Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A11P0073

LOSS OF SEPARATION

NAV CANADA − VANCOUVER TOWER
VANCOUVER INTERNATIONAL AIRPORT
RICHMOND, BRITISH COLUMBIA
15 APRIL 2011

Canada

Aviation Investigation Report

Loss of Separation

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Summary

At 2300 Pacific Daylight Time, a Jazz Airlines de Havilland DHC-8-311, Flight 269, took off from Runway 26L, adjacent to the intersection of the Echo taxiway, at Vancouver International Airport, British Columbia. Moments later, a Westjet B-737-700, Flight 628, was cleared for take-off from the threshold of Runway 26L. A third aircraft, Westjet B-737-800, Flight 2057, which was on short final for landing on Runway 26L, was directed to carry out a missed approach. It was dark at the time of the occurrence, and all 3 aircraft were on instrument flight rules flight plans. The 2 Boeing 737s came within approximately 2000 feet lateral spacing before instrument flight rules separation was restored.

Ce rapport est également disponible en français.

Factual Information

History of the Flight

Runway 08L/26R at the Vancouver International Airport (CYVR) was closed by notice to airmen (NOTAM) for construction from 1900 [1] on 15 April 2011 to 0800 on 17 April 2011. At the time of the occurrence, Runway 26L was in use for arrivals and departures, and Runway 12/30 was being used occasionally as a taxiway for arriving flights. The YVR control zone includes that airspace within 7 nautical miles (nm) of the airport, up to and including 2500 feet above sea level (asl), and within 13 nm of the airport above 800 feet asl, up to 2500 feet asl.

The CYVR weather issued at 2300 was reported as wind calm, visibility 10 statute miles (sm), light rain, broken ceiling at 2600 feet above ground level (agl), overcast ceiling at 4100 agl, temperature 6˚C, dew point 3˚C, and altimeter 30.00 inches of mercury. It was dark at the time of the occurrence, but visibility was reported as good.

Two controllers were on duty at the time of the occurrence, working the midnight shift, which commenced at 2230 and was scheduled to finish at 0630 the following day. YVR Tower has 7 control positions available. At the time of the occurrence, Tower South, Tower North, Advisory Hi and Advisory Lo were combined into the Airport position. The Ground position was combined to include Ground South, Ground North and Clearance Delivery. The occurrence controller occupied the airport control (airport controller) position. [2]

Westjet Flight 628 (WJA628) was a regularly scheduled flight departing CYVR for Toronto/Lester B. Pearson International Airport (CYYZ). WJA628 received its air traffic control (ATC) clearance and standard instrument departure (SID) instructions, Georgia 2, at 2222. At 2254, WJA628 was given taxi clearance for Runway 26L via taxiways Echo and Delta. Jazz Airlines Flight 269 (JZA269) was a regularly scheduled flight from CYVR to Victoria International Airport (CYYJ), and had received its ATC clearance and SID instruction, Richmond 1, at 2218. At 2255, JZA269 was issued taxi clearance for Runway 26L via taxiway Echo. WJA628 was ahead of JZA269 leaving the ramp, with a tractor towing an aircraft between them. WJA628 continued left onto Delta taxiway, and JZA269 continued straight ahead on Echo taxiway toward Runway 26L (Figure 1).

WJA2057, a Boeing 737-800, was an arriving flight from Cancun International Airport (MMUN). At 2254, WJA2057 was number 2 in the arrival sequence. WJA2057 was 12 nm southeast of CYVR, following another B737 on an instrument landing system (ILS) approach to Runway 26L. At 2259, WJA2057 contacted the control tower and advised that WJA2057 was 9 nm back, on final approach for Runway 26L.

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

2 A duty controller assigned to the airport control position in an airport control tower

Between 2251 and 2304, the ground controller was responsible for 6 aircraft and 1 tow vehicle. Two of the aircraft were taxiing in to the terminal, and 4 were taxiing out for take-off. During the same period, the airport controller was responsible for 10 aircraft: 5 arrivals and 5 departures. The traffic situation was light and non-complex.

At 2300:07, WJA628 was nearing the threshold Runway 26L on taxiway Delta, and the flight crew advised the airport controller that WJA628 was ready for departure. The airport controller instructed WJA628 to hold short of Runway 26L, and advised the flight crew that they were number 2 for departure. Ten seconds later, WJA628 was instructed to line up on Runway 26L and to be ready to depart without delay. There was no mention of threshold in the instruction, and no sequence number was issued to the flight crew of WJA628. The flight crew of WJA628 confirmed that WJA628 would line up and wait on Runway 26L. At 2300:32, JZA269, holding on the Echo taxiway, was also instructed to line up on Runway 26L. This instruction was acknowledged by JZA269.

