Transportation Safety Board of Canada | Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A13O0049

RISK OF COLLISION

BETWEEN
KELOWNA FLIGHTCRAFT AIR CHARTER LTD.
BOEING 727-281, C-GKFJ
AND
AIRPORT MAINTENANCE VEHICLES (SNOW SWEEPERS)
HAMILTON AIRPORT, ONTARIO
19 MARCH 2013

Canada

Aviation Investigation Report A13O0049

Risk of collision

Between
Kelowna Flightcraft Air Charter Ltd.
Boeing 727-281, C-GKFJ
and
Airport maintenance vehicles (snow sweepers)
Hamilton Airport, Ontario
19 March 2013

Summary

A Kelowna Flightcraft Air Charter Ltd. Boeing 727-281 (registration C-GKFJ, serial number 21455), operating as KFA273, was departing on Runway 30 at Hamilton Airport, Ontario, at 0208 Eastern Daylight Time during the hours of darkness destined for Winnipeg–James Armstrong Richardson International Airport, Manitoba. Two snow sweepers were working near the departure end of Runway 30. During the take-off roll, air traffic control instructed the aircraft to abort the take-off, and the flight crew rejected the take-off. The aircraft came to a stop at approximately the halfway point of the 10 006-foot-long runway, separated from the snow sweepers by approximately 1200 feet. There was no damage, and there were no injuries.

Le présent rapport est également disponible en français.

Factual information

The Hamilton Airport (CYHM) is the main base for Purolator air cargo operations, operated by Kelowna Flightcraft Air Charter Ltd (Flightcraft). Flightcraft has several scheduled cargo flights, which normally depart CYHM between the hours of 0115[1] and 0140 every morning.

Air traffic services (ATS) at CYHM are provided by NAV CANADA through a control tower located at the airport and by the Toronto Area Control Centre (ACC), located at Toronto–Lester B. Pearson International Airport. Instrument flight rules (IFR) clearances are relayed from the Toronto ACC, and departure clearances are required to be validated by the ACC before departure. This validation is accomplished by verbal communication over the interphone between the tower controller and the ACC controller in the satellite sector.[2]

Events in the control tower

The control tower was staffed by 2 controllers at the time of the occurrence; however, one controller was on break and not in the tower cab during the occurrence. The controller in the tower (hereinafter referred to as the controller) was responsible for both airport and ground positions, which is normal procedure at that time of night. The radios were set up so that ground frequencies and air frequencies were coupled. Operating under this setting allows broadcasts made on either frequency to be heard by anyone monitoring either frequency. For example, a broadcast made by a ground vehicle on the ground frequency will be relayed through both radios and heard by an aircraft monitoring only the air frequency.

Approximately 45 minutes before the occurrence, the controller cleared 2 snow sweepers to work on Runway 30 to facilitate snow and ice removal. The snow sweepers were instructed to vacate the runway to accommodate a departure at 0156, and were re-cleared onto the runway at 0200.

The controller was busy for the 20 minutes preceding the occurrence, and made or received, on average, 7 transmissions per minute during this time. Several of these communications were lengthy, as the controller had to issue IFR clearances, runway surface condition reports, and complex taxi instructions. While communicating with the ACC, the controller mistakenly requested a flight release for KFA275. The request was supposed to be for KFA273. This error was corrected in subsequent communications with the ACC.

The controller has an extended computer display system (EXCDS) (Figure 1). EXCDS is a computer-based coordination system that permits controllers to manage electronic flight data using display screens instead of paper flight progress strips. The system incorporates a visual reminder called a blocked-runway indicator, which the controller activated to indicate that the runway was occupied.

