Transportation Safety Board of Canada

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AVIATION INVESTIGATION REPORT
A09P0187

WAKE TURBULENCE ENCOUNTER – COLLISION WITH TERRAIN

INTEGRA OPS LTD. (DBA CANADIAN AIR CHARTERS)
PIPER PA-31-350 CHIEFTAIN, C-GNAF
RICHMOND, BRITISH COLUMBIA
09 JULY 2009

Canada

Aviation Investigation Report

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Synopsis

The Canadian Air Charters Piper PA-31-350 Chieftain (registration C-GNAF, serial number 31-8052130) was operating under visual flight rules as APEX 511 on the final leg of a multi-leg cargo flight from Vancouver to Nanaimo and Victoria, British Columbia, with a return to Vancouver. The weather was visual meteorological conditions and the last 9 minutes of the flight took place during official darkness. The flight was third for landing and turned onto the final approach course 1.5 nautical miles behind and 700 feet below the flight path of a heavier Airbus A321, approaching Runway 26 Right at the Vancouver International Airport. At 2208, Pacific Daylight Time, the target for APEX 511 disappeared from tower radar. The aircraft impacted the ground in an industrial area of Richmond, British Columbia, 3 nautical miles short of the runway. There was a post-impact explosion and fire. The 2 crew members on board were fatally injured. There was property damage, but no injuries on the ground. The onboard emergency locator transmitter was destroyed in the accident and no signal was detected.

Ce rapport est également disponible en français.

1.0 Factual Information

1.1 History of the Flight

Runway 26 Right (26R) was the active runway at Vancouver International Airport, the other 2 runways being closed for maintenance.

At 2157,[1] the crew of APEX 511 made initial contact with Vancouver tower 20 nautical miles (nm) south of the airport at 1500 feet above sea level (asl). The flight was among 4 aircraft inbound to Vancouver at the time; the other 3 were larger Airbus aircraft under the control of Vancouver terminal arrival controller. The first was joining left base from the southeast, the other 2 straight-in from the east. The Vancouver tower airport controller directed the crew of APEX 511 to follow the published Coal Pile visual flight rules (VFR) arrival route for Runway 26R (see Appendix A).

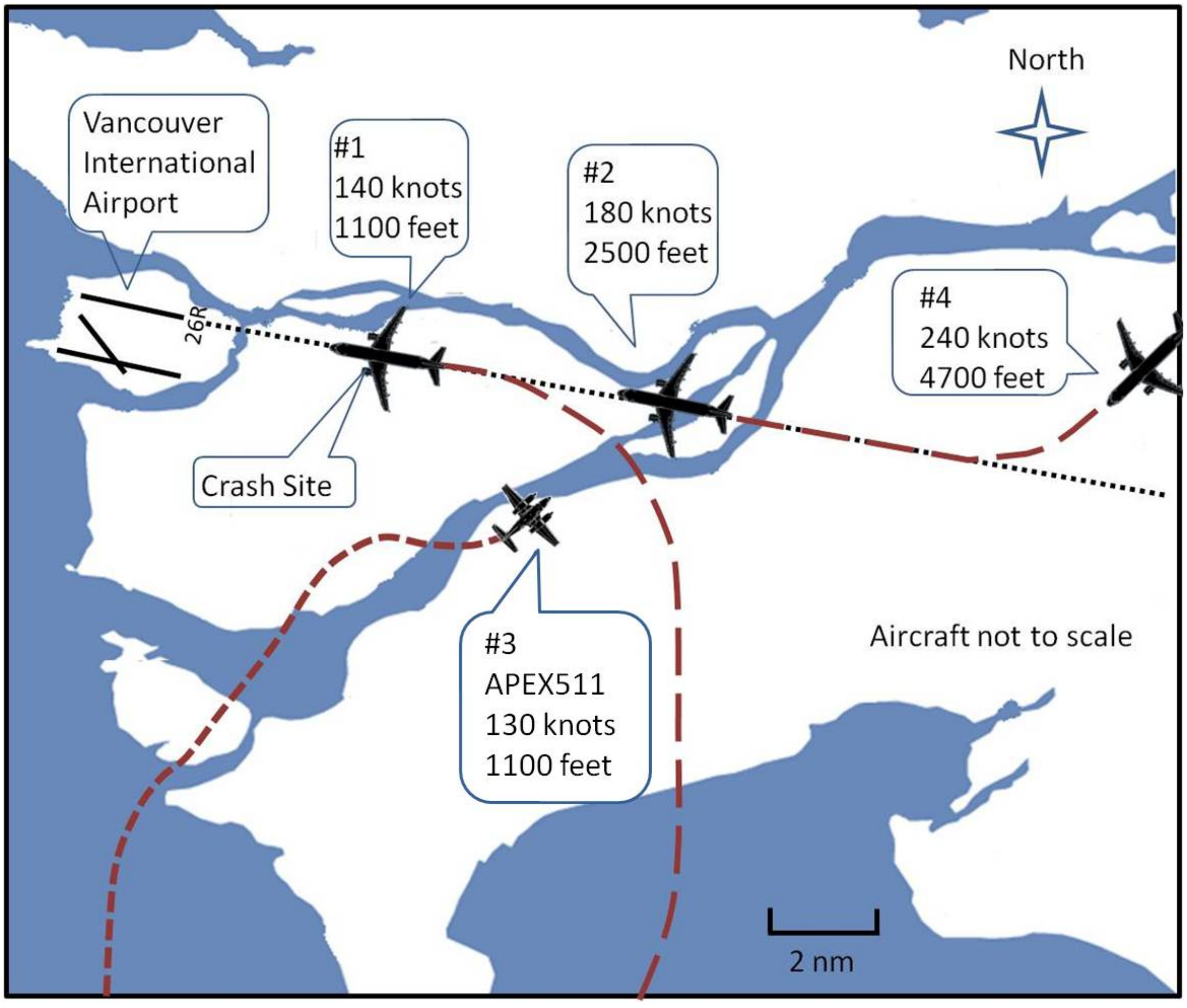

Figure 1. Aircraft traffic pattern at 2204:42

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1 All times are Pacific Daylight Time (Universal Coordinated Time minus 7 hours).

At 2201, APEX 511 was advised by Vancouver tower that it would be second or third on the approach (see Figure **1**). At 2202, APEX 511 crossed the Vancouver VOR (very high frequency omnidirectional radio range), 7 nm south of the airport, at 1500 feet asl and proceeded northwest toward a checkpoint about 2 nm southeast of the airport. After crossing the VOR, APEX 511 descended to 1000 feet asl. At 2203, APEX 511 was advised that it would be number 3 behind an Airbus. The airport controller instructed APEX 511 to widen its approach to the east, downwind and issued a wake turbulence cautionary, including the position of the aircraft it was to follow. The crew of APEX 511 queried the airport controller as to whether they should do a 360° turn. The airport controller confirmed to widen its approach to the east and follow the traffic when in sight.

At 2204, the airport controller pointed out the traffic on final approach, 6.5 nm away and descending through 3000 feet asl. APEX 511 reported the traffic in sight. APEX 511 was then instructed to follow that traffic, but not too far behind, as another Airbus flight was 8 nm from the preceding Airbus. APEX 511 was again cautioned about wake turbulence. The crew indicated that they would keep it in tight. This was the last communication from APEX 511.