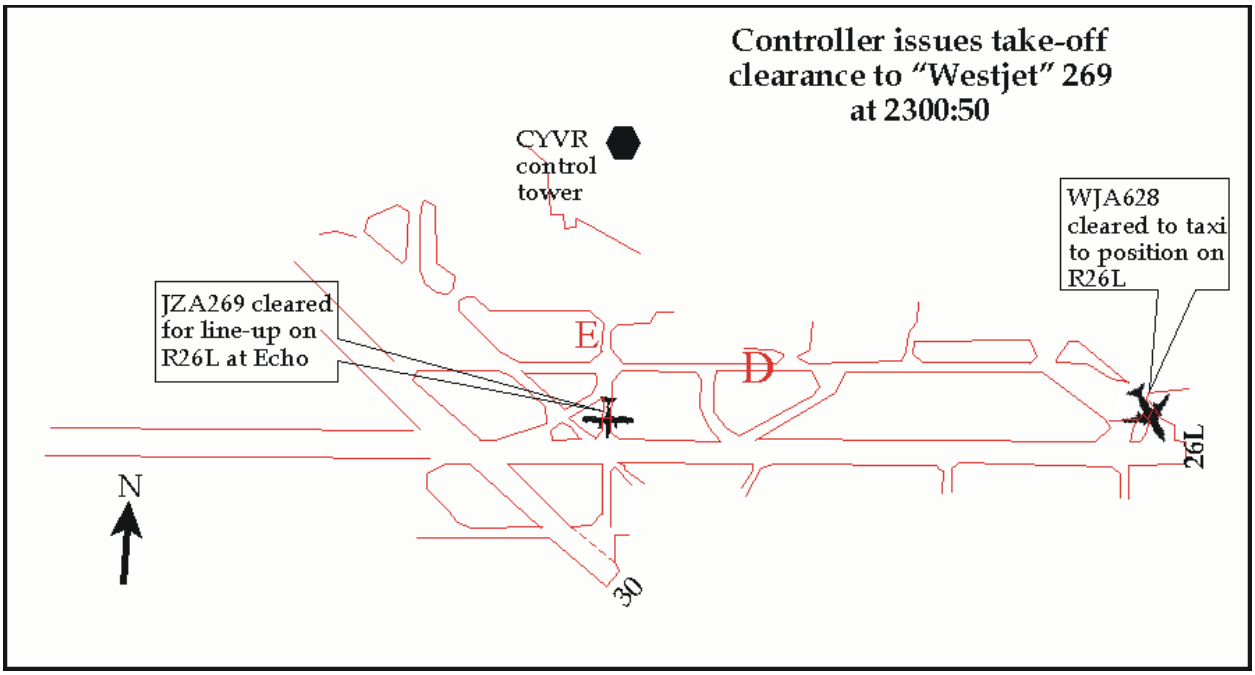

Figure 1. Departure positions of JZA269 and WJA628 at 2300:50 (drawing not to scale)

At 2300:50, as both WJA628 and JZA269 taxied into position on Runway 26L, the airport controller issued a take-off clearance (Figure 1). The aircraft cleared for take-off was identified as "Westjet 269," and the clearance included the instruction to fly the Richmond 1 SID. The clearance did not name the taxiway/runway intersection, as required by the NAV CANADA ATC *Manual of Operations* (ATC MANOPS). At 2300:58, the flight crew of WJA628 read back the take-off clearance and questioned the change in SID from the previously issued Georgia 2 SID to the Richmond 1 SID. The Richmond 1 SID is designed for use by non-jet aircraft only. Five seconds later, the flight crew of JZA269 advised that JZA269 was lined up on Runway 26L. The airport controller, realizing that a mistake had been made, then cleared JZA269 for take-off, and instructed WJA628 to hold position. The take-off clearance for JZA269 did not include the

intersection from which the aircraft departed. JZA269 and WJA628 acknowledged the revised clearance/instructions. Neither aircraft had commenced a take-off roll at this time.

At 2301:05, the airport controller advised the flight crew of WJA2057, 2.5 nm from the threshold of Runway 26L, that they were number 1 for landing, and to expect landing clearance at 1 nm. At that point, WJA2057 was approximately 1 minute's flying time from the threshold of Runway 26L. [3] At 2301:25, JZA269 commenced the take-off roll. Twenty-two seconds later, the airport controller advised the flight crew of WJA628 that the departing JZA269 would be turning further south than them, instructed them to fly the Georgia 2 SID, and cleared the aircraft for take-off. At that time, WJA2057 was 1.8 nm, which equates to 43 seconds' flying time, from the threshold of Runway 26L. WJA628 read back the clearance at 2301:54. At 2302:00, the airport controller requested WJA628 not to delay the departure. At 2302:04, WJA628 commenced the take-off roll (Figure 2). Two seconds later, the airport controller instructed WJA2057, now at 400 feet asl and 0.9 nm from the threshold, to pull up, go around, and make a left turn. During this communication, the airport controller did not specify an altitude or a heading for WJA2057.

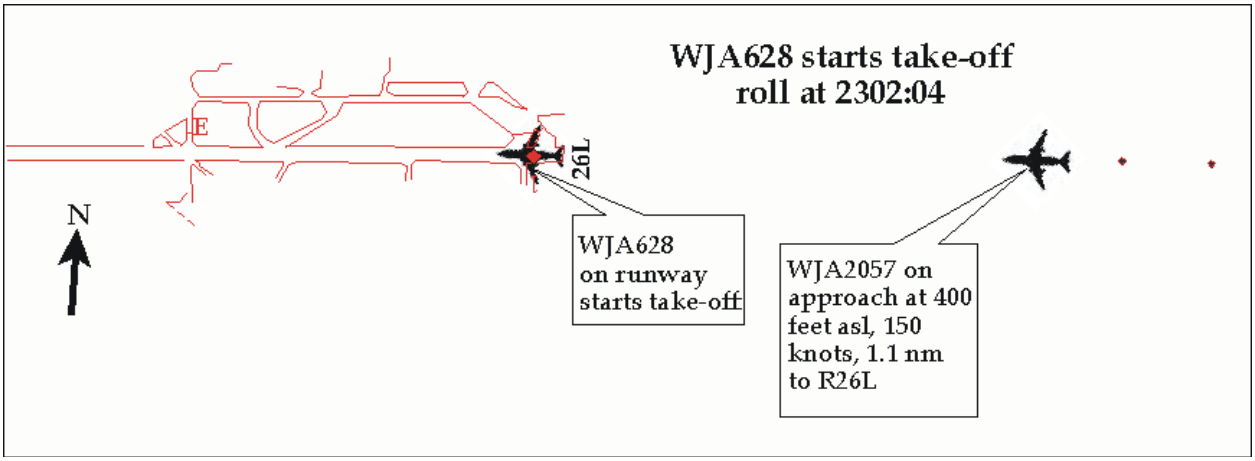

Figure 2. WJA628 starts take-off roll at 2302:04 (drawing not to scale)

