AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A19Q0015

RUNWAY INCURSION

Aéroports de Montréal
Four Oshkosh Corporation HT Tractors (snowplow-sweepers)
Montréal/Pierre Elliott Trudeau International Airport, Quebec
02 February 2019

Canada

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

Summary

On 02 February 2019, a Bombardier CRJ 200 aircraft (registration N902EV, serial number 7620), operated by SkyWest Airlines as flight SKW3130, was conducting an instrument flight rules flight from Chicago O'Hare International Airport, Illinois, to Montréal/Pierre Elliott Trudeau International Airport, Quebec, with 2 flight crew members, 1 cabin crew member, and 22 passengers on board. The aircraft was flying the instrument landing system approach and had been cleared to land on Runway 24L.

Snow removal operations were being conducted at Montréal/Pierre Elliott Trudeau International Airport, and an Aéroports de Montréal snow removal convoy, consisting of 7 vehicles, had been instructed to proceed from Runway 24R to holding bay 24L. At 1119:04 Eastern Standard Time, a runway incursion occurred when the lead snowplow-sweeper crossed the runway holding position and continued onto the runway. At that time, radar data indicated that the aircraft was on the approach profile 0.3 nautical miles from the runway and at approximately 157 feet above aerodrome elevation.

The flight crew initiated a go-around and overflew the lead snowplow-sweeper, which was now on the runway centreline. Three other snowplow-sweepers had also crossed the runway holding position. The aircraft landed safely on Runway 24R about 15 minutes later. The snow removal convoy regrouped and completed the snow removal operations on Runway 24L. There were no injuries or damage.

1.0   FACTUAL INFORMATION

The International Civil Aviation Organization (ICAO) and Transport Canada (TC) define a runway incursion as:

> [a]ny occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft.[1,2]

1.1   History of the occurrence

On 02 February 2019, airport traffic at the Montréal/Pierre Elliott Trudeau International Airport (CYUL), Quebec, was light; however, snowfall conditions were such that visibility was reduced and snow removal operations were required.

At approximately 0930,[3] an Aéroports de Montréal (ADM) snow removal convoy departed the maintenance garage to remove snow from the CYUL taxiways and runways. The convoy consisted of a team leader (PER20) in a Ford F-150 pickup truck, and 6 operators driving 5 snowplow-sweepers (CHA142, CHA82, CHA81, CHA88, and CHA145) and 1 snowblower truck (SOU125). The team leader would either lead or follow the convoy. One of the snowplow-sweepers, CHA142 (Figure 1), was designated the convoy lead.

That morning, parallel runways 24R and 24L were the active runways for arriving and departing aircraft; Runway 10/28 was closed and being used as a taxiway. Because snow removal operations were in progress, one of the parallel runways was temporarily closed for snow removal while the other runway remained active.

Figure 1. Snowplow-sweeper CHA142, an HT tractor with plow and XT tow-behind broom (Source: TSB)

The convoy was authorized by the NAV CANADA air traffic control (ATC) ground controller (the ground controller) to proceed[4,5] from the maintenance garage to holding bay 24R.

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[1]   International Civil Aviation Organization, Doc 9870 AN/463, *Manual on the Prevention of Runway Incursions*, First Edition (2007), Chapter 1, Section 1.1, p. 1-1.

[2]   Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* (TC AIM), GEN – General (11 October 2018), section 5.1, p. 38.

[3]   All times are Eastern Standard Time (Coordinated Universal Time minus 5 hours).

[4]   "For surface movement instructions, PROCEED is used only for vehicles." (Source: NAV CANADA, *Manual of Air Traffic Services,* Tower-EN (26 June 2018), Traffic Management, Surface Movement, Aircraft Taxi or Ground Traffic Operations, Table 15: Movement Instructions Format, p. 66.)

[5]   When a convoy is instructed to "proceed" by ATC, it is authorized to move or reposition to a specified location on the airfield. During snow removal operations, the convoy may conduct snow removal and clearing operations at the same time along the route.

From that point, it was authorized to go onto the runway to conduct snow removal. The team leader was required to complete an aircraft movement surface condition report (AMSCR).[6]

At approximately 1110, the team leader informed the ground controller that the convoy had cleared and exited Runway 24R. The team leader was the last to exit the runway, in accordance with ADM procedures.[7] The ground controller then instructed the team leader and the convoy to proceed via Taxiway B onto Taxiway B2, Runway 10/28, Taxiway A, and finally to holding bay 24L (Figure 2) without any intermediate stops.

Figure 2. Aerial view of CYUL showing the route taken by the convoy (Source: Google Earth, with TSB annotations)

The team leader read back only part of the ATC instruction. The convoy lead, who had heard the ATC instruction over the ground frequency on his radio, read back the full instruction to

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6 "AMSCRs are issued to alert pilots of natural surface contaminants—such as snow, ice or slush—that could affect aircraft braking performance. The RSC [runway surface condition] section of the report provides information about runway condition in plain language, while the CFRI [Canadian Runway Friction Index] section describes braking action quantitatively using the numerical format described in AIR 1.6.3." Source: Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* (TC AIM), AIR – Airmanship (11 October 2018), section 1.6.4, p. 382.

7 Aéroports de Montréal, *Guide — Déneigement des aires de mouvements, Aéroport Montréal-Trudeau* (ADM Field Maintenance movement area snow removal guide) (December 2018), Chapitre 8.1: Scénarios, p. 9.

the team leader over the internal convoy frequency on his second radio to expedite and minimize radio communications on the ATC frequency, and to ensure that the team leader knew that the convoy lead had understood the instructions. Discussion between the convoy lead and the team leader confirmed that the team leader had not read back the full ATC instruction. This also included the question of whether the ATC instruction had included the term "hold short."[8] Even though the initial ATC instruction did not include the instruction to hold short, the team leader reconfirmed his readback with the ground controller, including the requirement to hold short of Runway 24L. The ground controller then acknowledged the readback.[9]

The convoy proceeded as instructed and continued snow removal on the designated route to holding bay 24L. The distance of the designated route from holding bay 24R to holding bay 24L is 6.77 km, which took the convoy approximately 9 minutes to travel.

The team leader had exited Runway 24R last and was at the rear of the convoy. Normally, while the convoy was moving from one runway to another, the team leader would complete the AMSCR using the on-board laptop[10] in the truck and send the form to CYUL's ATC using NAV CANADA's web-based application SNOWiz.[11] He would then go back to the head of the convoy.

On the morning of the occurrence, the SNOWiz application was not working, and the team leader had to call in the AMSCR over the phone to CYUL ATC. This took him longer than if he had used the application, because each item on the AMSCR form had to be communicated individually to ATC. As the team leader exited Runway 06L/24R and the convoy made its way to holding bay 24L along the designated route, the team leader slowed his vehicle to call in the AMSCR information and remained behind the convoy.

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8   "HOLD SHORT: Instruction to hold at least 200 feet from the edge of a runway while awaiting permission to cross or proceed onto a runway." (Source: NAV CANADA, *Manual of Air Traffic Services* [MATS], Glossary [26 June 2018], p. 71).

9   A total of 58 seconds elapsed from the initial ATC instruction, including the confirmation from the convoy lead with the team leader, the full readback from the team leader to the acknowledgement from the ground controller.

10   Using the on-board laptop, the team leader enters the runway surface conditions into the AMSCR form via a touchscreen and drop-down menus, and then files and transmits the form directly to the SNOWiz app.

11   SNOWiz allows NAV CANADA to accept AMSCRs from reporting authorities and to make the information available immediately as a NOTAMJ or SNOWTAM. At CYUL, select ADM vehicles, equipped with a laptop, can transmit AMSCR forms directly to NAV CANADA via the web-based SNOWiz application. If the application or server is not working, runway braking and surface conditions must be transmitted directly to ATC by radio or phone. SNOWiz outages are uncommon but do occur at times. NAV CANADA does not support the SNOWiz app nor track system serviceability or maintenance issues. (Source: NAV CANADA Aeronautical Information Management, *Accountable Sources SNOWiz User Manual*, version 15.11 [September 2015), sections 1.1 and 1.3.].

After the ground controller instructed the team leader and the convoy to proceed to holding bay 24L, he then continued to control various taxiing aircraft and ground vehicles. Because it was snowing and the visibility was limited, the ground controller monitored both air and ground operations, including the convoy's progress, by scanning his work station displays. These included the Advanced Surface Movement Guidance and Control System (A-SMGCS) or ground radar display. The ground controller was also the ATC tower supervisor on duty and was responsible for making several operational phone calls to airport stakeholders.[12] After the ground controller instructed the convoy to proceed, he called the CYUL Flight Planning section, the NAV CANADA Terminal unit, and the shift manager about the AMSCR.

On the morning of the occurrence, a Bombardier CRJ 200 aircraft (registration N902EV, serial number 7620), operated by SkyWest Airlines as flight SKW3130, was conducting an instrument flight rules flight from Chicago/O'Hare International Airport (KORD), Illinois, to CYUL with 2 flight crew members, 1 cabin crew member and 22 passengers on board. At 1114:54, the aircraft, which was flying the instrument landing system approach for Runway 24L, was cleared to land on Runway 24L by the ATC airport controller (the airport controller).

At 1115, the convoy reached the intersection of Runway 10/28 and Taxiway A. The convoy lead started to plan the convoy formation and path along Runway 24L based on the snowfall intensity and the wind direction.