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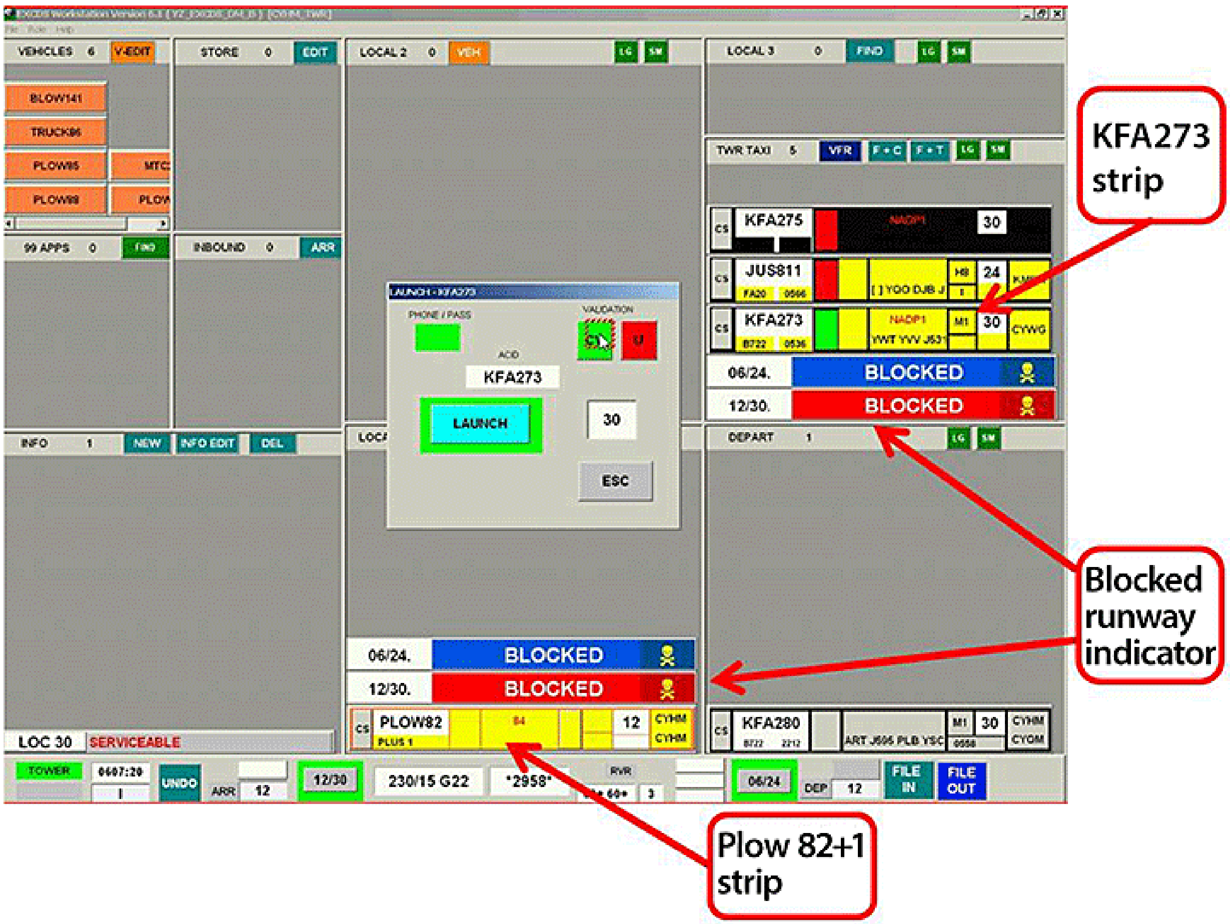
1 All times are Eastern Daylight Time (Coordinated Universal Time minus 4 hours).

2 Airspace controlled by the Toronto Area Control Centre is divided into several specialties, and those specialties are further subdivided into sectors. The satellite sector is responsible for the airspace surrounding the CYHM control zone.

As the controller began issuing the take-off clearance to KFA273 (Appendix A), the EXCDS display was scanned; however, the blocked-runway indicator was overlooked. As the controller was uttering the words “cleared for take-off Runway 30”, a visual scan of the runway surface was completed, and the snow sweepers were noticed. The controller paused for a second without releasing the push-to-talk button (PTT), and then used the non-standard phrase “actually standby”. When the PTT was released, the controller heard the aircraft respond “273”.

Figure 1. The display on the extended computer display system (EXCDS) at the time of take-off clearance of KFA273



The controller then instructed the snow sweepers to exit the runway, and verified visually that KFA273 had not begun the take-off roll. While waiting for the plows to exit, the controller then issued taxi instructions to KFA271, another Boeing 727 parked at the Purolator Apron.

When viewing the airport environment (Appendix B) from the tower cab, the Purolator Apron is approximately 90º to the right of the Runway 30 threshold. As the controller was issuing taxi instructions to KFA271 and viewing the Purolator Apron, KFA273 began its take-off roll and, as the runway was out of the controller’s direct view, this movement went unnoticed for 22 seconds.

Immediately after KFA271 read back the taxi instructions, the controller’s attention returned to Runway 30, and KFA273 was noticed to be on the take-off roll. The controller immediately instructed KFA273 to abort the take-off. At this point, the aircraft was 1130 feet down the runway.

History of the flight

Flightcraft operates 13 Boeing 727 aircraft dedicated to freight operations. The aircraft type requires a minimum crew of 3, including a captain, first officer, and second officer.