WJA2057 did not immediately acknowledge the airportcontroller's instruction; however, recorded radar information indicates that WJA2057 arrested its descent at 300 feet asl and commenced a climb at 2302:18. The aircraft was 0.3 nm from the threshold of Runway 26L at the time. Fourteen seconds after advising WJA2057 to go around and make a left turn, the airport controller instructed WJA2057 to turn to a heading of 240° magnetic (M) and climb to 2000 feet asl. The flight crew of WJA2057 acknowledged the turn and requested confirmation of the altitude. WJA2057 crossed the threshold of Runway 26L at 2302:26, at an estimated altitude of 800 feet asl and 150 knots indicated airspeed (KIAS). At that time, WJA2057 was approximately 0.23 nm behind WJA628, still on the take-off roll, with an overtake speed of 64 knots, decreasing as WJA628 accelerated. The closest distance between the 2 aircraft occurred at 2302:41, when WJA2057 was 1947 feet, or 0.32 nm, behind WJA628, at which point WJA2057 completed its immediate go-around actions and then commenced a left turn as the aircraft climbed through

[3] Based on a reported ground speed of 150 knots

1100 feet asl (Figure 3). No traffic or sequencing information was provided to either WJA628 or WJA2057. Although the flight crew of WJA2057 saw WJA628 on the button of Runway 26L during the approach, they lost visual contact with WJA628 when they commenced the missed approach. The crew of WJA628 did observe a target corresponding to WJA2057 on the traffic collision-avoidance system (TCAS) display in the cockpit. WJA628 was ahead of WJA2057, and did not acquire WJA2057 visually.

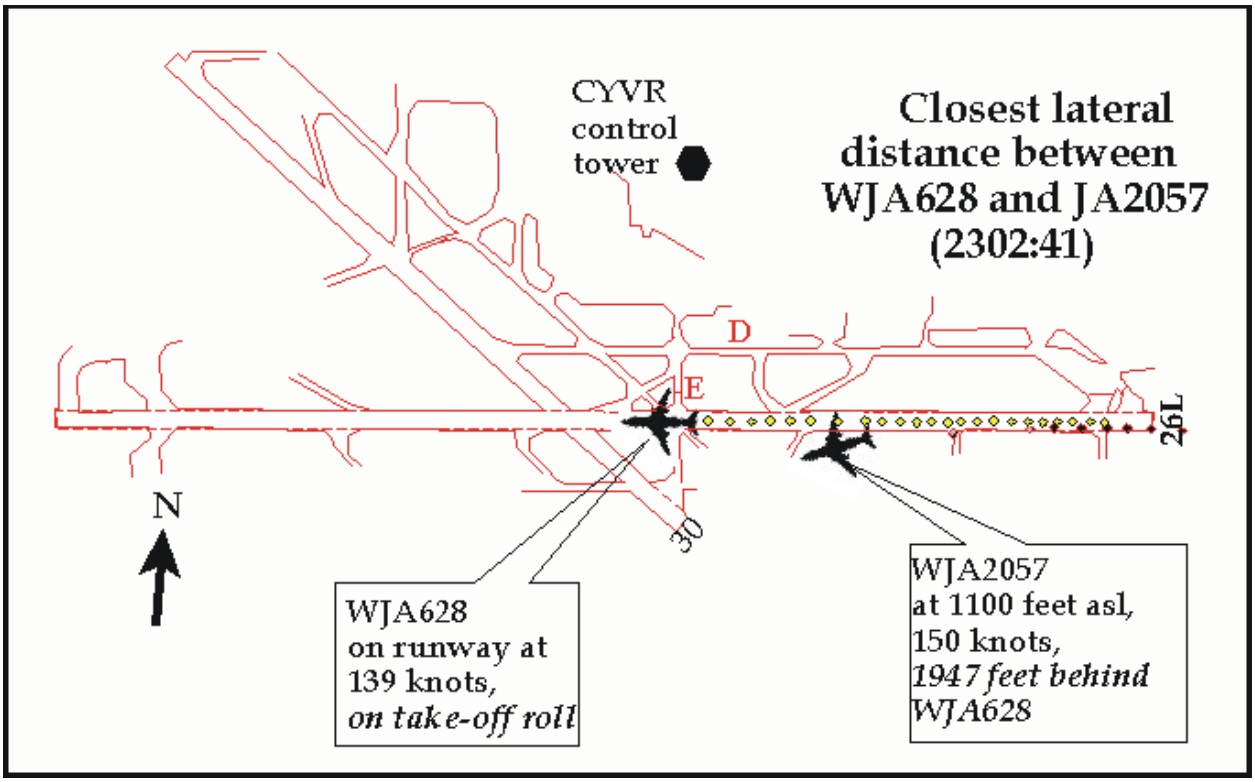

Figure 3. Closest lateral distance between WJA2057 and WJA628 (drawing not to scale)

ATC MANOPS Section 352.2 states that controllers are to separate an arriving aircraft from a preceding aircraft that is using the same runway. They must do so by ensuring that the arriving aircraft does not cross the landing threshold until the preceding aircraft is airborne and at a sufficient distance from the threshold that the arriving aircraft will not overtake it during the landing roll or conflict with it in the event of a missed approach.