At 1118:31, as the convoy proceeded along Taxiway A and approached holding bay 24L, the ground controller called the shift manager to discuss discrepancies between a term used in an AMSCR and the content of an ADM operational directive that had been issued. Holding a paper copy of the ADM operational directive, the ground controller continued the conversation with the shift manager while scanning between the operational directive and his displays. The ground radar display showed all of the convoy vehicles, except CHA81,[13] proceeding on Taxiway A, and the air radar showed the aircraft on approach approximately 1.3 nautical miles (NM) from Runway 24L.

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[12] Montreal Tower supervisor duties are listed in the NAV CANADA *Montreal Tower Operations Manual* (18 June 2018)*,* Chapter 3: Procedures, Section 3.2: Supervisor responsibilities.

[13] The A-SMGCS did not display CHA81, possibly because the vehicle locator transmitter (VLT) had failed. Because CHA81 was part of a convoy, it was not required to have a functioning VLT. "All vehicles in a controlled portion of the movement area must be equipped with a VLT with the exception of those that are part of a convoy." (Source: Aéroports de Montréal, *Restricted Area Traffic Directive* [June 2017], Section 2.31.)

At 1119:04, a runway incursion occurred when the convoy lead crossed the runway holding position[14] and continued onto the runway protected area.[15] At that time, radar data indicated the aircraft was on the approach profile 0.3 NM back from the runway, at approximately 157 feet above aerodrome elevation, which is 275 feet above sea level (ASL).[16] The airport controller, who was monitoring the aircraft's approach, saw the convoy lead crossing the runway holding position on his ground radar display.

At 1119:07, the flight crew saw the convoy on the runway and in the holding bay and initiated a go-around. At the same time, the airport controller instructed the aircraft to pull up and go around. Neither the team leader nor any of the other convoy vehicle operators alerted the convoy lead to the runway incursion over the radio. The convoy lead reached the runway surface at 1119:08, and the 2nd snowplow-sweeper (CHA82) in the convoy crossed the runway holding position at 1119:09.

At 1119:10, the flight crew read back the airport controller's instruction to go around. Immediately after, the airport controller informed the ground controller of the convoy's position and the runway incursion.

At 1119:16, the convoy lead reached the runway centreline, and the aircraft flew directly over his vehicle (Figure 3).

Figure 3. Screen shot of NAV CANADA Webview media player showing holding bay 24L and Runway 24L. The inset image shows the aircraft (SKW3130) overflying the convoy. The screenshot was captured as the radar target identifier for SKW3130 appeared over CHA142 and CHA82. The CHA81 radar target was not visible. (Source: NAV CANADA, with TSB annotations)

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14 Runway holding positions are described in section 1.10.2 of this report.

15 The runway protected area is "the area around an active runway established to protect aircraft taking off and landing from taxiing aircraft and ground traffic." (Source: NAV CANADA, *Manual of Air Traffic Services* (MATS), Glossary [26 June 2018], p. 96)

16 Radar altitude is subject to an error of +/- 50 feet and was corrected for standard and actual barometric altitude settings. Runway elevation is 118 feet above sea level.

Until then, no one in the convoy was aware that a runway incursion had occurred. The team leader, who was approaching holding bay 24L on Taxiway A, was expecting to see the convoy lead perpendicular to the runway, stopped in the holding bay. Instead, he saw the convoy lead on the runway just as the aircraft flew over. The team leader and the convoy lead heard, but did not see, the aircraft fly overhead.

At 1119:16, the ground controller saw and understood the situation on his ground radar display, and at 1119:18, he informed the team leader of the runway incursion.

At 1119:19, the airport controller instructed the aircraft to climb to 3000 feet and maintain the runway heading. The flight crew confirmed the go-around instructions with the airport controller and that they had seen the snowplows, then carried on with the go-around.

By 1119:26, a third snowplow-sweeper (CHA81) had crossed the runway holding position and the convoy lead had realized he had not held short of the runway; the convoy lead immediately tried to make his way back to the holding bay, just as the convoy's fourth snowplow-sweeper (CHA88) crossed and stopped just past the runway holding position.

Shortly after, the team leader confirmed the convoy's runway incursion with the ground controller. With no other arriving air traffic, the ground controller instructed the team leader to proceed onto Runway 24L to complete the snow removal operations. Once the convoy had finished the snow removal, the vehicles returned to the garage without further incident.

The aircraft completed a 2nd instrument approach and landed safely on Runway 24R approximately 15 minutes later.

1.2 Injuries to persons

There were no injuries to persons.

1.3 Damage to aircraft

There was no damage to aircraft or ground vehicles.

1.4 Other damage

There was no damage to property or other objects.

1.5 Personnel information

1.5.1 Air traffic controllers

Records indicate the air traffic controllers involved in the occurrence were licensed and qualified in accordance with existing regulations. The investigation found no evidence to indicate that the controllers' performance was degraded by physiological factors, nor was there evidence to suggest that fatigue was a factor.

Table 1. Information about the controllers

Controller position	Airport controller	Ground controller
Air traffic controller licence	Airport: CYUL Terminal: CYOW*, CYQB** Area: CYUL	Airport: CYQB**, CYUL, CYZV***
Medical expiry date	24 October 2020	15 January 2020
Experience as a controller	14 years	25 years
Experience in present unit	3 years	22 years
Hours on duty prior to the occurrence	4.8 hours	4.8 hours

*   Ottawa/MacDonald-Cartier International Airport
**   Québec/Jean-Lesage International Airport
***   Sept-Îles Airport

1.5.2   Ground personnel

Records indicate that the ADM operators involved in the occurrence were licensed and qualified in accordance with existing regulations.

The team leader was hired by ADM as a full-time employee. The convoy lead was hired by ADM as a seasonal worker for the winter season only.

Table 2. Information about the ADM operators involved in the occurrence

Operator	Team leader	Convoy lead
Date hired by ADM	Autumn 2010	Autumn 2016
Employment status	Full time	Seasonal
Restricted Operator Certificate–Aeronautical (ROC-A)*	10 December 2010	01 December 2016
Restricted Area Traffic Directive**	10 December 2010	25 November 2016
Airside Vehicle Operator's Permit (AVOP)–Type D***	16 February 2011	12 December 2016
Experience in present unit	9 years 2 years as team leader	3 seasons Winter seasons only
Hours on duty prior to the occurrence	4.3 hours	4.3 hours

*   The Restricted Operator Certificate with Aeronautical Qualification (ROC-A) is issued by Industry Canada and "required by operators of radiotelephone equipment on board aircraft and at aeronautical land (fixed and mobile) radio stations using aeronautical mobile frequencies." (Source: Industry Canada Study Guide for the Restricted Operator Certificate with Aeronautical Qualification [ROC-A] RIC-21, Issue 3 [February 2010].)
**   The *Restricted Area Traffic Directive* is an ADM directive "designed to provide for the orderly and safe flow of aircraft, vehicles and pedestrians within restricted areas and inside buildings" at the Montréal-Trudeau and Montréal-Mirabel international airports. To comply with the directive, all vehicle operators must complete classroom training and pass a written examination. (Source: Aéroports de Montréal, Restricted Area Traffic Directive [2017 Edition]).
***   The Airside Vehicle Operator's Permit (AVOP) allows the certificate holder to operate ground vehicles within the ADM roadways and movement areas. The holder of a Type "D" AVOP is authorized to operate a vehicle within the movement area of the airport named on the permit. (Source: Aéroports de Montréal,

Airside vehicle operator's permit [AVOP], https://www.admtl.com/en/adm/safety/adminstration-and-permits-office/airside-vehicle-operators-permit [last accessed on 22 October 2019])

The operators of CHA82, CHA81 and CHA88 were also seasonal workers; the operator for CHA82 had 1 year of experience, and the operators for CHA81 and CHA88 had 2 years of experience.

The investigation found no evidence to indicate that the ADM operators' performance was degraded by physiological factors, nor was there evidence that fatigue was a factor.

1.5.2.1   Vehicle operator training

All operators receive training on vehicle and radio operations as well as convoy and aerodrome procedures in order to obtain the ROC-A and AVOP qualifications. According to the ADM vehicle operator's training plan,[17] vehicle operator training consists of 7 weeks of classroom instruction with practical exercises and is validated with written examinations and practical tests. During training, operators are taught equipment and vehicle operating procedures, convoy operations, ADM's aerodrome procedures, and NAV CANADA's communication procedures.

The training and procedures used by ADM emphasized the following:

- The primary responsibility for all members in a convoy is to follow the lead vehicle. This is important during convoy snow removal operations to ensure that the convoy remains in its formation to remove snow and contaminants on the route as quickly and efficiently as possible.

- With the varying experience levels of seasonal operators, the less experienced operators are often placed behind the convoy lead, in the convoy's 2nd and 3rd positions, so that they are led and followed by more experienced operators.

- Operators are familiar and comply with proper NAV CANADA phraseology.

During training, operators are also exposed to various procedural and communication scenarios including situations when to hold short or exit a runway in an emergency. The training briefly introduces the topic of runway incursions but it does not include specific training or discuss runway incursion scenarios, such as

- what actions operators are to take in the event of an incursion,

- the radio communications that need to be made, and

- the vehicle operating procedures that need to be followed to reduce the likelihood or to mitigate the consequences of an incursion.

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[17]   Aéroports de Montréal, Division de l'entretien des terrains, *Plan de formation* (01 May 2018) (available in French only).

1.6   Aircraft and ground vehicle information

1.6.1   Aircraft

The CRJ 200 aircraft was manufactured in 2002 and operated by SkyWest Airlines at the time of the occurrence. No aircraft serviceability or maintenance deficiencies were reported. Radar data indicated the aircraft was at 275 feet ASL at 0.3 NM from the runway and again at 275 feet ASL approximately 1000 feet along the runway centreline.