The Airbus traffic that APEX 511 was to follow checked in on the tower frequency when APEX 511 was on the base leg. The airport controller pointed out the Chieftain traffic, 2 nm to its left and cleared the Airbus to land. When APEX 511 completed the turn onto the final approach track, 5.1 nm to the threshold at 1000 feet asl, it was 1.5 nm behind the Airbus, which crossed the same point 33 seconds earlier, descending through 1700 feet asl. At that point, APEX 511 was 6.1 nm ahead of the trailing Airbus traffic.

APEX 511 intercepted the flight path of the Airbus from below at about 3.2 nm from the runway threshold, 44 seconds after the Airbus passed that point. Nine seconds later, the radar target showed APEX 511 at 700 feet before radar contact was lost.

While on the approach, the aircraft wallowed from side to side and there was a change in sound consistent with an increase in engine power. The aircraft then went into a nose-up attitude at a noticeably slower speed before entering a steep descent to the left. Communications from APEX 511 did not indicate that it was having problems at any point during the approach.

1.2 Meteorological Information

The 2200 aviation routine weather report (METAR) recorded for the Vancouver International Airport indicated winds 160° True (T) at 2 knots with 30 statute miles visibility. Cloud cover was described as few at 4000 feet agl with a broken layer at 22 000 feet agl. The temperature was 18°C and the dew point was 10°C.

There were no appreciable winds or atmospheric instability that could have caused an aircraft upset or promoted the rapid dissipation of wake turbulence from the preceding flight.

1.3 Wreckage Information

The accident site was located in an industrial compound in Richmond, 3 nm east of the threshold, approximately 500 feet south of the extended centreline of Runway 26R. An intense post-crash fire consumed a significant portion of the aircraft. The aircraft's direction of flight at impact was south, 80˚ left of the approach path.

The aircraft tail initially struck a chimney before the aircraft struck 2 buses parked end-to-end that were used as storage containers. The distance between the point on the extended centreline where radar contact was lost to the point of impact with the chimney represents a descent angle of 61°. The distance between the point where the aircraft struck the chimney and the point of impact with the first bus represents a descent angle of 17°. Airframe examination was limited by extensive impact-related destruction and subsequent fire damage. Of the airframe component examinations that could be performed, no anomalies were detected.

Engine examinations did not identify any indications of in-flight fire or engine malfunction nor were any internal anomalies detected that would have prevented the engines from delivering power. Both propellers exhibited signs of receiving engine power at impact.

1.4 Aircraft Information

Upon departing Victoria for Vancouver, the fuel on board was recorded as 456 pounds with 800 pounds of cargo. The total takeoff weight departing Victoria was recorded as 6158 pounds with an estimated landing weight of 6068 pounds. The maximum take-off weight for the aircraft is 7368 pounds and the maximum landing weight is 7000 pounds. Since the destruction of the aircraft eliminated any possibility of determining the actual position of the cargo, the figures used were taken from the operational flight plan. The weight and centre of gravity were within prescribed limits.

Technical examination of the aircraft records did not identify any aircraft defects that would have precluded proper flight. An issue concerning on-condition maintenance, however, was identified but was not considered contributory to this accident.

The operator was approved to follow the Piston Engine On-Condition Maintenance Program [2] as an alternate to the manufacturer's recommended hard time program. This is based on the premise that each part of an aircraft required periodic overhaul. Times between component overhaul were strictly controlled, and the entire aircraft was periodically disassembled, overhauled and re-assembled. The engine manufacturer prescribes a time before overhaul (TBO) of 1800 hours for this engine model. An overhaul would normally include engine accessories such as the engine-driven fuel pump.

With experience, it was concluded that some components did not require overhaul on a fixed time basis. Consequently, a second process evolved referred to as on-condition. This designation was assigned to components, such as engines, whose condition could be determined by visual inspection, measurement, testing or other means not involving disassembly or overhaul. [3] Under this program, the right-hand engine of the occurrence aircraft

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[2] *Canadian Aviation Regulations* (CAR) Standard 625.86(2) Appendices C and D – Out of Phase Tasks and Equipment Maintenance Requirements - allows for the On-Condition maintenance of engines operated in Commercial Operations. Air Operators and Flight Training Unit Operators may incorporate such programs in their aircraft maintenance schedules.

[3] Transport Canada, Airworthiness Manual Advisory 571.101/1- 4.a,b.

had accumulated 11 617 hours total time since new (TTSN) and 2531 hours time since overhaul (TSO). The left engine had 7548 hours TTSN and 3418 hours TSO.

Aircraft operators that have been approved for an on-condition maintenance program may, through the application of their maintenance schedule approval process, extend the intervals of repeat inspection criteria. This is based upon demonstrated reliability data established through the operator's reliability program. [4] Transport Canada (TC) Airworthiness Manual Advisory 571.101/1, Section 3c, provides guidance for reliability programs for operators of a fleet of 5 or more aircraft. The operator's fleet consisted of 6 Piper Chieftains. No reliability program records were maintained by the operator, which meant that the engine driven fuel pumps remained subject to a requirement to inspect the pumps at various time intervals outlined in the operator's maintenance program documentation and replaced or overhauled at the manufacturer's specifications.

Examination of the right-hand engine (Textron-Lycoming model LTIO-540-J2BD, s/n: L-2331-68A) revealed an anomaly with the engine-driven fuel pump drive splines, which were worn to the point of impending failure. The wear of the fuel pump drive splines will eventually result in the inability to drive the fuel pump, potentially resulting in an engine stopping due to fuel starvation any time the emergency electric fuel pump is not in use.

The engine manufacturer's (Lycoming Engines) position is that on-condition maintenance should not occur at intervals greater than those stated in the manufacturer recommendations. Specifically, the TBO should be used as the upper limit for on-condition actions.

The condition of the right-hand engine-driven fuel pump drive splines (Lear Romec, part number RJ9080J4A, serial number D-6872) indicates that it was operated beyond its overhaul life and was not subject to any inspection program to monitor its condition.

1.5 Operator Information

Integra Ops Ltd. holds a valid Air Operator Certificate issued by TC under Subpart 703 of the CARs. The company operates under the trade name Canadian Air Charters (CAC). The company's principle business is scheduled air cargo.

Following the accident on 09 July 2009, the company voluntarily suspended its operations until 13 July 2009. On 16 July 2009, TC carried out a special purpose inspection to determine the level of compliance with regulatory requirements. The inspection did not make any findings of a safety concern.

1.6 Vancouver Tower Operations

Five controllers and a supervisor were on staff at the tower, which met established requirements. Two controllers were on duty in the control tower cab, 1 controller was working the combined north and south tower position and the other was working the combined north and south ground position as well as clearance delivery.This is a normal configuration for that

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[4] Program requirements are listed in Transport Canada Airworthiness Notice - BO41 edition 4.

time of night in preparation for the shift change to the midnight crew of 2 controllers arriving at 2230 to begin their shift at 2300.

There was no training taking place and no equipment outages. The on-duty airport controller had just returned from a break and took over the airport control position when APEX 511 made its initial contact with the tower.

1.7 Airport Controller Training

The airport controller was originally qualified in an instrument flight rules (IFR) en route sector in the Vancouver Area Control Centre in 1995. The controller applied for a transfer in 2007 and completed the training program and qualified in the Vancouver tower in August 2008. The airport controller was completing the second day of work following 3 days off duty.The Vancouver tower course training plan outlines training objectives in detail and describes a series of lectures and simulation sessions in 18 subject areas. Candidates complete the theoretical portion of the training plan and then progress to the tower cab for continuous on-the-job training with an assigned on-job-instructor (OJI). Throughout this process, candidates receive progressive evaluations against the expected standard until they qualify or training ceases. Controllers are trained in aircraft performance and wake turbulence – its causes, how it can be avoided and how to sequence VFR aircraft into a stream of IFR arrivals.