The airport controller then advised the flight crew of JZA269 that a Boeing 737 would be turning to a heading of 240˚ behind them at 2000 feet asl. A few seconds later, at 2302:54, the airport controller instructed JZA269 to fly directly to the Vancouver very high-frequency omnidirectional range (VOR) beacon. Then, at 2302:56, the airport controller instructed WJA628 to fly runway heading. The Georgia 2 SID would have required WJA628 to turn to heading 245˚M after climbing through 420 feet asl. Just before crossing the departure end of Runway 26L at 2302:57, WJA628 passed 400 feet asl climbing to 7000 feet asl. WJA2057 was 0.4 nm southeast of WJA628, climbing through 1800 feet asl to 2000 feet asl at that point. The airport controller then amended the heading for WJA2057 to 245˚M. A few seconds later, at 2303:22, the airport

controller advised the departure controller that WJA2057 was going around and climbing to 2000 feet asl on a heading of 245˚M, and that WJA628 was instructed to fly runway heading.

At 2303:36, the airport controller, intending to instruct JZA269 to contact departure control, again used the wrong call sign—"Westjet 269" (Appendix A). Several transmissions between the airport controller and JZA269 were required to clarify the instruction, after which JZA269 acknowledged the change in frequency. While intending to transfer WJA2057 to the departure frequency, the airport controller again confused the aircraft call signs and used "Jazz 2057." This instruction was not acknowledged, and WJA2057 remained on the airport controller's frequency. At 2304:13, the airport controller instructed WJA628, now 3.8 nm from the departure end of Runway 26L and climbing through 2700 feet, to contact departure control. At this point, WJA2057 and WJA628 were 1.6 nm laterally and 700 feet vertically apart. This distance did not provide the minimum instrument flight rules (IFR) separation required by ATC MANOPS. The minimum separation required would have been 3 nm lateral, or 30° heading difference, until 1000 feet vertical was achieved. At 2304:23, WJA628 was climbing through 3200 feet asl to its cleared altitude of 7000 feet asl.

Controller–Pilot Communications

Voice communication between pilots and air traffic services (ATS) personnel is a critical safety link in the ATS system. [4] Incorrect, non-standard or imprecise phraseology by controllers and pilots has been a recurring factor in risk-of-collision and loss-of-separation incidents. [5] A multi-disciplinary effort headed by NAV CANADA, titled *The First Defence*, identifies several practices to enhance pilot-ATS communications. These practices are as follows:

- Practice proper communication
  - Give full read backs of:
    - IFR clearances and instructions
    - Instructions to hold short of a runway
  - Pay attention to similar call signs
  - Use standard phraseology
  - Use full call signs
  - Speak up if you detect an error
  - Request confirmation
- If in doubt, ask
- Minimize distractions
- Challenge poor communications

A review of the phraseology used during this occurrence was conducted and compared to the requirements as stated in the ATC MANOPS. A number of anomalies were noted in clearances

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4 NAV CANADA, *The First Defence: Effective Air Traffic Services−Pilot Communication*, available at http://www.navcanada.ca/NavCanada.asp?Language=en&Content=ContentDefinitionFiles/Services/ATS-Pilot/default.xml (last accessed on 29 May 2013)

5 International Civil Aviation Organization (ICAO) DOC 9432-AN/925: *Manual of Radiotelephony*

and instructions issued by the airport controller, both before and after the loss of IFR separation (Table 1).

Table 1. Comparison of phraseology used in occurrence versus ATC MANOPS phraseology

Phraseology used	**ATC MANOPS phraseology**
Westjet 6 2 8 actually, line up 2 6 left, but be ready to go without delay	*336.2 B. Phraseology:* LINE UP AT THRESHOLD, RUNWAY (number).
Westjet 2 6 9, the wind's calm, make an early left turn on the Richmond One departure, you're cleared take-off 2 6 left	*336.8 A. Phraseology:* FROM (taxiway or intersection), CLEARED FOR TAKE-OFF RUNWAY (number)
…that clearance for Jazz 2 6 9 left turn and cleared take-off 2 6 left…	*336.8 A. Phraseology:* FROM (taxiway or intersection), CLEARED FOR TAKE-OFF RUNWAY (number). *336.14 D. Example:* DELTA TANGO MIKE, RIGHT TURN OUT AFTER DEPARTURE, FROM BRAVO CLEARED FOR TAKE-OFF RUNWAY TWO SEVEN.

Controller Duties/Responsibilities

ATC MANOPS states, in Part 3, Section 301, that "the objective of airport and VFR [6] control service is to maintain a safe, orderly, and expeditious flow of air traffic under the control of a Control Tower." To accomplish this objective, controllers are to:

> Apply separation between aircraft through consistent reference to and use of the following three elements that are fundamental to safe, orderly, and expeditious control:
>
> A. Planning — determine the appropriate separation required.
> B. Executing — implement the selected standard.
> C. Monitoring — ensure that the planned and executed separation is achieved and maintained.

Controllers receive extensive training in rules and procedures, including periodic knowledge-verification testing, and monitoring of operational and communication skills, to ensure that they are able to safely and efficiently maintain the flow of air traffic. Serious operational errors are rare, and most controllers may never experience such an error over the course of their careers. However, operational errors do occasionally occur, and recovering from such an error

[6] Visual flight rules

often requires a quick and measured response to resolve the situation. Previous training is required to prepare controllers to react to such situations. Controllers receive limited training, either in written form, through group discussions, or using simulation, in how to best recover from these errors.