On the occurrence flight, the captain was the pilot flying (PF), and the first officer was the pilot not flying (PNF).

The aircraft maximum allowable take-off weight is limited to 185 000 pounds for this segment, and the aircraft was loaded to 168 516 pounds for the 2.4-hour flight. The PNF calculated the take-off speeds as follows: V_1 / V_R = 130 knots, V_2 = 144 knots.[3]

The flight crew received take-off clearance while backtracking on Runway 30. Once the controller uttered the phrase “cleared for take-off Runway 30”, the PNF immediately pressed the PTT and read back the clearance, ending the transmission with “273”. The remainder of the controller’s transmission, which included the pause and instruction to stand by, was not heard by the flight crew. The simultaneous activation of the PTT in the cockpit will override any incoming transmissions. In a recording of the subsequent similar take-off clearance, the PNF responded by stating “from the threshold cleared take-off 30, Flightcraft 273”.

The aircraft began its take-off roll at 0207:47. As the aircraft accelerated through 80 knots at 0208:09, the PNF made the standard call of “80 knots”, and the PF responded “80 knots”. At the same time, an approach chart clipped to the PF’s control column fell off the clip, and both the PF and PNF were momentarily distracted. Also at this same time, the controller issued the instruction to abort take-off. At this point, KFA273 was approximately 1130 feet down the runway. The instruction to abort take-off went unrecognized for approximately 9 seconds (Appendix A).

At 02:08:18 and approximately 2750 feet down the runway at an airspeed of 122 knots, the PNF of KFA273 saw bright white lights at the far end of the runway. Recognizing that the call to abort take-off was for them, the PNF informed the PF, and the crew initiated a rejected take-off (RTO). The airspeed peaked at approximately 130 knots before deceleration began. Initially during the RTO, the PF applied maximum braking; however, once it was apparent that the aircraft would stop well short of the snow sweepers, brake pressure was reduced to light braking.

The aircraft was brought to a stop approximately 1700 feet following initiation of the RTO, at a position 4800 feet from the threshold and approximately 1200 feet short of the snow sweepers (Appendix B).

The *Boeing 727 Performance Manual*, carried in the cockpit, contains a brake-cooling schedule which details the amount of time required to sufficiently cool the brakes following a landing or RTO. The schedule is advisory only, but is designed to assist the operator in reducing the risk of brake overheating, or tire fuse plug release.

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[3] V_1 refers to take-off decision speed; V_R refers to rotation speed; and V_2 refers to take-off safety speed (Transport Canada, TP 14371E, *Aeronautical Information Manual* [TC AIM], [16 October 2014], GEN 1.9.1).

Given the heavy braking conditions of this RTO, the schedule advised that 56 minutes of ground cooling would be required.

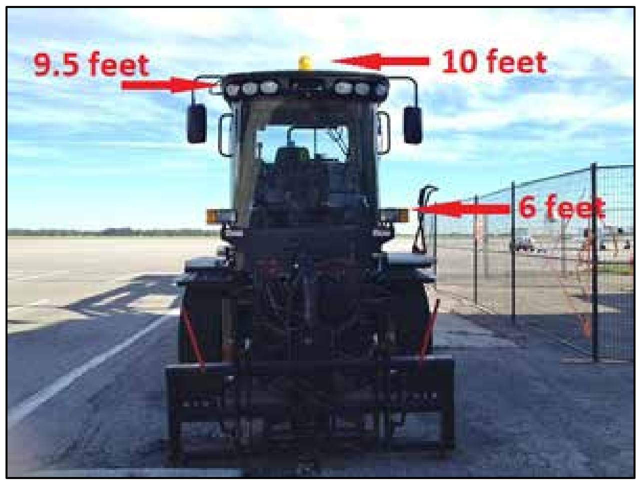
After coming to a stop and receiving clearance to backtrack on the runway, the flight crew discussed brake cooling and decided that, given the reduction of brake pressure during the deceleration, no additional cooling time would be required. The brake-cooling schedule under light braking conditions would still recommend 22 minutes of ground cooling.

KFA273 departed CYHM less than 5 minutes after the RTO.

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR). However, as the aircraft completed its scheduled flight to Winnipeg, the 2-hour CVR recording was overwritten and not available for the investigation.

Ground vehicles

Figure 2. A CYHM snow sweeper



The airport authority, Hamilton International Airport Ltd., operates a fleet of vehicles for the purpose of keeping the airport movement area[4] safe and available for aircraft operations.

At the time of the occurrence, 2 snow sweepers were deployed to Runway 30. The snow sweepers were identical in appearance and were driven in a staggered formation for the sweeping operation.