The investigation was unable to determine the exact height to which the aircraft descended, but it may have been as low as 107 feet above ground level (AGL).[18]

1.6.2   Ground vehicles

The team leader's truck is equipped with 2 radios (1 for ATC ground communications and 1 for internal convoy radio communications), an on-board laptop computer (for inputting AMSCRs), a decelerometer (to take runway friction measurements for making a Canadian Runway Friction Index report), and a vehicle locator transmitter (VLT), "a transmitter installed on the roof of the vehicle that emits a signal allowing to [*sic*] locate its exact position on the airport movement area and which displays its call sign on radar screens."[19] No serviceability or maintenance deficiencies with the team-leader truck were reported.

The ADM snowplow-sweepers are designed and manufactured by Oshkosh Corporation. These vehicles are an HT Tractor operated by a single driver. When fitted with a plow and an XT tow-behind broom, they are approximately 22 feet wide and 60 feet long. They are also equipped with 2 radios and 1 VLT.

The A-SMGCS recordings provided to the investigation did not display the VLT signal of the 3rd snowplow sweeper (CHA81) at the time of the incursion. As a result, CHA81's exact position and time it crossed the runway holding position were not available.

No other serviceability or maintenance deficiencies with the convoy leader's snowplow-sweeper or any of the other snowplow-sweepers in the convoy were reported.

1.7   Meteorological information

The aerodrome routine meteorological report (METAR) for CYUL issued at 1116 indicated:

- surface winds from 220° true at 14 knots gusting to 20 knots
- visibility of 1¼ statute mile in light snow and drifting snow
- overcast cloud at 2000 feet AGL

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[18]   Calculations are based on radar altitude, radar error, and field elevation.

[19]   Aéroports de Montréal, *Restricted Area Traffic Directive* (June 2017), Chapter 1: General, Section B: Interpretation, Article 1.03.

- temperature of −9 °C
- dew point of −12 °C
- altimeter setting of 29.92 inches of mercury
- remarks[20] indicating stratocumulus at 8 oktas and pressure falling rapidly

Given the distance from the control tower to holding bay 24L and the reduced visibility, the team leader's truck, the convoy, and the aircraft were visible to the controllers only on their respective air and ground radar displays.

In addition, even though the cloud bases were forecast at 600 feet AGL in the graphic area forecasts and reported at 2000 feet AGL in the METAR, the visibility was reduced and the flight crew only started seeing the runway environment once the aircraft was descending below 400 feet AGL.

1.8   Aids to navigation

Not applicable.

1.9   Communications

1.9.1   General

NAV CANADA air traffic controllers at the CYUL control tower follow the communication and phraseology guidelines set out in NAV CANADA's *Manual of Air Traffic Services –Tower* (MATS – Tower-EN).[21] When the airport and ground controllers are in position, they use various tools or systems to monitor, control, and communicate with aircraft and ground vehicles, including ground radar or surveillance systems, communication radios, and ground lighting. At each position, the controllers can monitor the various displays and can turn to face each other to talk or discuss issues. At the time of the incursion, the airport controller was communicating with the aircraft flight crew, and the ground controller was communicating with the convoy team leader.

No communication difficulties or issues were reported between ATC and the aircraft.

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20   "Remarks will appear in reports from Canada, prefaced by RMK. Remarks will include, where observed, layer type and cloud or obscuring phenomena (in eighths of sky covered or oktas), general weather remarks, and sea level pressure, as required." (Source: Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* [TC AIM], MET- Meteorology [11 October 2018], Section 8.0: Aerodrome routine meteorological reports [METARs], 8.3 Sample Message, p. 157.)

21   The *Manual of Air Traffic Services* (MATS) is a collection of guidance provided by NAV CANADA to all air traffic services personnel. MATS – Tower-EN specifies procedures for controllers working in airport tower positions.

1.9.2 Ground traffic phraseology

Ground traffic phraseology is set out in NAV CANADA's MATS and is also included in the training ADM provides to ground vehicle operators for their ROC-A and AVOP qualifications.

MATS – Tower-EN provides the following directives for controllers:

> When issuing aircraft taxi or ground traffic movement instructions:
>
> - Issue instructions as necessary, in plain, concise language.
> - Instruct the pilot or driver to either cross or hold short of a runway or taxiway on their route.
> - Obtain a readback of a hold or hold short instruction.[22]

When providing ground traffic movement instructions to a runway, controllers can include a "hold short" instruction or they can simply provide the final point, such as the holding bay or the intersecting taxiway, without including the statement "Hold short."

MATS – Tower-EN does not indicate a requirement for the controllers to include a runway hold instruction or a "hold short" statement with all taxi or ground traffic movement instructions because no aircraft or vehicle should proceed onto an active runway without a specific ATC authorization to do so,[23,24] whether or not the instruction to hold short is included in the ATC instruction. However, controllers, at their discretion, can include a "hold short" instruction if they want to emphasize the protection of an active runway. If they do, they must obtain a readback, as specified in the MATS – Tower-EN and the *Transport Canada Aeronautical Information Manual* (TC AIM).[25,26]

NAV CANADA has also published the *Ground Traffic Phraseology* manual[27] as a learning tool and reference document to be used by ground vehicle operators operating at Canadian airports. This guidance material is based on NAV CANADA's MATS and contains radio communication procedures, examples, and best practices, including information on "hold short," readback, and operations on a runway (Appendix A).

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[22] NAV CANADA, *Manual of Air Traffic Services* (MATS), Tower-EN (26 June 2018), Traffic Management, Surface Movement, Aircraft Taxi or Ground Traffic Operations, Movement instructions, p. 65.

[23] Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* (TC AIM), RAC – Rules of the Air and Air Traffic Services (11 October 2018), section 4.2.5.

[24] NAV CANADA, *Ground Traffic Phraseology*, Version 1 (April 2018), at https://www.navcanada.ca/EN/media/Pages/publications-operational.aspx (last accessed on 26 July 2019).

[25] NAV CANADA, *Manual of Air Traffic Services* (MATS), Tower-EN (26 June 2018), Traffic Management, Surface Movement, Aircraft Taxi or Ground Traffic Operations – Movement Instructions, p. 65.

[26] Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* (TC AIM), RAC – Rules of the Air and Air Traffic Services (11 October 2018), section 4.2.5.

[27] NAV CANADA, *Ground Traffic Phraseology*, Version 1 (April 2018), at https://www.navcanada.ca/EN/media/Pages/publications-operational.aspx (last accessed on 26 July 2019).

1.9.3   Communications between air traffic controllers and convoys

All convoy operators, including the team leader, communicate internally within the convoy on 1 radio, often to coordinate convoy and snow removal operations. They can also all communicate externally with ATC on a 2nd radio. However, the team leader is normally the only one who communicates with ATC.

When providing ground movement instructions following a request by the team leader, controllers will try to authorize the most efficient and direct routing, taking into consideration current and anticipated vehicle and aircraft traffic. At CYUL, when traffic warrants it and when the distance between the convoy's original position and its destination on the field is significant, the controllers may typically break the route into segments and progressively give the convoy ground movement instructions and authorizations to intermediate points. Conversely, controllers may issue an entire routing in one instruction.

In this occurrence, the ATC instruction contained a lengthy route that indicated several taxiways, a runway, and a holding bay. Although this instruction was lengthy and did not contain any intermediate points or stops, it was issued this way because there was little air and ground traffic that morning. Furthermore, issuing instructions in this format is permitted by NAV CANADA's procedures.

In all cases, ATC, team leaders, convoy leads, and convoy operators all understand the requirement to adhere to the specific routing, to hold at the last authorized position and to wait for further instructions before proceeding along the route.

1.10   Aerodrome information

1.10.1   General

CYUL has 3 runways:

- Runway 06R/24L, which is 9600 feet long and 200 feet wide
- Runway 06L/24R, which is 11 000 feet long and 200 feet wide
- Runway 10/28, which is 7000 feet long and 200 feet wide

The NAV CANADA control tower at CYUL is located over the main passenger terminal at the south end of the airfield. The distance between the tower and holding bay 24L is approximately 1.9 NM.

1.10.2   Runway holding position lighting, signage and markings

Runway holding positions can be identified with lighting, signage, and markings on the ground to give pilots and vehicle operators visual cues indicating their position and proximity to the runway. The holding position for Runway 24L was identified with elevated runway guard lights, runway designation signs, and runway holding position markings (Figure 4).

Elevated runway guard lights, commonly referred to as "wig wags," are a raised unit on each side of the taxiway that contain 2 yellow, unidirectional lights side by side that illuminate alternately. Their purpose is to draw attention to the holding position. Due to the reduced visibility, the lights were illuminated at the time of the occurrence.

Runway designation signs are a set of raised boxes on each side of the runway holding position that show the name of the intersecting taxiway (in yellow lettering on a black background) and the runway identifier (in white lettering on a red background). These signs indicate which runway is ahead.

Runway holding position markings, commonly referred to as "hold lines," are 4 yellow parallel lines (2 solid and 2 dashed lines) highlighted with a black background. They mark the holding position and span the width of the taxiway.