Controller Procedures

According to ATC MANOPS Section 334.4 and the Transport Canada (TC) *Aeronautical Information Manual* (AIM) Section RAC 4.2.8, a controller may authorize a departure from an intersection if the aircraft requests it, or if the controller suggests it and the aircraft accepts it. Section 334.5 states that, before suggesting an intersection departure, the controller must inform the aircraft of the runway length remaining from the intersection.

ATC MANOPS Section 335.1 states that a controller may clear 2 departing IFR aircraft from the same runway in sequence if the controller's "visual observation confirms that the preceding IFR aircraft has departed and has turned to clear the departure path of the succeeding aircraft, or has reached a point on its departure path where it will no longer conflict with the departure path of the succeeding aircraft."

Section 336.5 of ATC MANOPS states, in part, that a controller may line up more than 1 aircraft for take-off on the same runway if traffic information is given to the second and subsequent aircraft in the departure sequence, and if the controller specifies the name of the runway intersection, taxiway, or threshold as appropriate.

At some locations, airport controllers are authorized to provide initial IFR separation for departing aircraft, without prior coordination with the applicable IFR unit. At CYVR, airport controllers are authorized to employ this procedure.

In addition, there is an inter-unit arrangement in place between Vancouver terminal and Vancouver control tower that allows the control tower, weather permitting, to automatically assume responsibility for control of all arriving aircraft once they reach 4 nm from the threshold.

Decision-making

Effective decision-making involves accurate understanding of the current situation, appreciation of the potential implications of changes to the current situation, and formulation of a plan(s) and contingencies, followed by the implementation of the best course of action. In the ATS environment, controllers are often required to manage multiple arriving and departing aircraft and to make time-critical decisions based on rapidly changing cues from the environment. A critical component of a controller's decision-making process is situational awareness (SA). SA may be formally defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the

projection of their status in the near future." [7] From this definition, SA can be broken down into 3 levels. Level 1 SA (perception) involves an individual's ability to detect critical factors from the environment. Level 2 SA (comprehension) involves understanding what those factors mean and their relation to higher-level goals. Level 3 SA (projection) involves taking levels 1 and 2 SA and using that information to anticipate the impact that those factors will have in the near future. A breakdown in SA can occur at any of the 3 levels explained above, particularly when "challenged by the limitations of human attention and working memory." [8]

Once a plan has been implemented, it is vital that controllers recognize changes in their situation and reinitiate the decision-making process, to ensure that changes are accounted for and plans modified accordingly. For example, if something unexpected occurs, controllers must consider this change in the current situation and revise their plan accordingly. Failure to adequately consider the potential implications of a situation increases the risk that a decision will produce an adverse outcome that may reduce safety margins. In addition, as stress levels increase, they can adversely impact an individual's ability to perceive and evaluate critical cues from the environment, and may result in attentional narrowing. [9] In many cases, this attentional narrowing can lead to confirmation bias, which causes people to seek out cues that support the desired course of action, to the possible exclusion of critical cues that may support an alternate, less desirable hypothesis. [10] That means that potentially serious outcomes may not be given the appropriate level of consideration when determining the best possible course of action. As a result, controllers must remain flexible and be able to adapt to changes in a situation, whatever those changes may be.

When controlling multiple arriving and departing aircraft, it is important that controllers take into account the time required for flight crews to carry out a controller's instructions. In some cases, flight crews are able to respond quickly to a controller's instructions. In other instances, flight crews are required to carry out a series of procedures before they can comply with a controller's instruction. For example, it took approximately 15 seconds for WJA628 to commence the take-off roll after receiving take-off clearance from the airport controller. In addition, WJA2057 was anticipating the possibility of a missed approach, and it took 28 seconds from the time the controller called for the go-around until WJA2057 had completed all of its go-around actions and commenced the left turn to 240˚M.

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7 J.A. Garland, V.D. Wise, D.J. Hopkins (editors), *Handbook of Aviation Human Factors*, (Lawrence Erlbaum Associates, 2009), page 258

8 Ibid

9 Crew Resource Management (CRM) Standing Group, *Crew Resource Management* (London, UK: Royal Aeronautical Society, 1999)

10 C.D. Wickens and J.G. Hollands, *Engineering Psychology and Human Performance*, 3rd edition, (New Jersey: Prentice Hall, 1999)

Controller Fatigue

In 2001, TC published the *Report to the Tripartite Steering Committee on ATC Fatigue* (TP13742E). [11] The report examined 3 key areas of concern, namely scheduling practices, knowledge of human factors, and workplace conditions. The report concluded that "…fatigue can pose a risk to safety and must be managed systematically." The report goes on to state that "practices and strategies to effectively mitigate the occurrence and effects of unacceptable levels of fatigue are also needed to promote the acquisition of high quality sleep (which is at the core of this issue)." With respect to controllers working midnight shifts, the report states:

> In any 24/7 operation such as air traffic control, it is understood that there will be a requirement for employees to work shifts that fall over the midnight hours… Midnight shifts have the most impact, and are generally accepted as being the most difficult shifts to adapt to in terms of fatigue management, as the body's natural tendency towards sleep increases over these hours. The literature also indicates that more than two consecutive midnight shifts has a cumulative impact and that the longer the shift and the earlier the start, the greater the disruption to circadian rhythms.