1.8 Controller Actions

The challenge facing the airport controller was to fit APEX 511, a lighter, slower aircraft operating VFR, into the flow of heavier, faster inbound IFR traffic, all for the same runway. The speeds of the heavier IFR aircraft would change over time and APEX 511 would be initially travelling downwind, in the opposite direction to the 2 flights arriving from the east.

Two of the spacing options available to the airport controller were to instruct APEX 511 to do one or more 360° turns until sufficient space between the traffic on final would enable it to complete a close base leg for a short final leg for landing or instruct APEX 511 to extend its downwind leg. The airport controller elected to do the latter and negotiated an increase in spacing between the 2 other IFR aircraft with the arrival controller.

At an airport within a radar environment, wake turbulence separation is achieved by either radar (distance) or visual means. During the provision of radar control service, the minimum wake turbulence separation applied to a light category aircraft operating behind a medium is 4 nm or 1000 feet below. Regardless of whether flights operate under VFR or IFR, the onus for the provision of radar wake turbulence separation rests with the air traffic controller until such time as visual separation is established by the lighter aircraft reporting the heavier aircraft in sight. Under visual separation, wake turbulence avoidance relies solely on the pilot.

Before APEX 511 sighted the traffic, the airport controller monitored the flight for potential traffic conflicts. Once APEX 511 reported the traffic in sight, the airport controller instructed APEX 511 to follow that traffic. A second wake turbulence cautionary was issued at the same time. APEX 511 was also pointed out as traffic ahead and 2 nm left for the Airbus that it was going to follow (see Figure 1).

APEX 511 was provided with distance information regarding the trailing Airbus traffic. APEX 511 was also pointed out as traffic for the trailing Airbus, which then reported the Chieftain in sight 5 nm ahead. The airport controller then considered that visual separation had been established for all 3 involved aircraft in accordance with Air Traffic Control (ATC) Manual of Operations (MANOPS) 392.4. About 30 seconds later, while the airport controller was scanning the runway for the arrival of the Airbus ahead of APEX 511, the target for APEX 511 disappeared from radar.

The NAV CANADA ATC MANOPS Section 180, entitled Wake Turbulence, advises airport controllers to "be alert to possible hazards caused by wake turbulence." An associated note states in part that "[…] all aircraft produce vortices somewhat in proportion to their weight and that since wake turbulence is invisible, its presence and exact location cannot be determined with precision." In this regard, ATC MANOPS advises airport controllers in a radar environment that if it is judged necessary, they can increase a wake turbulence separation minimum or apply a wake turbulence separation minimum to a situation not covered by another separation minimum. ATC MANOPS also provides a short discussion regarding wake turbulence considerations and avoidance techniques. Since APEX 511 was operating under VFR and had reported the traffic in sight, the airport controller, in accordance with ATC MANOPS, elected to issue a wake turbulence cautionary rather than apply wake turbulence separation.

1.9 Flight Crew

The flight crew was certified and qualified for the flight in accordance with existing regulations. The crew regularly flew in and out of the Vancouver International Airport at night.

The captain held an Airline Transport Pilot Licence and had accumulated 2300 hours total flight time. The captain began working full-time for CAC in September 2006. In August 2008, at the captain's request, his employment status with CAC changed to part-time when he became a self employed contractor. The captain flew earlier in the day for CAC, worked the day as a contract house-painter and then later flew on the occurrence flight. The CAC flight and duty time records did not account for time worked elsewhere in a non-flying capacity, nor was it required by regulation. [5] A review of the captain's 72-hour work rest history indicated an accumulated sleep deficit of about 3.5 hours in the 3-day period before the accident. The captain had been awake since 0430 on the day of the accident.

The first officer held a Commercial Pilot Licence and had accumulated 400 hours total flight time. While working part-time for CAC since June 2008, the first officer worked a non-flying, part-time afternoon position for another employer for 4 hours per day, Monday to Friday. The CAC flight and duty time records did not account for duty time acquired at other non-air carrier employers. A review of the first officer's 72-hour history did not identify any concerns.

5 CAR 700.14, 700.15 and 700.16.

1.10 Fatigue

Fatigue affects perception, risk judgement and other cognitive processes, and can have comparable effects to that of alcohol consumption. [6] Everyone has a minimum sleep requirement to maintain alertness and a reasonable level of functioning. Research shows that over 90% of the population needs between 7.5 and 8.5 hours of sleep per day. If less is obtained, a sleep debt is acquired, which is cumulative. That is, missing an hour of sleep per day for 4 days results in about the same degree of impairment as missing 4 hours of sleep in one night. When a sleep debt is combined with circadian disruption, or a long day, the effects can be seriously detrimental. Sleep debt can result in attention impairment which can include indicators such as:

- not appreciating the gravity of the situation;
- not anticipating danger;
- displaying decreased vigilance;
- an impairment of problem-solving ability which can be indicated by:
  - not accurately interpreting the situation;
  - displaying poor judgement of distance, speed and/or time.

1.11 Flight Crew Actions

APEX 511 was operating under VFR. The crew was thus required to use visual means for collision avoidance, terrain and obstacle clearance as well as wake turbulence avoidance. The circumstances of the approach for APEX 511 included darkness, an extended traffic circuit as well as traffic that was larger, faster and changing speed on straight-in visual approaches. APEX 511 initially reported their traffic in sight from 6.5 nm away. When APEX 511 was on the base leg, the traffic ahead was initially higher than it and descending. APEX 511 was pointed out as traffic to the crew of the Airbus when the Airbus was given its landing clearance. This traffic information presented an update for APEX 511, which indicated that its traffic was crossing from its right to left 2 nm ahead and above its altitude. It is not known if the crew of APEX 511 heard this information.

APEX 511 was operating with 2 pilots on board, which is regarded as a safety defence through redundancy. When two-pilot operations are employed, operators must apply Standard Operating Procedures (SOP's) to ensure effective crew resource management between crew members. The CAC SOP for the Piper Chieftain stipulates that the crew must complete a pilot approach briefing for all flights. The aircraft was not equipped with a cockpit voice recorder, nor was it required by regulation, and it could not be determined what level of collaboration or communications occurred between the 2 pilots.

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[6] Williamson, AM, and Feyer, Anne-Marie (2000). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication, Occupational Environmental Medicine Online, retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1739867/pdf/v057p00649.pdf. Website address confirmed accessible as of report release date.

Although wake turbulence is always generated by an aircraft in flight, it may not necessarily be encountered by a trailing aircraft. APEX 511 travelled about 2 nm behind and below the Airbus. Prior to the upset, the flight may not have encountered any effects of wake turbulence. It is unknown whether either crew member had ever previously encountered any effects of wake turbulence.

Given the controller's plan, APEX 511 had several options to fit into the traffic pattern taking into account the need for wake turbulence spacing, collision avoidance and landing intervals. The base leg provided opportunity for flight path modifications such as turning sooner and proceeding direct toward the midfield for a long landing, slowing down to increase spacing or crossing through the final approach course and manoeuvring on the north side of the approach to increase spacing. Additional options included maintaining the existing altitude and remaining clear of the extended runway centreline until above the glidepath or flight path of the Airbus ahead before aligning with the runway, or rejecting the controller's plan and requesting a different landing sequence. The radar record did not show any flight path modifications consistent with any of the above options. APEX 511 did not request the controller to provide vectors to intercept the final approach course or for additional distance-from-their-traffic information.