Figure 4. Aerial view of holding bay 24L, with inset images showing the runway holding position lighting, signage, and markings (Main image source: Google Earth, with TSB annotations. Inset images source: Aéroports de Montréal)
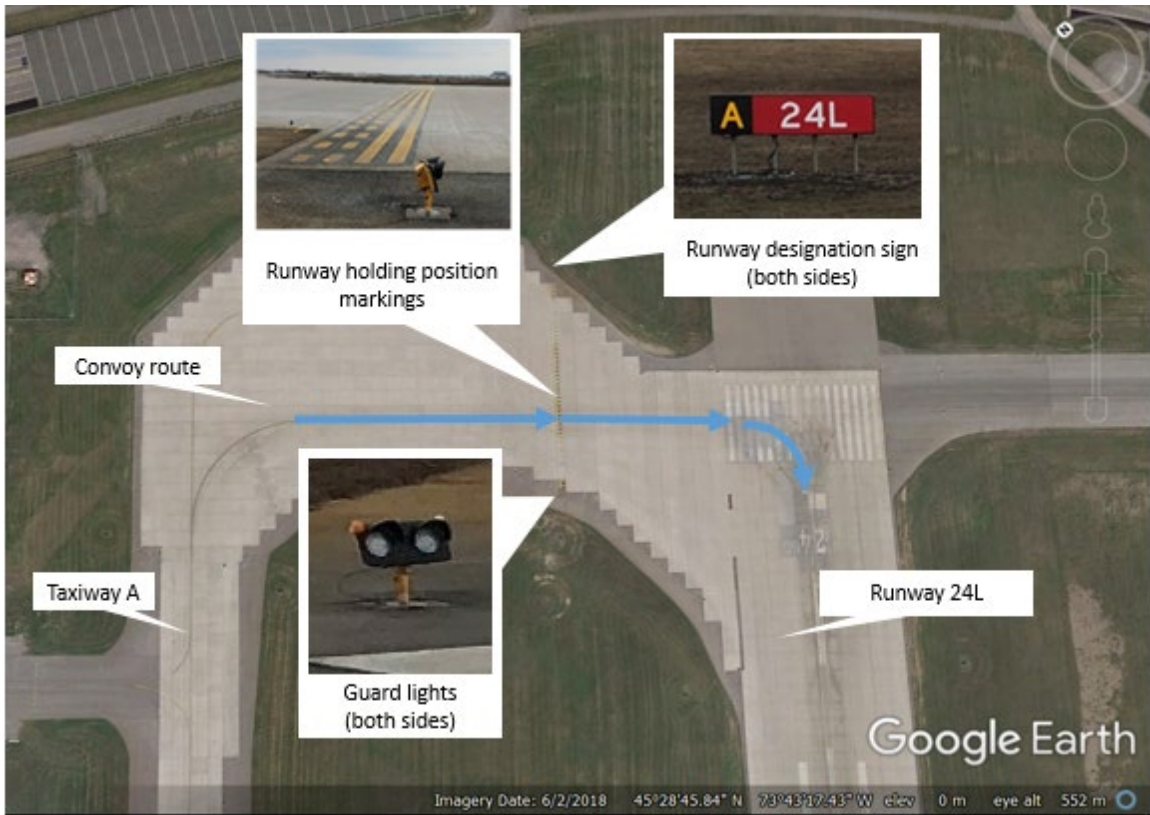
1.10.3 Advanced surface movement guidance and control system

The control tower at CYUL is equipped with an A-SMGCS, which receives data from primary surface radar and multilateration antennas[28] and provides controllers with a real-time display of aircraft and vehicle traffic on the airport manoeuvring areas. Each control position in the tower is equipped with its own A-SMGCS display. In this occurrence, this allowed the airport controller, who was monitoring the aircraft's approach, to notice the convoy's movement, including the runway incursion, and to give the go-around instruction to the aircraft.

1.11 Flight recorders

Not applicable.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

Not applicable.

1.17 Organizational and management information

1.17.1 NAV CANADA

ATC services at CYUL are provided by NAV CANADA. The control tower provides control services on the manoeuvring area and to aircraft in flight in the control zone. The control tower is staffed with 1 tower supervisor and a number of controllers who are either on duty

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[28] "Multilateration (MLAT) provides accurate, low-cost surveillance using existing transponder technology. It improves situational awareness in areas where radar coverage is not available, supporting the management of complex traffic flow and safer, more efficient customer operations. MLAT can also be used for surface surveillance at airports to provide full coverage of runways, taxiways and terminal areas." (Source: NAV CANADA, "Multilateration," at http://www.navcanada.ca/EN/products-and-services/Pages/on-board-operational-initiatives-mlat.aspx [last accessed on 26 July 2019]).

in the tower or available for recall. The actual number of controllers at their work stations varies based on traffic.

An agreement between NAV CANADA and ADM provides for coordination of aircraft and ground vehicles between the control tower and the ADM apron management service. The apron management service is responsible for coordinating aircraft and vehicles around the main terminal and on the main apron area as well as for transferring and handing off their control to NAV CANADA's controllers.

This incident was examined by NAV CANADA's personnel, who listened to the audio tapes and reviewed the air and ground radar playbacks. NAV CANADA determined that this was a non-air traffic services (ATS) operating irregularity,[29] and therefore no internal safety report was initiated. However, a NAV CANADA Aviation Occurrence Report (AOR-244648-3) was filed with TC and the TSB.

1.17.2   Aéroports de Montréal

ADM is a private, not-for-profit, and financially independent corporation responsible for the management, operation, and development of CYUL.

ADM maintains various policies, plans and directives for the safe, effective, and efficient operation of the aerodrome. In accordance with the ADM safety management system policy,[30] the incident was examined by ADM personnel, who conducted a review of current procedures and policies and initiated risk assessment activities. Initial mitigating actions were carried out, as described in section 4 of this report.

The CYUL aerodrome is split into a public side and an airside. The airside is further subdivided into 3 sectors: the de-icing centre, the main apron, and the taxiways and runways.

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[29]   "**ATS operating irregularity** - A situation that occurs when air traffic services are being provided and when a preliminary investigation indicates that a hazardous situation or a loss of separation may have occurred."

"**Non-ATS operating irregularity** - A situation that occurs when ATS are being provided and when a preliminary investigation indicates that safety may have been jeopardized, less than minimum separation may have existed, or both; and where it was determined that NAV CANADA ATS had not contributed to the negative outcome." (Source: NAV CANADA, *Manual of Air Traffic Services* (MATS), Glossary [26 June 2018], pp. 48 and 85).

[30]   Aéroports de Montréal, PO-101, *Politique du système de gestion de la sécurité (SGS)* (effective 28 November 2007, last modified 12 November 2018).

1.17.2.1   Snow removal operations

Snow removal operations at CYUL are described in the ADM *Winter Operations Plan*,[31] the ADM Field Maintenance movement area snow removal guide,[32] and the ADM operational directive on runway inspections.[33]

The ADM Field Maintenance Division is responsible for snow removal activities on the main apron as well as on the taxiways and runways. It comprises 4 supervisors, 8 team leaders, and over 100 full-time and seasonal operators.

The supervisors and team leaders oversee the planning of all snow removal convoys. As part of this planning, they assess the actual and forecast weather conditions and determine

- the convoy size (number of vehicles required),
- the equipment needed (types of vehicles required for de-icing or anti-icing, snow clearing or removal),
- the convoy formation (position of each vehicle), and
- the staff assignments (each operator assigned to a specific piece of equipment).

The number of operators in a convoy can vary from only a few to more than 10. In all cases, a team leader oversees the convoy. At times, depending on the weather conditions and the size of the convoy, additional team leaders and a supervisor may also be required to assist.

For all convoys, one of the snowplow-sweeper operators is designated the convoy lead. Supervisors and team leaders rely on the experience and knowledge of the convoy lead to help with the snow removal operations. In consultation with the supervisor or team leader, the convoy lead can be responsible for the speed, positioning, and orientation of the convoy formation on the selected routing, taking into consideration snowfall intensity and wind direction, and where the cleared and excess snow will be placed along the route. Because the convoy lead position requires an advanced knowledge of equipment operations and airfield layout, it is typically assigned to an experienced operator.

Safe operating practices are detailed in ADM directive PR-3-7-804, Précautions pour prévenir les incursions de pistes lors des opérations (Precautions to prevent runway incursions during operations).[34]

Once the convoy is ready, it will depart the field maintenance garage and wait for further authorization before proceeding onto the taxiways and runways. The convoy operates under the control of the supervisor or team leaders, who actively participate in the

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[31]   Aéroports de Montréal, *Winter Operations Plan—Montréal-Trudeau International Airport* (December 2018).

[32]   Aéroports de Montréal, Division de l'entretien des terrains, *Guide — Déneigement des aires de mouvements, Aéroport de Montréal-Trudeau* (December 2018) (available in French only).

[33]   Aéroports de Montréal, Direction des opérations, Directive opérationnelle DO1-227, *Inspection de pistes* (effective 28 October 2014, last modified 08 November 2017) (available in French only).

[34]   Aéroports de Montréal, Division de l'entretien des installations, Procédure PR-3-7-804: "Précautions pour prévenir les incursions de pistes lors des opérations" (effective 19 April 2013, last modified 26 February 2019) (available in French only).

coordination with ATC and execution of convoy operations out on the airfield. The supervisor or team leaders are also responsible for inspecting the areas that have been or will be cleared and for filling in and submitting the AMSCR form.

When only 1 supervisor or 1 team leader is required—as in a small convoy—they will move around the airfield in a truck and take different positions around the convoy as the snow removal operations progress. Once they have obtained the ATC authorization to enter a runway, they can either lead the convoy onto the runway or allow the convoy to enter on its own. At times, operational or equipment issues or time constraints may make it impractical for the team leader to lead the convoy onto the runway; instead, the team leader may need to be in a different position in the convoy. The ADM procedures do not state specifically that a single supervisor or team leader should be the 1st to lead a convoy onto a runway when only 1 supervisor or team leader is required.

