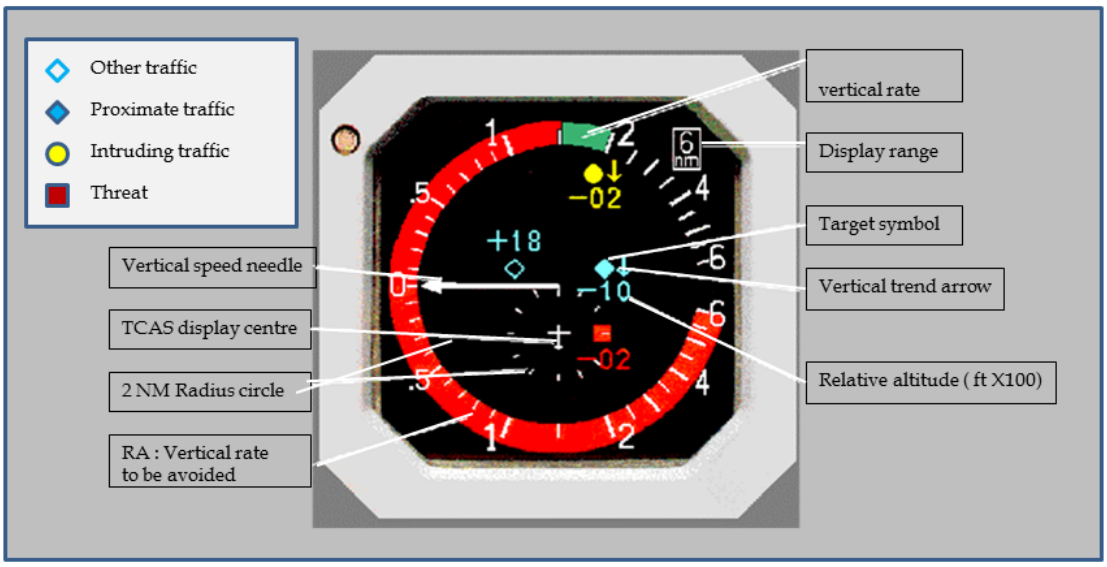
[35] CPA = closest point of approach

[36] RA = resolution advisory

Appendix B—Approximate Tracks of Aircraft



Appendix C—Example of RA Display



Appendix D—Safety Risks (ICAO Doc 9859 AN/474)

Safety risk: probability

Probability of occurrence	Meaning	Value
Frequent	Likely to occur many times (has occurred frequently)	**5**
Occasional	Likely to occur sometimes (has occurred infrequently)	**4**
Remote	Unlikely to occur, but possible (has occurred rarely)	**3**
Improbable	Very unlikely to occur (not known to have occurred)	**2**
Extremely improbable	Almost inconceivable that the event will occur	**1**

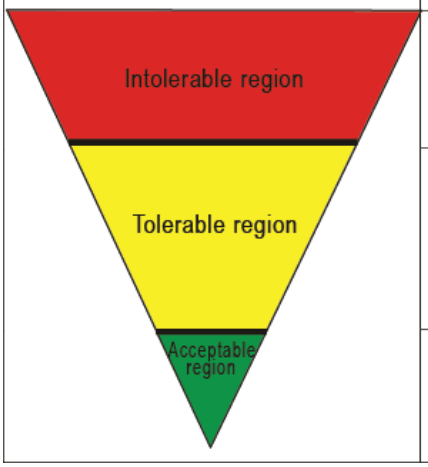
Safety risk: severity

Severity of occurrence	Meaning	Value
Catastrophic	· Equipment destroyed · Multiple deaths	**A**
Hazardous	· A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely · Serious injury	**B**
Major	· A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of increase in workload, or as a result of conditions impairing their efficiency · Serious incident · Injury to persons	**C**
Minor	· Nuisance · Operating limitations · Use of emergency procedures · Minor incident	**D**
Negligible	· Little consequence	**E**

Safety risk assessment matrix

Risk probability		Risk severity				
		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely improbable	1	1A	1B	1C	1D	1E

Safety risk tolerability matrix

Suggested criteria	Assessment risk index	Suggested criteria
	5A, 5B, 5C, 4A, 4B, 3A	Unacceptable under the existing circumstances
	5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C	Acceptable based on risk mitigation. It may require management decision.
	3E, 2D, 2E, 1A, 1B ,1C, 1D, 1E	Acceptable