1.12 Visual Separation

Visual separation is defined in CARs as:

> A means employed by controllers to separate aircraft operating in visual meteorological conditions (VMC). (a) VFR – The controller, having determined that a potential conflict exists, issues clearances, instructions and/or information, as necessary in order to either aid aircraft in establishing visual contact with each other or to assist aircraft in avoiding other aircraft.

The Aeronautical Information Manual (AIM) discusses VFR operations within Class C airspace and states that "Visual separation may be effected when the pilot reports sighting a preceding aircraft and is instructed to follow it."

Human vision, particularly depth perception, [7] is diminished in darkness. Depth perception is the ability to determine the relative position of objects in space. [8] During the day, objects can be identified at a great distance with good detail resolution, but against a featureless sky, very few of the normal depth perception cues are available so the ability to judge distances is poor compared to more typical ground-based situations. Flying at night, a person loses more of their ability to judge the distance and size of an object. [9] Very few of the necessary cues remain

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7 U.S. FAA Rotorcraft Flying Handbook, FAA-H-8083-21, Figure 13-4; American Optometric Association, 2006. *The Eye and Night Vision*. Retrieved from http://www.aoa.org/x5352.xml?prt. Website address confirmed accessible as of report release date.

8 The Merck Manuals Online Medical Library, retrieved from www.merck.com/mmhe/sec20/ch225/ch225b.html. Website address confirmed accessible as of report release date.

9 U.S. FAA Rotorcraft Flying Handbook, FAA-H-8083-21, Figure 13-4.

available to the eye and the few cues that may still be available in darkness such as motion parallax and kinetic motion are significantly degraded.

The Airbus traffic that APEX 511 was following was operating with conventional navigation lights, red flashing anti-collision lights on the top and bottom of the fuselage, white flashing strobe lights on both wing tips and the tail, logo lights in the horizontal stabilizers, which illuminate both sides of the vertical stabilizer, and with landing lights at the leading edge of both wings. Wing inspection lights may or may not have been operated.

If the direction of flight and the size of the wingspan are known, it is possible to use a grouping of lights to judge distance. However, even with familiar sized objects, people do not judge absolute distance accurately. This can be especially difficult in an aviation context since many airliners are basically the same shape, simply scaled up or down versions of another model. Motion parallax, where close objects appear to move faster than distant objects and kinetic motion would not be very useful in the case of 1 aircraft trailing behind and below another, since the relative speeds are similar and there are no background features in the night sky. Under the circumstances of visual separation, the flight crew is responsible for establishing and maintaining wake turbulence separation and will be issued a wake turbulence advisory. The AIM, wake turbulence section, AIR 2.9, advises aircrew that ATC utilizes specific separation distances that are listed in RAC 4.1.1, but does not state that these distances should be used by aircrew after receiving a wake turbulence cautionary from ATC when conducting visual operations.

In May 2008, NAV CANADA issued Aeronautical Information Circular (AIC) 12/08 detailing the implementation plans and associated procedures for new applications of visual separation between departing aircraft using IFR in VMC. In September 2008, AIC 40/08 was issued to provide information to supplement AIC 12/08 in response to comments and suggestions from various operating agencies. The following excerpts are taken from AIC 12/08 and 40/08:

- It is expected that these visual separation procedures will significantly increase efficiency at our major airports during good weather conditions.
- Unlike traditional IFR separation standards, no separation criteria are connected to visual separation. Visual separation procedures have been designed in accordance with the International Civil Aviation Organization principles for the reduction of separation minima.

These circulars were replaced in AIC 15/10 on 01 July 2010. These procedures were implemented in order to leverage the efficiencies available to the industry from visual separation between IFR traffic on departure. These efficiencies had previously been available only to arriving IFR traffic. However, ATC will not use pilot applied visual separation between successive departing IFR aircraft if wake turbulence separation is required.

1.13 Wake Turbulence

ICAO defines wake turbulence as "[…] the effect of rotating air masses generated behind the wing tips of large jet aircraft". The term wake turbulence can refer to several types of turbulence generated by aircraft such as jet blast, propeller wash, helicopter rotor wash and wingtip or wake vortices. Wake vortices are generated by the same forces that provide lift to the airplane. High-pressure air beneath the wing flows outward around the wingtip into the low-pressure air above the wing and forms a vortice (horizontal tornado) behind each wing that counter-rotate and descend behind the aircraft. The typical risk to a trailing aircraft encountering these vortices is an induced roll which can exceed the control authority of the affected aircraft. [10]

At the time of the upset, APEX 511 was 1.9 nm, or 44 seconds, behind the Airbus and was approaching its flight path from below. No satisfactory system has been discovered that can decrease current in-trail separation standards while assuring that safety is maintained or increased. For IFR operations, ATS defences to mitigate the risks of wake turbulence exist in the form of separation standards. When visual meteorological conditions exist and flights operate under VFR, or IFR crews accept visual approaches, the responsibility to maintain spacing rests with the flight crew (including wake turbulence separation).

The effects of wake turbulence have been known since the 1950's and the hazards illustrated by studies conducted by organizations including National Aeronautics and Space Administration (NASA), the Federal Aviation Administration (FAA), the National Research Council of Canada (NRC) and aircraft manufacturers. This resulted in the introduction of separation standards primarily for arriving and departing aircraft. With some modification, these standards continue to be applied, with spacing based upon distance in radar environments and upon time in non-radar environments.

In France, between 1989 and 1991, 4 accidents and 1 incident were determined to have been caused by wake vortices. A study of these cases showed that the wake vortex phenomenon is still not fully understood and that pilots and controllers may not be fully aware of the combinations of different parameters that can lead to a dangerous situation. The circumstances of this accident include darkness in addition to the main common factors, which were identified in the 5 cases in France. The main common factors between these cases were:

- the aircraft involved was small;
- it was following a larger aircraft;
- it was operating under VFR;
- the wake vortices were encountered during approach;
- wind speed was less than 8 knots;
- the flight crew was aware of the preceding aircraft;
- separation was less than 2 minutes 30 seconds;
- the flight crew was experienced;

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10 Flight Safety Foundation, Flight Safety Digest, Vol. 21 No. 3-4, March-April 2002.

- the Air Traffic Control System was not required to ensure spacing between VFR/VFR and VFR/IFR. [11]

NASA conducted a series of flight tests to investigate the vortex wake characteristics behind a Boeing 727-200 during instrument landing system (ILS) approaches. A Lear Jet LR-23 and a Piper PA-30 Twin Comanche were used to intentionally encounter the wake vortices. A conclusion of the tests indicated that 4.5 nm would be a minimum separation distance at which roll control could be maintained by a small aircraft during a parallel encounter with the wake turbulence of the B727 in landing configuration.

An article published in the Flight Safety Foundation's *Flight Safety Digest* [12] reported that from January 1983 through December 2000, there were 190 accidents and incidents in the United States involving wake turbulence. Among those, 14 were fatal accidents killing 35 people. Of 130 wake-turbulence accidents in the National Transportation Safety Board (NTSB) database, 57% occurred in the approach and landing phase of flight and 98% occurred in VMC; 3% occurred in night conditions.

Visual approaches conducted by IFR aircraft in VMC have been in use in Canada for decades. In order for flight crews to independently establish and maintain wake turbulence spacing, they must employ visual separation. A recent TC draft preliminary statistical analysis, entitled *The Increase of Wake Turbulence Events in Canada*, [13] raises questions as to the adequacy of current practices and states that valid predictive models would help air traffic service providers maximize the efficiency of the system while ensuring safety. Attempts at predictive modeling so far have had limited success.