Once the convoy is on the runway, the team leader can proceed and conduct a reconnaissance of the areas that need snow removal. Sometimes they will follow the convoy to ensure that all areas have been cleared, and to evaluate the braking conditions and assess the runway conditions for the AMSCR. As stipulated in ADM procedures, the supervisor or team leader will always be the last to exit a runway, and they will then tell ATC the runway is clear.[35]

When the convoy moves from one runway to another, the supervisor or team leader can then use this time to complete AMSCRs and reposition their vehicle at the head of the convoy. But regardless of their position relative to the convoy, they will be responsible for the convoy's movements about the airfield and for communications with ATC, including obtaining authorizations to move about the airfield and onto taxiways and runways.

When weather conditions deteriorate, larger convoys, additional operators, and a 2nd team leader and even a supervisor may be required. In this case, 1 team leader will typically be ahead of the convoy and will supervise the convoy, while the 2nd team leader will be at the rear and will fill in the AMSCR and communicate with ATC. If a supervisor is present and participating in the convoy operations, the supervisor may replace or assist the team leaders with these duties or take a nearby position to enhance supervision and safety.

In this occurrence, based on weather conditions and the composition of the convoy, a supervisor was not necessary, only 1 team leader was required, and the operator of CHA142 was identified as the convoy lead. The team leader was the last one to exit Runway 24R, as stipulated in the ADM procedures. While driving from Runway 24R to holding bay 24L, he supervised the convoy, communicated with ATC, and maintained his position behind the convoy.

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[35] Aéroports de Montréal, Division de l'entretien des terrains, *Guide — Déneigement des aires de mouvements, Aéroport de Montréal-Trudeau* (December 2018), p. 9.

1.18 Additional information

1.18.1 Human factors

1.18.1.1 Prospective memory

Prospective memory is the memory used to remember to perform an intended action in the future. There are 2 types of prospective memory:

- **event-based**: remembering to perform an intended action when specific circumstances occur; and
- **time-based**: remembering to perform an intended action at a particular point in time.

Prospective memory involves encoding, retention, execution, and evaluation. When an intentional action has been successfully encoded and retained in memory, the person wishing to execute the action must first be able to retrieve this memory. Prospective memory retrieval can happen through cognitive processes such as strategic retrieval (monitoring or search) or automatic retrieval. Environmental cues associated with the intended action stimulate retrieval processes.[36,37] The success of automatic retrieval depends on the characteristics of the prospective memory task, the saliency of the aural or visual target cue, the ongoing task, and individual differences.[38]

1.18.1.2 Effect of mental models on expectations and attention

Mental models are critical for effective performance in dynamic, time-critical environments, because they reduce the need for time-consuming evaluations of a given situation and enable quick actions. However, they can also lead to errors in how information is perceived.

In operational situations, people use their prior experience and knowledge to rapidly categorize the situation and select an appropriate course of action.[39] Therefore, in situations that have been practised often, attention and expectations are often driven by the person's existing mental model of the situation, with previous experience dictating what information is important and how the situation will unfold.

Human attention and the capacity to process information are, however, limited. While attention can be switched rapidly from one information source to another, humans can

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[36] M. A. McDaniel and G. O. Einstein, "Psychology of Prospective Memory," *International Encyclopedia of the Social & Behavioral Sciences* (2001), pp. 12241–12244.

[37] M. Kliegel, M. A. McDaniel, and G. O. Einstein, *Prospective Memory, Cognitive, Neuroscience, Developmental, and Applied Perspectives* (Lawrence Erlbaum Associates, Taylor and Francis Group, 2008), Chapter 1, pp. 12–16.

[38] M. A. McDaniel, G.O. Einstein, "Strategic and automatic processes in prospective memory retrieval: a multiprocess framework," *Applied Cognitive Psychology*, Vol. 14, No. 7, Special Issue: New Perspectives in Prospective Memory (2000), pp. S1–S144.

[39] G. Klein, "Naturalistic decision making," *Human Factors*, Vol. 50, No. 3 (June 2008), pp. 456–460.

attend well to only 1 information source at a time. These limitations of attention require operators to adapt their focus according to the situation.

1.18.1.3 Attention, scanning and monitoring

In order to provide safe, efficient, and effective control of air traffic and ground movements, ATC controllers must rely on NAV CANADA and aerodrome procedures; use proper radio communications; and continuously and actively scan and monitor radios, displays, aircraft, and vehicles. They must also monitor for compliance and trust that pilots and ground vehicle operators will comply with procedures and instructions.

Distance, obstacles, or weather conditions can create limitations and prevent a clear line of sight from the control tower to the manoeuvring areas. Often, controllers must shift their attention from one display to another. For example, they might be looking at an aircraft in flight on the air radar display and shift their attention to an aircraft on the ground on the ground radar display. This scanning can also occur on a single display, such as the A-SMGCS display. On this display, controllers must focus on 1 position of the aerodrome (on the screen) and shift their attention to another position later. When actively monitoring progress of aircraft and vehicles, controllers continuously scan their various displays, shifting their attention from one aircraft or vehicle to another.

1.18.2 Runway incursions

1.18.2.1 International Civil Aviation Organization guidance on the prevention of runway incursions

ICAO published Document 9870 AN/463, *Manual on the Prevention of Runway Incursions*, in order to specifically address "the subject of runway incursion prevention as it relates to the safe operation of aircraft, air traffic management, vehicle movement on the manoeuvring area and aerodrome management."[40]

The manual provides a systemic approach in examining contributory factors and in offering recommendations on the prevention of runway incursions. It is important to note that the focus is not only on operational personnel and human limitations but also on the operational system in its entirety.

> Active failures by operational personnel are sometimes a consequence of flaws in the system, sometimes a result of well-known and documented human limitations, but usually are a combination of the two. A true systemic approach to safety must consider latent conditions in the system as well as active failures on the front lines of operations. Such a systemic approach underlies this manual.[41]

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[40]   International Civil Aviation Organization, Document 9870 AN/463, *Manual on the Prevention of Runway Incursions*, First Edition (2007), Chapter 1, Section 1.3, pp. 1–2.

[41]   Ibid., Foreword, p. 2.

In examining "latent conditions in the system" as well as "human limitations," ICAO, in its manual, provides best practices to be used for communications, on the flight deck, by ATC, and for vehicle driving. It also provides tools for training and prevention programmes and lists common controller- and driver-related factors that can contribute to an incursion.

Common controller-related factors include distraction and not having a clear line of sight from the control tower.[42] Some common driver-related factors include not obtaining clearance to enter the runway and not complying with ATC instructions.[43]

The manual also recommends using a system to classify the severity of runway incursions. This system is shown in Table 3.

Table 3. ICAO classification of the severity of runway incursions (Source: International Civil Aviation Organization, Doc 9870 AN/463, *Manual on the Prevention of Runway Incursions*, First Edition [2007], Chapter 6, Table 6-1)

Severity classification	Description*
A	A serious incident in which a collision is narrowly avoided.
B	An incident in which separation decreases and there is significant potential for collision, which may result in a time-critical corrective/evasive response to avoid a collision.
C	An incident characterized by ample time and/or distance to avoid a collision.
D	An incident that meets the definition of runway incursion, such as the incorrect presence of a single vehicle, person, or aircraft on the protected area of a surface designated for the landing and takeoff of aircraft but with no immediate safety consequences.
E	Insufficient information or inconclusive or conflicting evidence precludes a severity assessment.

*   Refer to ICAO Annex 13 to the Convention on International Civil Aviation for ICAO's definition of "incident" and "serious incident."

Using these criteria, NAV CANADA classified this occurrence as a Level B incursion.

The manual contains a sample form that can be used to identify the causal factors in a runway incursion. The form lists causal factors that apply to ATC and ground personnel, among others. These include:

1.   **AIR TRAFFIC CONTROL**

1.1   *Communications*

1.1.1   Transmitted instructions were long, complex, spoken rapidly or not in accordance with ICAO language requirements for air-ground radiotelephony communications

[…]

1.2   *Situational Awareness* […]

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42   Ibid, Chapter 2, section 2.4: Air Traffic Control Factors, p. 2.3.

43   Ibid., Chapter 2, section 2.5: Airside Vehicle Driver Factors, p. 2.4.

> 1.2.3 Distractions due to:
>
> - performing other assigned duties, such as conducting operational telephone calls, weather observations and recording, issuing NOTAM and other operational information
>
> [...]
>
> 1.2.7 Lack of visual scanning of ground movements
>
> 1.2.8 Limitations on the view of the manoeuvring area from the ATC tower. [44]

The section of the form listing causal factors related to vehicle operators includes the following factors:

> 3. **VEHICLE DRIVERS AND PEDESTRIANS**
>
> [...]
>
> 3.2 *Situational awareness*
>
> 3.2.1 Forgot the details/limits of any clearance to operate on the manoeuvring area
>
> 3.2.2 Distracted by:
>
> • current work
>
> [...]
>
> 3.5 *Clearances and instructions*
>
> 3.5.1 Did not comply with ATC clearances and instructions[45]

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[44] International Civil Aviation Organization, Document 9870 AN/463, *Manual on the Prevention of Runway Incursions*, First Edition (2007), Appendix G, pp. App-G1–App-G3.