Other research has shown that most people require 7.5 to 8 hours of sleep for every 24 hours. [12] When sleep is reduced to less than 6 hours, fatigue reliably reduces human performance. [13] Likewise, circadian disruptions, typically associated with changing sleep-wake cycles that are common in shift workers, can also lead to performance degradations due to fatigue. [14] Studies have established that fatigue can result in a breakdown in vigilance, degraded response times, and poor decision-making and risk assessment." [15] In addition, the effects of fatigue typically worsen as the period of wakefulness increases.

A risk of fatigue-induced human performance decrements is inherent in all 24-hour operations. To address this risk, NAV CANADA developed a fatigue management program (FMP), which is integrated into its safety management system. The FMP includes a number of components, such as controller education, preventive and operational strategies, controller scheduling practices, and the concept of shared responsibility. All operational controllers receive information on fatigue management during their basic and recurrent training. The goal of the

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11 Transport Canada (TC), *Report to the Tripartite Steering Committee on ATC Fatigue* (TP13742E) (2001)

12 See, for example: A. Anch, C. Browman, M. Mitler, and J. Walsh, *Sleep: A scientific perspective* (New Jersey: Prentice-Hall, 1988)

13 See, for example: M. Rosekind and D. Dinges, cited in: "Experts: Human fatigue bigger risk to safety than realized," *Air Safety Week*, 18(12) (2004), pages 1−4

14 M. Rosekind, R. Smith, D. Miller, et al, "Alertness management: Strategic naps in operational settings," *Journal of Sleep Research*, 4, Suppl. 2, (1995), pages 62−66

15 J.A. Caldwell, "Fatigue in the aviation environment: An overview of the causes and effects as well as recommended countermeasures," *Aviation, Space, and Environmental Medicine*, Vol. 68(10) (1997)

training is to encourage controllers to use operational and preventive strategies to help manage the risk of fatigue and related decrements in human performance. Preventive strategies are used before shifts to properly manage sleep-wake patterns and reduce the likelihood of fatigue. [16]

In the 72 hours before the occurrence, the airport controller's schedule was as follows:

13 April 2011 − Day shift (0630 to 1458)
14 April 2011 − Day shift (0530 to 1358)
14 April 2011 − Midnight shift (2230 to 0630)
15 April 2011 − Midnight shift (2230 to 0630) (occurrence shift)

The airport controller had approximately 6 hours of sleep in the 8.5 hours after completing the day shift on 14 April, before commencing the midnight shift later that night. In the 15.5 hours off after completing the first midnight shift, the airport controller slept for approximately 5 hours. The incident occurred 30 minutes into the second consecutive midnight shift.

A Fatigue Avoidance Scheduling Tool (FAST) [17] analysis was conducted by the Transportation Safety Board of Canada (TSB) to determine the role, if any, that fatigue played in the occurrence. The TSB's analysis of the airport controller's sleep pattern indicated that the airport controller did not obtain sufficient sleep before the occurrence shift, which would likely have contributed to degraded performance. In addition, the airport controller's schedule did not permit enough adaptation time, due to the requirement to sleep during the day in an attempt to be adequately rested for the night shift.

Supervision

There was no supervisor on duty in the control tower after 2230, nor was one scheduled. Following the occurrence, the airport controller completed the balance of the shift, and was relieved by the regularly scheduled day shift controller the next morning.

According to Section 232 of NAV CANADA's *Air Traffic Services Administration and Management Manual*, managers shall process operating irregularities in accordance with the *Operations Safety Investigations (OSI) Guidelines Manual*. [18] The OSI states in part:

> Employees are to inform their immediate supervisor or manager, as soon as possible, of any reportable occurrence. If the immediate supervisor or unit manager is not available, the ACC shift manager shall be informed …

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16 Transportation Safety Board of Canada (TSB) Investigation Report A10O0089

17 The Fatigue Avoidance Scheduling Tool (FAST) is software that employs the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) mathematical model and sleep-wake schedule data to predict (1) fatigue factors that are likely to increase the risk of human performance decrements; and (2) specific human performance metrics. FAST is distributed by Fatigue Science, available at www.fatiguescience.com.

18 NAV CANADA, *Operations Safety Investigations (OSI) Guidelines Manual,* 500 Overview - Employee and Management Roles and Responsibilities, 1st and 2nd paragraphs

> Managers shall immediately arrange for the removal of ATS personnel directly involved in the occurrence, from operational duties, until the circumstances have been fully examined. Removal from operational duties is mandatory, except where it is immediately clear and obvious to both the employee and the manager that the incident was caused solely by external influences and that full responsibility rests elsewhere.

The purpose of removing the controller from operational duties is to allow management time to properly analyze the circumstances of an operating irregularity, and to take any action deemed appropriate to reinstate the involved controller. Removal from duty is not intended to be punitive or disciplinary in nature.

Management was not contacted about this occurrence before the end of the midnight shift. Neither controller considered this to be a hazardous situation or a reportable incident. A control tower logbook entry was made, indicating that a missed approach had been directed for an arriving aircraft. After reviewing the recorded information, the day control tower supervisor concluded that a reportable incident had occurred, and took subsequent action in accordance with NAV CANADA policy.

Analysis

The analysis section of this report will focus on several of the communication and decision-making factors that reduced safety margins and resulted in a loss of instrument flight rules (IFR) separation between 2 medium-sized passenger transport aircraft. In an effort to enhance safety, the analysis will also examine the role that fatigue may have played in the occurrence.