The study compared the number of occurrences for each year to the total flying hours for all commercial operations of that year. Since 1999, the number of wake turbulence events and the rate expressed as number of occurrences per 100,000 hours of commercial operations is increasing, despite some fluctuations in 2006 and 2007.

The study discusses how the increasing rate of wake turbulence events is related to increased aviation activity, as measured by commercial operations hours flown. This relationship may not be a simple linear correlation. Modest traffic flow increases may lead to relatively higher rates of wake turbulence events, especially near airports, and increase the potential for more incidents.

The International Civil Aviation Organization (ICAO) believes detection is key: "Attention must be given to the absence of effective, reliable means of assessing and locating wake turbulence". [14] As air traffic is projected to increase 2 to 3 fold by 2025 [15], without intervention,

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11 U.S. Department of Transportation, Proceedings of the Aircraft Wake Vortex Conference, June 1992, Volume I, Papers 1 – 29, report # DOT-VNTSC-FAA-92-2-1.

12 Flight Safety Foundation, (2002). Data Show that U.S. Wake-turbulence Accidents Are Most Frequent at Low Altitude and During Approach and Landing. *Flight Safety Digest,* March-April 2002.

13 TC - Records Documents Information Management System (RDIMS) No. 5238009.

14 ICAO Working Paper, Assembly –36th Session; The Urgency of Wake Turbulence Problems in Civil Aviation, 13 September 2007.

the rate of wake turbulence events will likely continue to increase. There will be pressure upon the air traffic service provider to expedite departures and arrivals. Evidence suggests that the current minimum separation standards may be questionable in view of the high percentage of events that occur when the separation standards are being met or exceeded. As part of its statistical analysis, TC examined data from the Civil Aviation Daily Occurrence Reporting System (CADORS) for the period beginning 01 January 1999 through to 31 December 2008. A total of 155 incidents occurring in Canadian airspace were identified. There were 70 confirmed wake turbulence reports. In 18 of the 27 approach events (66%), wake turbulence separation requirements were being met or exceeded by a significant margin. [16]

The TC *Helicopter Flight Training Manual* (TP 9982) states that "Numerous aircraft incidents and accidents occur at the busier airports as a result of wake turbulence, despite the many studies on the subject and the increased publicity among the pilot community." The section concludes by stating that "It should be noted, however, that the movements of the vortices are not predictable with any degree of certainty."

The TC *Aeronautical Information Manual* (AIM) TP 14371 section Airmanship (AIR) 2.9 discusses wake turbulence in depth and provides wake avoidance guidelines; for example "*Vortex Avoidance* - Avoid the area below and behind other aircraft, especially at low altitude, where even a momentary wake turbulence encounter could be disastrous."

AIR 2.9.2 states in part:

> ATC will use the words 'CAUTION – WAKE TURBULENCE' to alert pilots to the possibility of wake turbulence. It is the pilots' responsibility to adjust their operations and flight path to avoid wake turbulence.
>
> Air traffic controllers apply separation minima between aircraft. See AIM section Rules of the Air and Air Traffic Services (RAC) 4.1.1 for these procedures which are intended to minimize the hazards of wake turbulence.

An aircraft conducting an IFR final approach should remain on the glide path as the normally supplied separation should provide an adequate wake turbulence buffer. However, arriving VFR aircraft, while aiming to land beyond the touchdown point of a preceding heavy aircraft, should be careful to remain above its flight path. If extending flight path, so as to increase the distance behind an arriving aircraft, one should avoid the tendency to develop a dragged-in final approach. Pilots should remember to apply whatever power is required to maintain altitude until reaching a normal descent path. The largest numbers of dangerous encounters have been reported in the last half mile of the final approach.

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15 Aeronautics and Space Engineering Board. *Technology Pathways: Assessing the Integrated Plan for a Next Generation Air Transportation System*, National Academics Press, Page 17, 2005.

16 Transport Canada. Draft preliminary statistical analysis entitled *The Increase of Wake Turbulence Events in Canada.* TC - Records Documents Information Management System (RDIMS) No. 5238009.

The AIM Section RAC 4.1.1 states in part:

> Wake Turbulence – Wake turbulence has its greatest impact on departure and arrival procedures; however, pilots should not assume that it will only be encountered in the vicinity of aerodromes. Caution should be exercised whenever a flight is conducted anywhere behind and less than 1 000 ft below a large aircraft […] In spite of these measures, ATC cannot guarantee that wake turbulence will not be encountered.

Section RAC 4.1.1 discusses wake turbulence separation minimums applied to IFR/VFR departures, but does not discuss wake turbulence separation minimums applied to IFR/VFR arrivals.

The CAC *Company Operations Manual* (COM) Annex 4-E, Operations in Hazardous Conditions includes a copy of the AIM section AIR 2.9 regarding wake turbulence. The COM Section 6 describes training requirements, but does not specifically require discussions, full motion simulator training or actual in-flight training regarding prevention strategies for potential wake turbulence encounters, nor is it required by regulation.

The U.S. FAA Advisory Circular 90-23E includes the following information (see Figure **2**):

> OPERATIONAL PROBLEM AREAS **-** Avoid the area below and behind the generating aircraft, especially at low altitude where even a momentary wake encounter could be hazardous. Pilots should be particularly alert in calm wind conditions and situations where the vortices could: a. Remain in the touchdown area.
>
> PILOT RESPONSIBILITY - Vortex visualization and avoidance procedures should be exercised by the pilot using the same degree of concern as in collision avoidance since vortex encounters frequently can be as dangerous as collisions.

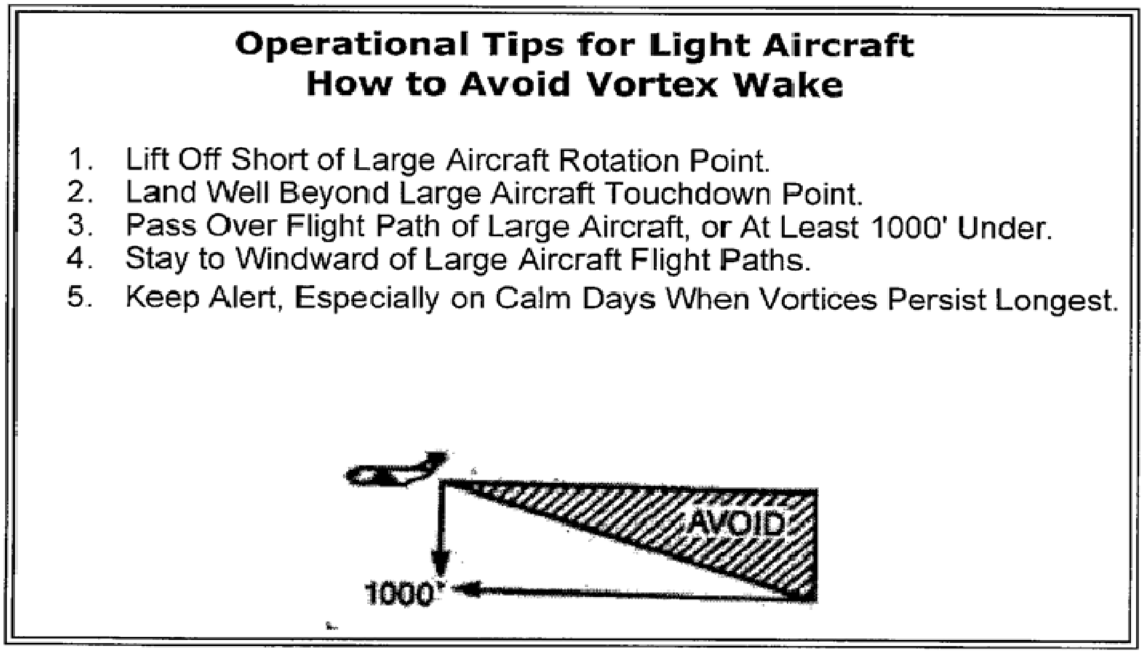

Figure 2. Operational tips from FAA Advisory Circular 90-23E

Wake turbulence theory is a written examination topic at every level of pilot training in Canada. Despite the many studies on the subject and increased publicity among the pilot community, incidents and accidents continue to occur.