[45] International Civil Aviation Organization, Document 9870 AN/463, *Manual on the Prevention of Runway Incursions*, First Edition (2007), Appendix G, pp. App-G6, App-G8.
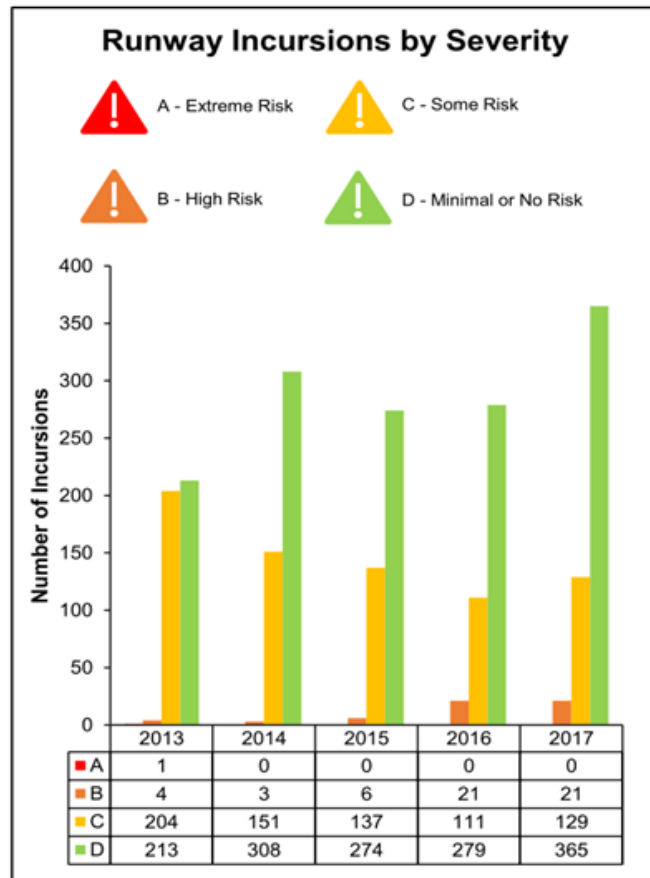
1.18.2.2   **Runway incursions in Canada**

TC, NAV CANADA, and airports across Canada have adopted many of the ICAO recommendations from the *Manual on the Prevention of Runway Incursions*; however, runway incursions continue to occur. Although there has not been a recent accident as a result of a runway incursion in Canada, the consequences of such a collision could be catastrophic.

From 2013 to 2017, NAV CANADA recorded an average of 445 runway incursions in Canada each year.[46] While the majority of these incursions posed little to no risk, there were 21 high-severity (Category B) events in each of the last 2 years of this study (Figure 5). These could have led to a collision with other aircraft, damage, injuries, or death.

Figure 5. Runway incursions in Canada from 2013 to 2017, categorized by severity (Source: NAV CANADA)

Runway incursions are also a global concern. ICAO's 2017 *Global Runway Safety Action Plan* notes that "[a]lthough the number of runway incursion accidents reported between the period of 2008 to 2016 is very low, the number of runway incursion incidents remains high […]."[47]

The aviation industry has started addressing factors that can lead to runway incursions by implementing incremental improvements to policies, procedures, technologies, and infrastructure. For example, in Canada, in-cockpit aids to increase situational awareness, such as electronic flight bags with moving maps, are becoming more prevalent. Despite these improvements, there has been an 18% increase in the overall rate of runway incursions from 2013 to 2017.

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[46]   This includes departures, arrivals, and touch-and-go practices at airports where NAV CANADA provides control of advisory services.

[47]   International Civil Aviation Organization, *Runway Safety Programme – Global Runway Safety Action Plan*, First Edition (November 2017), p. 3.

1.18.2.3   Runway incursions at CYUL

Data on runway incursions at CYUL from 2000 to 2019 was obtained from NAV CANADA (Appendix B). The incursions were classified as air traffic services, pilot, and vehicle or pedestrian deviations. From 2001 to 2019[48], an average of 9.1 vehicle or pedestrian deviations occurred per year (Table 4).

Table 4. Average number of runway incursions at CYUL from 2001 to 2019
(Source: NAV CANADA)

Type of deviation	Total number of incursions at CYUL (2001–2019)	Average number of incursions per year
Air traffic services	33	1.7
Pilot	343	18.1
Vehicle or pedestrian	172	9.1

From 01 January to 30 November 2019, ADM reported 8 vehicle or pedestrian runway incursions at CYUL.

1.18.3   Ways to mitigate runway incursions

The following systems are designed specifically for the prevention of runway incursions.

- **Runway incursion monitoring and conflict alert system (RIMCAS)**: A sub-system within the A-SMGCS. When RIMCAS is installed, it monitors aircraft and vehicle traffic to identify and alert air traffic controllers to possible conflict situations.[49] The system assesses the positions of radar targets and, within configurable parameters, identifies incursions onto that runway. When it detects a hazard, an alert message is sent to the air traffic controller identifying the targets involved, their locations, and the severity of the hazard.[50] RIMCAS-generated alerts and alarms are provided only to air traffic controllers; the system does not provide alerts directly to flight crews on board aircraft or ground vehicle operators.

- **Stop-bar lighting and overrun monitoring**:
  - Inset stop-bar lights are unidirectional red lights that are spaced evenly across the taxiway and set into the pavement. They can be installed at runway holding

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[48]   The data from the year 2000 was not included in this calculation because the data for that year was not complete. The data from the year 2019 did not include data from December.

[49]   Indra Navia AS, *Sub-System Description – Runway Incursion Monitoring and Conflict Alert* (RIMCAS), Revision 1.0 (18 December 2012), section 1.1, p. 1.

[50]   Ibid., section 2, p. 3.

positions. Supplemental elevated stop-bar lights, which are pairs of raised red lights, can also be placed on each end of the runway-holding position.[51]

- Stop-bar overrun monitoring is an additional function of RIMCAS. When enabled, this function assesses aircraft and vehicle target positions and generates a visual and aural alert to controllers when a target crosses an illuminated stop bar while entering a runway.[52] This alarm is reactive rather than predictive; it is triggered only once a stop bar has been crossed.
- **Runway status lights**:[53] A completely automated lighting system designed to enhance the pilot's awareness of when it is safe to enter, cross, or take off from a runway. There are 3 types of status lights: runway entrance lights, take-off hold lights, and runway intersection lights. Runway status lights are operational at many airports in the U.S. and at some airports internationally. There are none at Canadian airports.

At CYUL, stop-bar lighting and overrun monitoring is activated for Runway 06L during low visibility operations. The RIMCAS software is available but not activated because there are not enough radar towers to support radar triangulation calculations. The 5-year plans for ADM's runway infrastructure development include upgrades to RIMCAS, stop-bar lighting, runway status lights, and other systems as potential modernization and safety initiatives.

1.18.4 NAV CANADA runway safety initiatives

1.18.4.1 Runway Safety Action Team

As indicated on NAV CANADA's Runway Safety website, "In 2006, NAV CANADA joined with other aviation stakeholders to create the Runway Safety and Incursion Prevention Panel (RSIPP), which serves as a national forum for exchanging information on runway safety and runway incursions."[54] In 2019, to better align with U.S. Federal Aviation Administration initiatives, RSIPP was renamed the Runway Safety Action Team (RSAT). One of the main initiatives of RSAT is to support local runway safety teams at Canadian airports. The intent of these teams—composed of the airport, the air navigation service provider, air

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[51]   Transport Canada, TP 312, *Aerodrome Standards and Recommended Practices*, 5th Edition (15 September 2015).

[52]   Indra Navia AS, *Sub-System Description – Runway Incursion Monitoring and Conflict Alert* (RIMCAS), Revision 1.0 (18 December 2012), section 1.1, p. 1.

[53]   Runway status lights are "a type of autonomous runway incursion warning system (ARIWS)." (Source: International Civil Aviation Organization, Annex 14 to the Convention on International Civil Aviation, Volume I – *Aerodrome Design and Operations*, Seventh Edition [July 2016], section 5.3.30: Introductory Note, p. 5-82.)

[54]   NAV CANADA, "Runway Safety," at http://www.navcanada.ca/EN/products-and-services/pages/on-board-safety-initiatives-runway-safety.aspx (last accessed on 03 October 2019).

operators and any other relevant stakeholder—is to address local runway safety issues and initiatives. "These teams are a critical part of an effective safety program for the prevention and mitigation of Runway Excursions, Runway Incursions and other occurrences related to runway safety."[55]

1.18.4.2 Runway Incursion Prevention Action Group

In 2018, NAV CANADA created a working group "to analyze the runway incursion data at the 10 airports with the highest rates and total numbers of runway incursions in Canada [...] to help reduce and eliminate runway incursions."[56]

In order to determine the top 10 airports, this working group collected information from various documents, agreements, and plans as well as incursion data, reports, and studies that were relevant to runway incursions at 77 airports across Canada. It also embarked on a consultation process and conducted site visits and interviews with NAV CANADA operational staff, airport authorities and airline stakeholders. Based on data from June 2016 to June 2017, the total number of runway incursions for each airport was compared with the total number of arrival and departures to establish a rate per 100 000 arrivals and departures. CYUL ranked 1st with 39 as the highest number of runway incursions. However, with 228 045 total arrivals and departures, CYUL ranked 17th with a rate of 17.1 runway incursions per 100 000 arrivals and departures.

Once it has finished with the safety analysis, the working group will provide "recommendations for the implementation or modification of runway incursion [prevention] techniques."[57] The working group completed the report on 28 April 2019. At the time of report writing, NAV CANADA was expected to make a decision on the report recommendations at a later date.

1.18.5 TSB Watchlist

The TSB Watchlist identifies the key safety issues that need to be addressed to make Canada's transportation system even safer. The risk of collisions from runway incursions is a 2018 Watchlist issue and has been on every edition of the Watchlist since 2010. The TSB has completed 10 investigations[58] into runway incursions since the release of the 2010 Watchlist. In late 2018 and early 2019, the TSB opened 3 more investigations into runway incursions.[59]

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[55] Runway Safety and Incursion Prevention Panel, ALERT: RUNWAY SAFETY TEAMS, Newsflash 2 (June 2012), at http://www.navcanada.ca/EN/products-and-services/Runway%20Resources/Newsflash-Teams-EN.pdf (last accessed 03 October 2019).