Controller–Pilot Communications

In this occurrence, there were several examples of non-standard phraseology used by the airport controller. WJA628 had first been instructed to hold short of the runway and advised that it would be number 2 for departure. A few seconds later, the airport controller instructed WJA628 to line up on the runway and to be ready to depart without delay. Although required to do so by the *Air Traffic Control Manual of Operations* (ATC MANOPS), the airport controller did not repeat the departure sequence number of WJA628 during this radio communication. The airport controller then taxied JZA269 into position on the runway, at the Echo taxiway intersection, intending that this aircraft depart first. The purpose of assigning a departure sequence is to ensure that flight crews remain fully aware of their sequencing, to maintain the highest possible degree of situational awareness and to reduce the risk of collision.

The controller issued take-off clearance using the call-sign WJA269. WJA628 responded by repeating the take-off clearance but querying the standard instrument departure (SID). When the flight crew of JZA269 alerted the airport controller that JZA269 was in position on the runway, the airport controller realized that a mistake had been made when issuing the take-off clearance to JZA269. The airport controller then cleared JZA269 for take-off, and instructed WJA628 to hold position. When the airport controller issued take-off clearance to JZA269, the clearance did not include the intersection from which the aircraft departed. The purpose of stating the location of departure is to reduce the possibility that a take-off clearance is issued to the wrong aircraft holding on the runway. If non-standard phraseology is used when multiple aircraft are lined up for take-off on the same runway, there is increased risk of collision due to errors in departure sequencing.

The phraseology error that initiated the sequence of events of this incident was the call-sign/flight-number mix-up. The airport controller inadvertently mixed up the call signs / flight numbers when issuing the take-off clearance. As a result of the confusion and the resulting delay, there was no longer sufficient time to safely depart WJA628 and to allow WJA2057 to land without creating a risk of collision. The controller did not immediately recognize this situation.

The inclusion of the Richmond 1 departure generated a question by WJA628, because WJA628 had initially been given the Georgia 2 departure. The intent of that reply by the crew to the controller was to question which aircraft was meant to be cleared for take-off. However, the crew of WJA628 used vague, unclear wording in the attempt to alert the airport controller to the mistaken take-off−clearance wording. This lack of clarity extended the time before the controller realized the mistake. It was the statement by the flight crew of JZA269, that JZA269 was also on the runway, which made the controller realize that an error had been made. Since neither of the

2 aircraft on the runway commenced a take-off, and the error was almost immediately corrected, there was no risk of collision or loss of separation at that point in the sequence.

Decision-making

Intersection departures, in which an aircraft departs from a runway at a point other than the threshold, can provide an operational advantage for controllers and aircrew under some circumstances. However, with multiple departures, this type of procedure requires strict adherence to standard phraseology, correct traffic information, and sufficient space ahead of or between arriving flights. Before taxiing JZA269 and WJA628 onto Runway 26L, the airport controller assessed the departing and arriving air traffic, and determined that it would be feasible to depart those aircraft before the arrival of WJA2057. Since neither of the 2 aircraft on the runway commenced a take-off, and the mix-up in call sign was almost immediately corrected after the crew of JZA269 spoke up, there was no risk of collision or loss of separation at that time. However, while the airport controller was sorting out the confusion about the departure sequencing of the aircraft on Runway 26L, WJA2057 was rapidly approaching the airfield. The time required to straighten out this mix-up considerably reduced the time available to safely depart the 2 aircraft on the runway and land WJA2057.

Once the mix-up on the runway was sorted out, the airport controller tried to salvage the plan by quickly re-issuing take-off clearance to JZA269, instructing WJA628 to hold position, and advising WJA2057 to expect landing clearance at 1 nm. Once JZA269 was airborne, the airport controller cleared WJA628 for take-off; however, growing concerned about the separation between WJA628 and WJA2057, the airport controller requested no delay in rolling to the flight crew of WJA628. At this point, the airport controller's focus was on executing the original plan. The controller did not at this time consider the possibility of a missed approach for WJA2057, nor planned for one. Likewise, the airport controller did not consider other solutions or alternatives, such as taxiing WJA628 off the runway to allow WJA2057 to land on Runway 26L. Although able to perceive what was happening, the airport controller did not fully understand the severity of the situation in terms of reduced safety margins. As a result, the airport controller did not update the original plan in a timely manner to ensure that necessary safety margins were maintained between the departing and arriving aircraft. The airport controller's loss of situational awareness resulted in an operational decision that led to a loss of IFR separation between WJA628 and WJA2057.

The controller was now faced with 2 aircraft in close proximity, with the second aircraft overtaking the first, and both on similar headings. Since the controller had taken control of WJA2057, visual separation rules could be applied until another form of separation could be established. The airport controller subsequently instructed WJA2057 to turn to a heading of 240˚M and climb to 2000 feet above sea level (asl), and instructed WJA628 to continue on runway heading climbing to 7000 feet asl. Neither of the aircrafts' flight crew saw the other aircraft during this time as the distance between the 2 aircraft continued to close. However, a target corresponding to WJA2057 was showing on the traffic collision-avoidance display (TCAS) display in the cockpit of WJA628. This visual indication would have reduced the risk of the 2 aircraft colliding, but would have required constant monitoring to ensure continued safe spacing. No traffic information was passed to the flight crew of either aircraft by the airport controller. Although WJA2057 was able to arrest its descent and eventually turned to the south,

the urgency of the situation was not conveyed to its flight crew. When providing missed-approach instructions to WJA2057, the airport controller did not provide instructions that would ensure the minimum required separation.

This sequence of events involving the risk of collision between WJA628 and WJA2057 highlights the importance for controllers to be able to recover from a serious operational error and re-establish the necessary safety margins. However, controllers receive limited training or simulation on best practices to recover quickly and safely from a serious operational error. As a result, controllers may not be adequately prepared to restore the required IFR separation and associated safety margins following a risk-of-collision occurrence.