1.14 Previous Wake Turbulence Incidents/Accidents

TSB records show that for the 10 year period between 1999 and 2009, there were 25 wake turbulence encounters reported, of which 15 occurred in the approach and departure phases of flight. Of 7 encounters during the approach phase of flight, 3 occurred at night and at least 2 were on visual approaches. There was no information to indicate whether visual separation was a factor. Consequences ranged from benign turbulence to severe roll oscillations and 1 go around on short final. None of these occurrences resulted in accidents; however, some of them resulted in minor injury to occupants and minor damage to the aircraft. These records probably do not reflect the true extent of wake turbulence encounters in Canada since airplanes with a maximum certificated takeoff weight below 5700 kg are exempt from compulsory reporting of wake turbulence events and airplanes over 5700 kg are only required to report when difficulties in controlling the aircraft are encountered. Appendix B contains the summaries of the 7 occurrences reported during the approach phase of flight.

The study conducted by TC, entitled *The Increase of Wake Turbulence Events in Canada*, states that between 1999 and 2008, 76 of 155 identified wake turbulence related reports were events where the required wake turbulence separation between aircraft had eroded. These events were reportable even though there were no consequences. A further 70 events were confirmed wake turbulence encounters, of which 27 occurred during the approach phase of flight. In 18 of those events, wake turbulence separation requirements were being met or exceeded.

2.0 Analysis

2.1 Introduction

The wreckage distribution pattern indicates that the aircraft was upright with the wings approximately level. The change in the angle of descent likely commenced before the aircraft tail contacted the chimney, which suggests that the flight controls were functional and that a recovery from the upset was in progress, but altitude remaining precluded complete recovery. Technical examination of the aircraft and associated records identified a risk to safety, but did not identify any aircraft defects that were contributory to this accident.

The majority of this analysis will discuss factors that may have influenced decision making and the subsequent actions and conditions that may have contributed to the accident.

The investigation was hampered by a lack of recording devices on the aircraft that could have provided more insight into the decision making process of the APEX 511 crew and enhanced the potential safety messages.

2.2 Maintenance - Engine Components

The condition of the right-hand, engine-driven fuel pump drive splines indicates that it was not replaced or overhauled at the engine TBO of 1800 hours and it was not subject to any repetitive periodic inspections to determine its condition so that it could be removed from service prior to failure. The operator does not have a reliability program in place, as required under its approved maintenance program, to track the level of wear and the rate of deterioration of components, such as the fuel pump drive splines to forecast life expectancy. Therefore, the risk continues that components, such as fuel pumps, will remain in service in the operator's Piper Chieftain fleet until they stop functioning. The CAC SOP for the Piper Chieftain direct flight crews to turn off the back-up emergency electric fuel pumps, 1 per engine, for the cruise portion of flight.

2.3 Visual Separation and Wake Turbulence

Controllers frequently plan IFR traffic flows based upon the use of visual approaches when VMC exist. An expectation is then placed upon flight crews to accept a visual approach by instructing them to report their traffic or the airport in sight. It can also be announced on ATIS messages that visual approaches are in progress. In accordance with AIM RAC 9.6.2 "ATC considers acceptance of a visual approach clearance as acknowledgement that the pilot shall be responsible for: (b) maintaining adequate wake turbulence separation."

Once visual separation is established on the approach, the flight path of the aircraft is at the flight crew's discretion and ATC is not responsible for flight crew actions, which may result in more or less than the recommended wake turbulence spacing applied for IFR flights. However, research shows that humans are poor judges of distance, especially in darkness, and visual separation places the task of judging spacing solely upon flight crews. The following paragraphs compare departures to arrivals.

At the time of the occurrence, AIC 12/08 was in effect on a trial basis at Vancouver International Airport. AIC 12/08 stated that controller-applied visual separation could not be employed if wake turbulence separation was required between IFR departures. However, if pilot-applied visual separation was employed, ATC would still apply wake turbulence separation unless it was explicitly waived by the pilot.

In July 2010, AIC 15/10 was issued with a notable change to the pilot-applied visual separation procedure. In particular, AIC 15/10 states that "ATC will not use pilot-applied visual separation between successive departing IFR aircraft if wake turbulence separation is required." This reduces the likelihood of pilots underestimating the spacing from other aircraft. However, this procedure has not been applied to arrivals.

The TC study on *The Increase of Wake Turbulence Events in Canada* indicates that wake turbulence events have averaged about 15 per year. Of significance is that the trend is increasing at a time when air traffic volume is projected to increase substantially in the next 15 years. Given the number of incidents that occur when minimums are met or exceeded, the current wake turbulence separation standards may be inadequate. As air traffic volume continues to grow, there is a risk that wake turbulence encounters will increase.

Wake turbulence is always somewhere behind an aircraft in flight and this accident demonstrates that encounters with it, especially at low altitude, can produce catastrophic results with little or no warning. Although visual separation, whether pilot or ATS applied, may increase efficiency as air traffic grows, it may not be an adequate defence to ensure that appropriate spacing for wake turbulence can be established or maintained, particularly in darkness.

2.4 *Flight Duty Regulations*

Company policy, regulations and the personal responsibility of pilots are the primary defences against pilot fatigue. In this occurrence, both pilots worked part-time for CAC and had other non-aviation related jobs. The critical issue with respect to fatigue is that the captain had been awake for an extended period of time and had accrued a work-related sleep deficit when he woke up 3.5 hours earlier than normal on the day of the accident and did not get any subsequent sleep before the accident flight. In accordance with CARs, some of the work (duty) time was not considered for fatigue management because it was not defined as flight duty time. This creates conditions that could lead to fatigue. Although there are regulations placing the responsibility on pilots to report fit for duty, committing time to other employment may prevent people working in safety-critical positions from obtaining required rest. Without a mechanism requiring pilots to report duty time from all sources of employment, the current unsafe conditions will continue. CAC did not account for all employment obligations that could potentially contribute to the fatigue of its pilots, nor was it required by regulation to do so. Consequently, the current defences of accounting for and managing flight crew fatigue are inadequate.

2.5 Flight Crew Actions

APEX 511 joined the downwind leg in accordance with the airport controller's instruction. The controller's plan was to place APEX 511 in a position between 2 Airbus aircraft. By regulation, it was the responsibility of the flight crew to adjust their flight path to avoid the preceding aircraft's wake turbulence.

Until APEX 511 turned onto the base leg, the flight appeared to be completely normal. The crew was probably familiar with local landmarks, so the extended downwind leg posed no safety concern. The flight crew then had to use unaided eyesight, in darkness, to make a reasonably accurate judgement of the distance from preceding traffic in order to fit in the space available between the 2 Airbus aircraft from a perpendicular heading, after being advised not to get too far behind, while recognizing that the following aircraft might catch up.

Under IFR, the minimum wake turbulence separation for a light behind a medium weight category aircraft is 4 nm or 1000 feet below and is referred to in this report as the wake turbulence area. APEX 511 turned onto the final approach course within the wake turbulence area 1.5 nm behind and 700 feet below the approach path of a heavier aircraft. About 2 nm after turning final, a wake turbulence encounter resulted in an upset and loss of control at an altitude from which the crew could not recover.