[56] NAV CANADA, Runway Incursion Prevention Action Group, *Terms of Reference* (January 2018).

[57] Ibid.

[58] TSB aviation investigation reports A10W0040, A11Q0170, A13H0003, A13O0045, A13O0049, A14C0112, A14H0002, A14W0046, A16O0016, and A16W0170.

[59] TSB air transportation safety investigations A18P0177, A19O0006, and A19Q0015 (this occurrence).

The Board is concerned that the rate of runway incursions in Canada, and the associated risks of collision will remain until effective defences tailored to address identified hazards are implemented at airports and in aircraft, vehicles, and air traffic service facilities across Canada.

This issue will remain on the TSB Watchlist until the rate of runway incursions, particularly the most severe ones, demonstrates a sustained reduction.

Transport Canada and all sectors of the aviation industry must continue to collaborate and develop tailored solutions to identified hazards at Canadian airports. These solutions could include improvements in air traffic control procedures, surveillance and warning systems, runway and taxiway designs, holding position visual aids, and flight crew training and procedures.

Modern technical solutions, such as in-cockpit electronic situational awareness aids, and direct-to-pilot warnings, such as runway status lights, should also be implemented.

1.19   Useful or effective investigation techniques

Not applicable.

2.0   ANALYSIS

The flight crew saw the snowplow-sweepers, heard and complied with the air traffic control (ATC) airport controller's instructions, conducted a go-around, and landed safely. There was nothing to indicate that there were any operational or technical issues with the aircraft in this occurrence.

The personnel involved from NAV CANADA and Aéroports de Montréal (ADM) were all trained and qualified. There was nothing to indicate that their performance was degraded by fatigue or physiological factors. Therefore, this analysis will focus on memory and ADM convoy operations. As well, ATC communication and situational awareness issues will be examined.

2.1   Prospective memory

In this occurrence, the convoy lead proceeded past the runway holding position and onto the runway without an ATC authorization. The intended action was for the convoy lead to stop when he reached the runway holding position at holding bay 24L. This relied on event-based prospective memory, which is remembering to perform an intended action when specific circumstances occur.

The 4 steps required to successfully use prospective memory are encoding, retention, execution, and evaluation. The convoy lead heard, understood, and read back the ATC instruction to proceed to holding bay 24L, including the requirement to hold short, which indicates that the memory encoding and retention of the instruction was successful. The failure to remember and execute the intended action at the appropriate time occurred at the retrieval stage and could be explained by 2 possible factors: distraction and insufficiently salient target cues.

While approaching the runway holding position lighting, signage, and markings at holding bay 24L (the target cues for the intended action), the convoy lead's attention was on driving and on the current and future snow removal tasks on Taxiway A and Runway 24L. This meant that no attentional resources were allocated to the strategic retrieval (monitoring or search) of the environmental cues for the intended action encoded in his memory. The convoy lead, focused on the tasks of driving and snow removal, did not remember to stop at the runway holding position. The *Manual on the Prevention of Runway Incursions* published by the International Civil Aviation Organization (ICAO) identifies distraction by current work as a causal factor for vehicle operators.

The runway holding position lighting, signage, and markings located at holding bay 24L (the target cues) are always present and, as an experienced operator, the convoy lead would have grown accustomed to seeing them, regardless of the ATC instructions to hold short or to proceed beyond them and onto the runway. These cues may not have been sufficiently salient to allow the operator to automatically retrieve the intended action from memory. In addition, while the guard lights and designation signs would have been visible, it is unknown if the runway holding position was visible due to the snowfall conditions that day.

Assuming that they were all visible, these cues may not have been salient enough to remind the convoy lead to stop at the runway holding position.

A runway incursion occurred when the convoy lead, focused on the tasks of driving, snow removal, and planning the convoy's next snow removal pass on Runway 24L, missed the runway holding position lighting, signage and markings, forgot about the requirement to hold short, and proceeded past the runway holding position onto Runway 24L.

In this occurrence, 3 other vehicle operators crossed the runway holding position following the convoy lead, out of habit, as they are trained that this is their primary responsibility. None of them stopped in time, took action to prevent or reduce the severity of the incursion, or alerted the convoy lead to the incursion over the radio. Three other vehicles in the convoy did not hold short and, out of habit, followed the lead vehicle past the runway holding position, which increased the severity of the incursion.

2.2 Snow removal convoy operations by Aéroports de Montréal

2.2.1 Team leader responsibilities

Team leaders are responsible for the convoy on the aerodrome, which includes supervising the convoy's operations, communicating with ATC, and ensuring that the convoy complies with ATC instructions. When team leaders are not primarily focused on these tasks, they will rely on the specific radio communications and on the convoy lead to ensure that the convoy complies with ATC instructions. They will also rely on the convoy lead to coordinate specific convoy snow removal tasks such as the convoy's formation and position on the runways, the equipment orientation, and the placement of excess snow.

The roles and responsibilities of team leaders require them to coordinate and conduct all convoy–ATC communications. During normal convoy operations, their attention is primarily on leading and monitoring the convoy's movements and not on actual snow removal tasks. Therefore, while team leaders may also be driving a vehicle, they are less likely than a vehicle operator to forget part of an ATC ground traffic movement instruction. However, they are still susceptible to prospective memory failure.

In this occurrence, knowing that the convoy lead had heard, understood, and read back the ATC instruction, the team leader expected to see the convoy in the holding bay and the convoy lead complying with the requirement to hold short of Runway 24L. This expectation indicates that the team leader did not forget about the requirement to hold short.

The ADM procedures in place at the time of the occurrence indicated that when the convoy includes 2 team leaders or supervisors, 1 should lead the convoy, and the other should follow the convoy and be the last to exit the runway. The intent of this procedure is to enhance supervision and safety for convoy operations.

When the convoy includes only 1 team leader or supervisor, the procedures do not specify the positioning of the team leader or supervisor, or if this member of the convoy should be the 1st vehicle to enter a runway. While making this a requirement could be a way to

mitigate the risk of a convoy incurring on a runway, it may not eliminate the risk of a runway incursion by the team leader or supervisor themselves. In addition, the duties associated with the team leader or supervisor roles could make such a specific procedure difficult to implement.

The procedures do specify that, regardless of the number of team leaders or supervisors present, at least 1 team leader or supervisor should be last to exit the runway. Because the SNOWiz application was not working, the single team leader in the convoy had to slow down and communicate the aircraft movement surface condition report to ATC by phone. This and the requirement to be the last to exit Runway 24R placed him behind the convoy. The investigation was unable to determine why the team leader maintained this position.

The ADM team leader procedures in place at the time of the occurrence did not specify if team leaders or supervisors should lead a convoy onto a runway. As a result, the team leader could not ensure that the convoy complied with the ATC instruction and the requirement to hold short and therefore could not prevent the runway incursion.

2.2.2 Training for convoy operations

The training required for operators includes aerodrome, emergency and radio procedures. Aerodrome procedures highlight the importance for convoy team members to follow the convoy lead. The training and multiple days of operating in a convoy make following the lead vehicle a habit. Radio procedures and radios in each vehicle allow all operators to hear the communications and to clarify ATC instructions, convoy communications, or important safety messages.

Managing the risk of runway incursions by airport vehicles includes reducing its likelihood and mitigating the consequences if it occurs. While the training provided to operators includes procedural and communication scenarios including situations when to hold short or exit a runway in an emergency, it does not include or discuss scenarios for what to do during a runway incursion, what radio communications should be made, or what vehicle operating procedures need to be followed to reduce the likelihood or mitigate the consequences of an incursion. If vehicle operator training does not include runway incursion scenarios, convoy operators may not be sufficiently prepared to take necessary safety actions to reduce risks posed by runway incursions.

2.3 Air traffic control

2.3.1 Communications

The ATC instruction given to the team leader and convoy to proceed from Runway 24R to holding bay 24L contained a route that was long and contained several taxiways, a runway and a holding bay. The ground controller issued a single instruction, given that the route, although lengthy, was fairly simple and that air and ground traffic was light. Issuing a lengthy instruction can make communications faster and more efficient, but it can increase the likelihood of an individual forgetting a portion of the instruction.

The ATC instruction and routing from Runway 24R to holding bay 24L was in accordance with the procedures outlined in NAV CANADA's *Manual of Air Traffic Services* – Tower (MATS – Tower-EN), given the ground vehicle and aircraft traffic that day.

2.3.1.1 Runway "hold short" instructions

With regard to issuing aircraft taxi or ground traffic movement instructions, including using the term "Hold short," MATS – Tower-EN states "Instruct the pilot or driver to either cross or hold short of a runway or taxiway on their route" and "Obtain a readback of a hold or hold short instruction."[60] There are no specific directives for all situations; therefore, the inclusion of the term "Hold short" is sometimes left to the discretion of individual controllers. However, if controllers do not use the term "Hold short," there is no requirement to obtain a readback. Not requiring a readback alleviates controller workload, but if there is no readback, then there is no confirmation that the instruction was correctly received. Additionally, if there is no explicit instruction to "hold short" with a specific runway identifier, some personnel may not be clear on the instruction.