Once the 2 aircraft were on diverging headings, action was required by the airport controller to establish minimum IFR separation. WJA628 contacted departure at 2303:50 based on the instruction from the controller in which the erroneous flight number WJA269 was again used. WJA628 did not climb through 3000 feet (1000 feet above WJA2057) until 2304:23, at which point the 2 WJAs were still less than 2 nm apart laterally. The minimum vertical spacing of 1000 feet would have been required to restore the required spacing. Therefore, separation between the 2 aircraft was not assured for an extended time, because no other separation was provided.

Supervision

If an operating irregularity or other significant event takes place, immediate supervisors and management are to be advised as soon as possible. The controllers discussed the event among themselves, and an entry was made in the control tower logbook mentioning the missed approach. However, no further action was taken, because the controllers did not consider that a loss of separation had occurred. There was no supervisor scheduled for duty in the control tower during the night shifts. It was only after the day-shift supervisor came on duty the next morning that the event was reviewed and almost immediately considered significant. An operating irregularity or loss-of-separation occurrence has the potential to affect an individual's performance in the immediate aftermath, and removal from duty may provide a period of stress relief for the individual. When a controller involved in an occurrence is not removed from duty, there is increased risk that the controller's performance may be degraded due to the stress associated with being involved in an occurrence.

Controller Fatigue

At any time when individuals are required to work during periods that are significantly in opposition to their normal circadian rhythm, fatigue and its management may become a factor. Trying to get adequate sleep when one's body is normally in a wakened state is a challenge. Air traffic control (ATC) personnel are given information on recognizing fatigue and given strategies for minimizing its effects. However, it is not always possible for individuals to determine their fatigue level. The airport controller, as shown by the Fatigue Avoidance Scheduling Tool (FAST) analysis, was likely fatigued at the time of the occurrence. This probability of fatigue is consistent with the communication breakdowns observed in this occurrence, and likely also contributed to the breakdown in controller situational awareness. It is likely that the airport controller was experiencing the effects of fatigue at the time of the

occurrence. Those effects would have made it more difficult for the airport controller to recognize the developing situation, and to take timely corrective action to ensure that IFR separation was maintained.

Findings

Findings as to Causes and Contributing Factors

1. The airport controller's loss of situational awareness resulted in an operational decision that led to a loss of instrument flight rules separation between WJA628 and WJA2057.

2. The airport controller inadvertently mixed up the call signs / flight numbers when issuing the take-off clearance to JZA269. The crew of WJA628 used vague, unclear wording in the attempt to alert the airport controller to the mistaken take-off clearance wording. As a result, there was no longer sufficient time to safely depart WJA628 and allow WJA2057 to land with required separation.

3. When providing missed-approach instructions to WJA2057, the airport controller did not provide instructions that would ensure the minimum required separation.

4. It is likely that the airport controller was experiencing the effects of fatigue at the time of the occurrence. This would have made it more difficult for the airport controller to recognize the developing situation, and to take timely corrective action to ensure that instrument flight rules separation was maintained.

Findings as to Risk

1. If non-standard phraseology is used when multiple aircraft are lined up for take-off on the same runway, there is increased risk of collision due to errors in departure sequencing.

2. Controllers receive limited training or simulation on best practices to recover quickly and safely from a serious operational error. As a result, controllers may not be adequately prepared to restore the required instrument flight rules separation and associated safety margins following a risk of collision occurrence.

3. When a controller involved in an occurrence is not removed from duty, there is increased risk that the controller's performance may be degraded due to the stress associated with being involved in an occurrence.

Safety Action

Safety Action Taken

NAV CANADA

On 16 April 2011, the NAV CANADA Vancouver control tower management issued Vancouver Control Tower Operations Bulletin 11-21, titled *Prohibition On Intersection Departures*. This bulletin cancelled the use of intersection departures at CYVR as a temporary safety measure. Subject to further review, this policy change has since been made permanent at CYVR. In addition, Vancouver control tower management is working on changing the missed-approach procedures to ensure aircraft that conduct a last-second missed approach have a greater safety margin.

NAV CANADA has a Fatigue Management Program. Launched in 2000, this program provides a comprehensive and holistic approach to managing fatigue in a 24-hours-per-day, 7-days-per-week operation. NAV CANADA is continuously looking for ways to improve the Fatigue Management Program. Three initiatives by NAV CANADA are currently underway:

- The redesign of its Sleep-Awake form to make it more user-friendly. It is a voluntary form that employees complete during an Operations Safety Investigation. The revised form will be implemented during fiscal year 2012−2013.
- The development of a self-assessment tool that provides a fatigue score to the person using it, based on

  a) hours of sleep in the past 24 hours,
  b) hours of sleep in the past 48 hours,
  c) hours awake since last sleep.

  The tool uses a point system, where the total number of points provides an indicator to the employee of that employee's level of fatigue. This project is in the development stage.
- Investigation of the feasibility of leveraging data from its shift-scheduling software and applying fatigue-related shift-scheduling assessment criteria. It is anticipated that analyzing shifts actually worked, and not just scheduled shifts, will allow NAV CANADA to understand what patterns of shifts are being worked today, and which patterns are most problematic when it comes to fatigue. This project is in the development stage.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 17 April 2013. It was officially released on 19 June 2013.

Visit the Transportation Safety Board's website (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 – Aircraft Positions on Hand-off of WJA628 to Terminal at 2303:35 PDT