The following 2 hypotheses could explain the flight crew's actions:

- The first hypothesis is that the crew intended to follow closely behind the traffic ahead. A lack of consequences during previous flights, possibly behind large aircraft, may have led the crew to underestimate the risk of a wake turbulence encounter. The standard wake turbulence cautionary was given by the airport controller, including the position and altitude of the preceding traffic. However this cautionary was accompanied by the information that the space for APEX 511 was limited. APEX 511 demonstrated its intention to keep it in tight by intercepting the final approach course 1.5 nm directly behind the Airbus. The controller's statement may have influenced the crew's actions allowing the crew to complete the visual approach without undue delay and without inconveniencing the trailing traffic. Even though the consequences of failure (encountering wake turbulence) could be serious, the probability of such an event may have been assessed as low. Under this hypothesis, an underestimation of the risk of the wake turbulence hazard would be consistent with the indicators of attention impairment due to fatigue.

- The second hypothesis is that the crew of APEX 511 did not intend to follow so closely behind the traffic ahead and misjudged the distance between the 2 aircraft. When APEX 511 was assigned the downwind leg for their arrival, visual separation became a larger component of the workload for the flight crew. However, the APEX 511 crew knew that the Airbus was initially above their altitude and would be following a straight in path to Runway 26R. The flight path flown by APEX 511 was consistent with intercepting the localizer portion of the ILS for Runway 26R. This inevitably meant that they would also be intercepting the vertical component (descent path) of the Airbus from below. They may have been aware of the wake turbulence risk behind the heavier aircraft, but simply misjudged their spacing due to reliance upon visual distance estimates. Attempting to achieve specific spacing in darkness carries a higher risk of error due to the known difficulty of judging absolute distances in darkness and being compounded by a background of city lights. This type of mental exercise would normally also be degraded by the effects of fatigue.

2.6 *Airport Controller Actions*

The airport controller considered the downwind method to be the most efficient arrival option for APEX 511. Even though the airport controller arranged to increase the spacing between the traffic to accommodate APEX 511, the faster trailing traffic combined with APEX 511's distance from the airport presented a limitation to the space available for APEX 511.

Many flight crews will make adjustments to their approach to help ensure the success of a controller's plan. Requests, instructions, suggestions or directives by controllers such as "keep it in tight," "don't get too far behind" or "keep the speed up" may give rise to flight crew confidence that controllers have the big traffic picture (through radar) and could influence pilot decision-making over their own judgement of existing or developing circumstances, especially at night.

The controller's plan employed visual separation and relied upon a belief that pilots can accurately judge distance in darkness. Although APEX 511 reported the traffic in sight, visual separation by itself did not ensure that appropriate spacing for wake turbulence would be established or maintained in darkness.

When an airport controller observes a situation that may create concern, the dilemma arises whether to intervene or not. The question centres on the responsibility of airport controllers, based upon their judgement of the situation, to override the flight crew's decisions. If concerned about the proximity of APEX 511 behind the Airbus, the airport controller could have taken action by issuing a further traffic position update to APEX 511. This occurred indirectly about 60 seconds before APEX 511 turned final when it was pointed out as traffic for the Airbus, which APEX 511 was to follow. Although that transmission was not directed to APEX 511, there was no congestion on the tower frequency that would have prevented the crew from hearing it. Airport controllers are trained in the provision of vectors to aircraft operating under VFR. [17] The airport controller had no reason to believe that APEX 511 had any difficulty and could not have known if APEX 511 intended to proceed through the approach track to increase its spacing behind the Airbus by manoeuvring on the north side of the approach track.

The following TSB Laboratory reports were completed:

LP146/2009 – Video Enhancement
LP158/2009 - Analysis of Oil Filter Gasket
LP159/2009 - Fuel Pump Examination
LP162/2009 – Differential Pressure Controller

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

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[17] NAV CANADA Vancouver Tower Course Training Plan.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. APEX 511 turned onto the final approach course within the wake turbulence area behind and below the heavier aircraft and encountered its wake, resulting in an upset and loss of control at an altitude that precluded recovery.

2. The proximity of the faster trailing traffic limited the space available for APEX 511 to join the final approach course, requiring APEX 511 not to lag too far behind the preceding aircraft.

3.2 Findings as to Risk

1. The current wake turbulence separation standards may be inadequate. As air traffic volume continues to grow, there is a risk that wake turbulence encounters will increase.

2. Visual separation may not be an adequate defence to ensure that appropriate spacing for wake turbulence can be established or maintained, particularly in darkness.

3. Neither the pilots nor Canadian Air Charters (CAC) were required by regulation to account for employee duty time acquired at other non-aviation related places of employment. As a result, there was increased risk that pilots were operating while fatigued.

4. Not maintaining engine accessories in accordance with manufacturers' recommendations can lead to failure of systems critical to safety.

3.3 Other Finding

1. APEX 511 was not equipped with any type of cockpit recording devices, nor was it required to be. As a result, the level of collaboration and decision making discussion between the 2 pilots remains unknown.

4.0 Safety Action

4.1 Safety Action Taken

4.1.1 Canadian Air Charters

On 24 July 2009, Canadian Air Charters held a wake turbulence refresher session for all of its pilots.

4.1.2 Transportation Safety Board of Canada

4.1.2.1 Aviation Safety Advisory A09P0187-D3-A1

On 12 January 2011, the TSB issued Aviation Safety Advisory letter A09P0187-D3-A1, entitled Wake Turbulence Encounters During Visual Operations in Darkness, to NAV CANADA and copied to Transport Canada. The advisory suggested that NAV CANADA may wish to address ways to reduce the possibilities of hazardous encounters with wake turbulence within radar service areas during visual meteorological conditions in darkness.

4.1.2.2 Aviation Safety Advisory A09P0187-D2-A1

On 12 January 2011, the TSB issued Aviation Safety Advisory letter A09P0187-D2-A1, entitled Pilot Fatigue, to Transport Canada. The advisory suggested that Transport Canada may wish to consider ways to ensure that all operators and flight crew take into account non-carrier time commitments for the purpose of flight crew fatigue management.