In this occurrence, once the ground controller had communicated the ATC instruction, the team leader read the instruction back, but only a portion of it. The team leader then realized that he might not have read the full instruction back and discussed this with the convoy lead. The discussion also included the question of whether the ATC instruction had included the term "hold short." The convoy lead clarified, and the team leader read back the full ATC instruction, including the term "hold short." Had the term "hold short" been used in the ground controller's initial instruction, the team leader would have been required to read back the instruction, the requirement to hold short would have been reinforced, and the confusion could have been avoided. The instruction was not an "explicit clearance [or instruction] to hold short of any runway,"[61] such as "Hold short of Runway two four left." As shown in this occurrence, the team leader required clarification on the instruction and the requirement to hold short of Runway 24L. This suggests that including "hold short" in the instruction provides clarification to vehicle operators.

Because the ground controller was not required to include the term "hold short" and did not include it in the instruction, he did not expect, nor was he required to obtain, a readback from the team leader. However, he did expect the convoy to comply with the instruction, follow the assigned routing, and stop in holding bay 24L. The ATC instruction was eventually understood by the convoy. However, ATC instructions that direct ground vehicles to runways and that do not contain an explicit instruction to hold short of an active runway can increase the potential for misunderstanding, and increase the risk of a runway incursion.

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[60] NAV CANADA, *Manual of Air Traffic Services* (MATS), Tower-EN (26 June 2018), Traffic Management, Surface Movement, Aircraft Taxi or Ground Traffic Operations, Movement instructions, p. 65.

[61] International Civil Aviation Organization, Document 9870 AN/463, *Manual on the Prevention of Runway Incursions*, First Edition (2007), section 4.5.6, p. 4-3.

2.3.2   Situational awareness

In its *Manual on the Prevention of Runway Incursions*, ICAO identifies distractions due to performing other assigned duties, lack of visual scanning of ground movements, and limitations on the view of the manoeuvring area as causal factors that can contribute to a runway incursion.

At the time of the incursion, air and ground traffic was minimal, and workload was low for the controllers on duty. The weather conditions were such that the controllers in the tower did not have a clear visual line of sight to several areas of the aerodrome and had a limited view of the manoeuvring area, including holding bay 24L. They had to actively scan and monitor the Advanced Surface Movement Guidance and Control System (A-SMGCS) display to see and coordinate ground movements on the aerodrome.

In the time leading up to the incursion, the ground controller was multitasking; controlling, reading an operational directive and on the phone with the shift manager. He did not become aware of the incursion and did not identify the issue until prompted by the airport controller who detected the incursion through active visual scanning and monitoring of the A-SMGCS display. Had RIMCAS or other runway incursion prevention systems been available for Runway 24L, they could have alerted both controllers at the same time. The airport controller immediately instructed the aircraft to pull up and go around, which prevented the aircraft from landing while part of the convoy was on the runway. The airport controller then told the ground controller about the runway incursion. The ground controller immediately contacted the team leader. The convoy lead, who also heard the ground controller radio communication, turned to exit the runway. By this time, 3 other vehicles had crossed the runway holding position.

Neither active scanning and monitoring of the A-SMGCS display, nor a direct line of sight of the convoy approaching the holding bay, would have prevented the runway incursion; however, active scanning and monitoring could have improved the timeliness of the response and reduced the severity of the incursion. In this occurrence, the ground controller was multitasking and conducting an operational phone call, which led to a breakdown of his scanning and monitoring, delayed his response to the runway incursion, and increased the severity of the incursion. An earlier call to the team leader might have prevented CHA142 from reaching the runway surface and perhaps have prevented the 2nd, 3rd, or 4th snowplows from proceeding past the runway holding position.

3.0   FINDINGS

3.1   Findings as to causes and contributing factors

These are conditions, acts or safety deficiencies that were found to have caused or contributed to this occurrence.

1. A runway incursion occurred when the convoy lead, focused on the tasks of driving, snow removal, and planning the convoy's next snow removal pass on Runway 24L, missed the runway holding position lighting, signage and markings, forgot about the requirement to hold short, and proceeded past the runway holding position onto Runway 24L.

2. Three other vehicles in the convoy did not hold short and followed, out of habit, the lead vehicle past the runway holding position, which increased the severity of the incursion.

3. The Aéroports de Montréal team leader procedures in place at the time of the occurrence did not specify if team leaders or supervisors should lead a convoy onto a runway. As a result, the team leader could not ensure that the convoy complied with the air traffic control instruction and the requirement to hold short and therefore could not prevent the runway incursion.

4. The ground controller was multitasking and conducting an operational phone call, which led to a breakdown of his scanning and monitoring, delayed his response to the runway incursion, and increased the severity of the incursion.

3.2   Findings as to risk

These are conditions, unsafe acts or safety deficiencies that were found not to be a factor in this occurrence but could have adverse consequences in future occurrences.

1. If vehicle operator training does not include runway incursion scenarios, convoy operators may not be sufficiently prepared to take necessary safety actions to reduce risks posed by runway incursions.

2. Air traffic control instructions that direct ground vehicles to runways and that do not contain an explicit instruction to hold short of an active runway can increase the potential for misunderstanding, and increase the risk of a runway incursion.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Aéroports de Montréal

Following the occurrence, Aéroports de Montréal (ADM) put an additional supervisor on duty for the rest of the day and held a debriefing meeting with the team leader and the convoy lead.

Meetings were held to raise awareness of runway incursions, and to obtain employee feedback on the occurrence.

An internal investigation within the ADM safety management system was initiated, which included brainstorming/mapping and a risk analysis.

ADM Procedure PR-3-7-804, Précautions pour prévenir les incursions de pistes lors des opérations (Precautions to prevent runway incursions during operations, available in French only), was reviewed and tasks 5, 6, and 7 of the safe work practices were modified as follows:

- Task 5 was modified to state that once the control tower has given clearance, the supervisor or team leader will clear operators to proceed onto the runway. The notes accompanying this task states that instructions must use appropriate phraseology and must specify the runway number (e.g., 24L).

- Task 6 was modified to state that once the supervisor or team leader has given clearance, the operator will read back the clearance using appropriate phraseology.

- Task 7 was modified to state that when the operator at the head of the convoy is at the runway holding position, the operator must confirm with the supervisor or team leader that the operator is in position and is ready to proceed before the convoy proceeds onto the runway. The operator must use appropriate phraseology and repeat the runway number (e.g., 24L).

ADM has modified its training for employees by adding presentations that deal specifically with runway incursions.

ADM has added the issue of runway incursions to the agenda for the next meeting of the ADM and NAV CANADA Runway Safety Action Team, which will be held in January 2020.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 8 January 2020. It was officially released on 21 January 2020.

Visit the Transportation Safety Board of Canada's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the key safety issues that need to be addressed to make Canada's transportation system even safer. 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.

APPENDICES

Appendix A – Extracts from the NAV *CANADA Ground Traffic Phraseology Manual*

Hold Short

When instructed to "hold short," you do not have permission to enter the runway; you must stay behind the hold short line until further advised. Being told to hold short of taxiways or other specific locations on the airfield is also a frequent occurrence. It should also be noted that you do not have permission to enter a runway unless you are given permission onto that runway. Vehicles should question an instruction that does not have a hold short or permission onto a runway if the route takes them to a runway.

ATS: (vehicle ident) HOLD SHORT (runway, taxiway, location).

DRIVER	**Thompson Radio, Sweeper one-five-one, at the south apron, request to go to the north apron via Alfa Charlie.**
FSS	**Sweeper one-five-one, negative, proceed via Alfa, hold short runway zero-six.**
DRIVER	**Thompson Radio, Sweeper one-five-one, proceeding via Alfa, hold short runway zero-six.**

Hold Short and Read Back

When you are told to "hold short," you are required to read back the instruction. When this occurs, read back the complete instruction given.

FSS: (vehicle ident) HOLD SHORT (runway, taxiway ident).

Driver: (vehicle ident) ROGER, HOLD SHORT (runway/taxiway ident).

FSS	**Staff two-two proceed onto taxiway Alfa, hold short runway two-four.**
DRIVER	**Staff two-two, Roger, proceed onto taxiway Alfa, hold short runway two-four.**

Operating on a Runway

ATS cannot give instructions that allow for unrestricted ground movement on the manoeuvering area. ATS cannot authorize you to: "proceed on the field," "proceed unrestricted," or "proceed on all manoeuvering areas." Clearances onto runways must specify the runway number.

DRIVER	**Saskatoon radio, Staff two-three on taxiway Charlie, request to proceed onto runway zero-nine.**
FSS	**Staff two-three proceed onto runway zero-nine, cross runway one-five until further advised.**

⚠	**When operating on a runway, keep your eyes and ears open; people can make mistakes.**

Note: While the examples provided here depict fictitious communications between a driver and a flight service specialist at a flight service station (FSS), these communications are also used by an air traffic controller at a control tower.(Source: NAV CANADA, *Ground Traffic Phraseology*, Version 1 [April 2018]).

Appendix B – Runway incursion data for CYUL, 2000 to 2019

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019 (Nov/nov.)
AD	2	1	1	2	3	2	0	0	1	0	2	4	1	1	1	2	2	6	2	2
PD	0	33	34	20	11	4	14	26	26	21	14	21	12	14	15	11	15	24	13	15
VPD	0	9	10	6	8	2	5	9	7	8	9	14	21	8	9	13	14	7	5	8
Total	2	43	45	28	22	8	19	35	34	29	25	39	34	23	25	26	31	37	20	25

Classification:
AD - ATS Deviation / déviations des services de la circulation aérienne
PD - Pilot Deviation / écarts commis par un pilote
VPD - Vehicle or Pedestrian Deviation / incursions véhicule ou piéton

December / decembre 2019
Sources: AOA_T, NC-SIS
Prepared by Corporate Performance / Préparé par
Performance de l'entreprise (MW)

Source: NAV CANADA