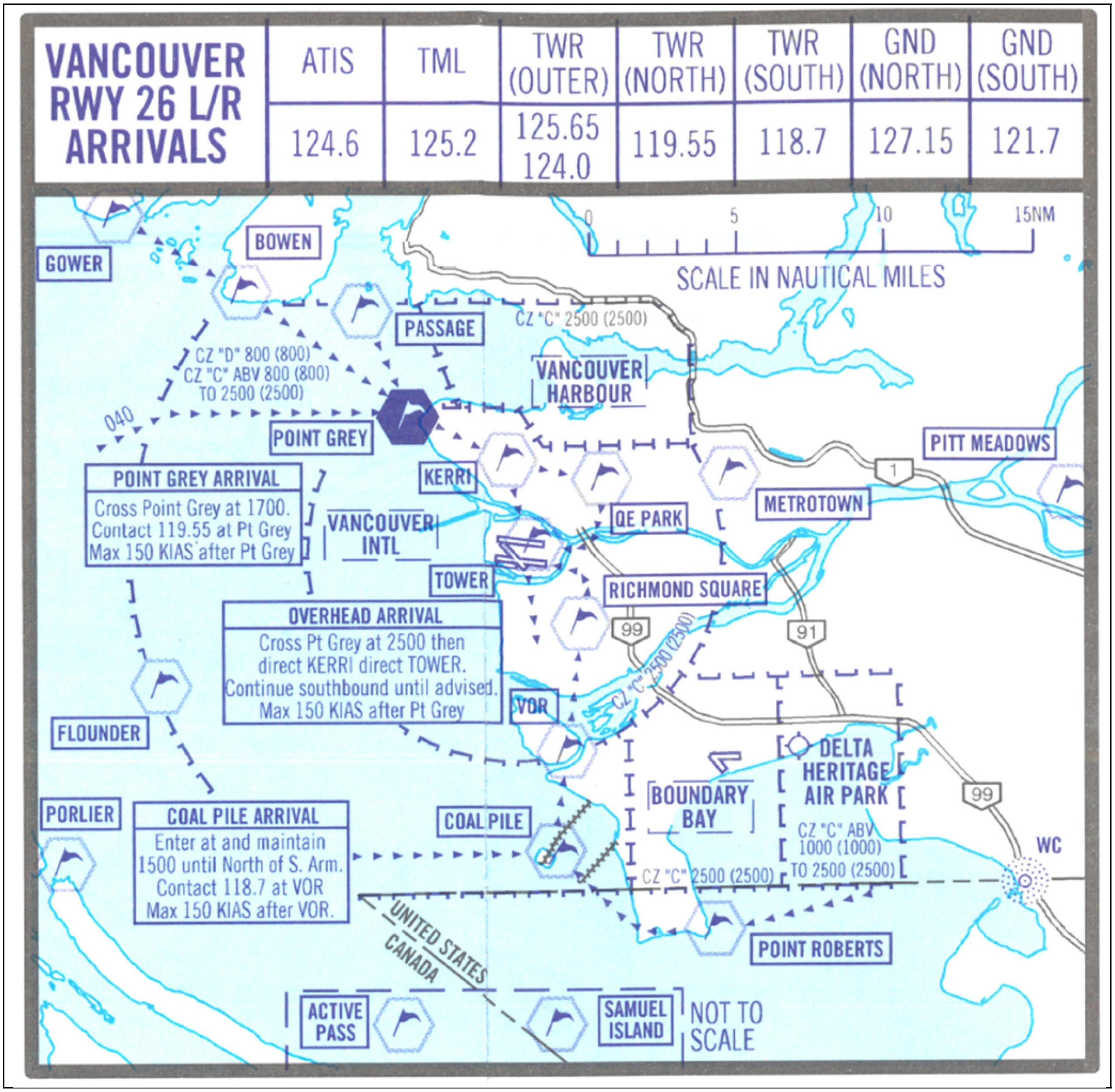
On 31 March 2011, Transport Canada responded and advised that in the summer of 2010, the Canadian Aviation Regulatory Advisory Council (CARAC) established the Flight Crew Fatigue Management Working Group. The Working Group has a mandate to review the CARs flight and duty time limitation and rest priod requirements, as well as make recommendations for change where it is felt necessary.

The response indicated that the Working Group has begun to discuss prescriptive requirements and that the matter raised in this Advisory has already been discussed extensively and will be considered further in their deliberations.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 08 April 2011.

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

Appendix A - Coal Pile Visual Flight Rules Arrival Route



Source: Nav Canada. (2010). Vancouver Visual Terminal Area Chart, AIR 1901.

Appendix B - Previous Wake Turbulence Encounters

A01P0238: The Cessna 172, C-FBOG was on a local training flight at Nanaimo, doing night circuits on Runway 16. A Sikorsky S76 helicopter, which was also doing circuits on Runway 16, took off from a position 200 to 400 feet past the threshold of Runway 16 when C-FBOG was 0.5 miles on final. C-FBOG was advised to watch out for wake turbulence. Over the threshold, the 172 encountered wake turbulence, veered to the right and passed over the main apron before regaining control and carrying out a go around. The 172 made another circuit and landed without further difficulty. (2054 PDT, 24 September 2001, darkness at 1940)

A03O0198: Air Canada Jazz flight 7732, a De Havilland DHC-8 aircraft, registration C-FHRC, was on approach to Runway 05 at Toronto/LBPIA after a flight from London, Ontario, following an Airbus A330 aircraft (Air Transat flight 421) that was 6.2 nm ahead. Jazz 7732 encountered wake turbulence resulting in a bank excursion in excess of 30˚ and an altitude deviation of plus 200 feet. The pilot increased power to maximum and recovered the aircraft to level flight and continued the approach, landing without further incident. The aircraft was undamaged by the wake turbulence encounter, but the engines were both over-torqued during the power application. (0640 EDT, 22 July 2003)

A05Q0010: The CRJ, registration C-FVKR, was on final approach for Runway 24R at Montreal/Pierre Elliott Trudeau International Airport, behind an Air France 777, when it experienced wake turbulence and an un-commanded bank of 45˚ to 60˚. The bank was momentary and the aircraft did not deviate from the normal approach path; the aircraft landed without further incident. (1755 EST, 13 January 2005, darkness at 1708)

A06W0126: The Westjet Boeing 737-700, C-FWSF, was operating as flight WJA661 from Toronto, Ontario, to Calgary, Alberta. WJA661 was being vectored for a visual approach to land number 2 on Runway 16 in Calgary. When the flight crew of WJA661 contacted the Calgary tower, they were advised that they were 6 miles behind heavy traffic and were number 2 to land. When WJA661 turned final, they encountered wake turbulence from the preceding Airbus A330, which resulted in a loss of about 15 knots of airspeed, a roll to the right and a climb of about 200 feet. The auto pilot was disconnected with a simultaneous application of thrust to correct for the upset. The remainder of the approach was uneventful. It was determined that the Airbus had been at a higher altitude on the approach than WJA661 and consequently flew a steeper visual approach. (0510 MDT, 22 July 2006, twilight at 0506)

A06O0236: On approach to Toronto, the De Havilland DHC-8-301 airplane, registration C-GHTA, operating as Jazz flight 7832, encountered wake turbulence from a Boeing 747-400 airplane (Korean Airlines flight 073) that was 7 nm ahead and had descended through the altitude of the Dash 8. The turbulence encounter resulted in a roll excursion to 60˚ right bank, then 60˚ left bank. The crew regained control of the aircraft and continued to an uneventful landing. ATC kept the Dash 8 above the 747's altitude until on final approach. Spacing was 7 nm throughout; the required spacing for a medium behind a heavy is 5 nm. (2050 EDT, 03 September 2006, darkness at 2019)

A08F0151: The Air Canada Boeing 767-300 (registration C-FTCA, flight number 888) was on the approach for Runway 09L at London Heathrow. The aircraft was at an altitude of 3000 feet (3 nm behind another B767) when wake turbulence was encountered. The aircraft rolled to the right, to a bank angle of approximately 30˚. The flight crew disconnected the autopilot and manually recovered without further incident. The flight crew adjusted the track and profile of the aircraft to avoid any further wake turbulence. (0625Z 19 September 2008)

A09Q0119: The DHC-8, registration C-FADT, operated by Air Canada Jazz originating from Quebec was on descent from 7300 feet to land on Runway 24L at Montréal when the flight crew reported experiencing wake turbulence. The flight path of the DHC-8 crossed the one from a Boeing 777, operated by British Airways, 12 miles ahead, which had descended through the same altitude (7300') about 3 minutes earlier on approach for Runway 24R. In spite of the wake turbulence encountered, the flight crew did not experience any control difficulty and the aircraft landed without further event. However, a cabin crew suffered minor injury while attempting to brace during the turbulence. The required spacing for wake turbulence between these 2 aircraft was 5 miles. (1938 EDT, 20 July 2009)