As required by Transport Canada's *Aerodromes Standards and Recommended Practices*, snow sweepers must have a beacon light installed. The snow sweepers have a beacon installed 10 feet above the ground on the top of the cab. Additionally, the snow sweepers are equipped with 6 white floodlights situated at 9.5 feet above the ground, and 2 headlights at 6 feet above the ground (Figure 2).

The snow sweepers are equipped with radios to communicate with air traffic control (ATC), and they did so as one unit—in this case, operating as call sign "Plow 82 Plus 1".

At the time the controller issued the take-off clearance to KFA273, the snow sweepers were on the departure end of Runway 30, proceeding southeast and bound toward KFA273. The drivers of the plows heard the take-off clearance on the radio and the subsequent instruction to stand by. The transmission that followed instructed Plow 82 Plus 1 to exit the runway via Taxiway G, which was 4000 feet from their position. As they proceeded down the runway, they saw the aircraft coming toward them, and at the same time, they heard the instruction to abort take-off.

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4 The airport movement area is the part of an aerodrome that is intended to be used for the surface movement of aircraft and that includes the manoeuvring area and aprons (Transport Canada, TP 14371E, *Transport Canada Aeronautical Information Manual* [TC AIM], [16 October 2014], GEN 5.1).

The plows moved toward the south side of the surface as a precaution in case the aircraft wasn't able to stop.

The snow sweepers were operating as designed, with no mechanical failures.

Flight deck environment

On Flightcraft's Boeing 727s, there is no live intercom between the 3 crew-member positions. To communicate over the intercom system, speakers must first select the interphone transmit position on their respective audio panel, then depress an intercom PTT (push-to-talk button). As this practice can be cumbersome during critical phases of flight, it is Flightcraft's policy to use natural voice communications on the flight deck of the B727, without the aid of electronics.

The crew members on KFA273 were wearing standard over-the-ear aviation headsets. To facilitate natural communication among each other, each crew member removed one ear cup, so that the ear closest to the other crew members was uncovered. This method is common practice at Flightcraft and on other similarly equipped aircraft.

Several factors can lead to increased noise levels in the cockpit during operations. Some of these factors, such as noise from the air conditioning system, are continuous and independent of aircraft position or speed. Other factors, such as wind, engine, or tire noise, can vary with aircraft speed.

Weather

Visibility was 5 statute miles in light rain showers and mist, with a temperature of 1°C. The latest wind information issued to the crew of KFA273 on departure was as follows: 230° Magnetic at 15 knots gusting to 22 knots.

Runway

A runway surface condition report was completed at 0024 and indicated the following: Runway 30 cleared for width of 180 feet, 80% bare and wet, 10% wet snow trace, and 10% ice. Turning bays and runway intersections were described as slippery, and sweeping was in progress. This report was included in the latest Automatic Terminal Information Service (ATIS) broadcast.

The take-off run available (TORA) for Runway 30 at CYHM is 10 006 feet. The middle section of the runway is higher than both ends. The elevation at the displaced threshold is approximately 14 feet lower than the middle section, while the runway departure end is approximately 11 feet lower.

A pilot seated correctly in the cockpit of a Boeing 727 has an eye-to-ground height of approximately 13 feet. Given the curvature of the runway (based on the higher middle section), the curvature of the earth, and the refraction of light,[5] the lead snowplow's beacon would not have been visible to the flight crew until the aircraft was approximately 1400 feet into the take-off roll. The plow's floodlights would become visible around 1700 feet, its headlights around 2700 feet, and the entire vehicle at 3450 feet.

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5 The earth's curvature and the light refraction were calculated based on generally accepted averages.

Air traffic controller

The controller in the tower cab during the occurrence had been a licensed and qualified air traffic controller at the CYHM tower since January 2012. This was the controller's first operational posting upon initial issuance of an ATC licence. The latest recurrent check was completed in January 2013.

Air traffic control procedures and phraseology

ATC, by design, has strict phraseology requirements. These have been developed or modified over the years to increase clarity and reduce misunderstandings.

The *Air Traffic Control Manual of Operations* (ATC MANOPS) details the appropriate phraseology to be used in certain situations. ATC MANOPS Section 337 (Cancellation of Take-Off Clearance) states the following:

> 337.1
> If circumstances require, cancel a previously issued take-off clearance and, when appropriate, inform the aircraft of the reason.
>
> 337.1 Phraseology
> If a clearance to take off is cancelled:
> A. before the aircraft has started to roll —
> TAKE-OFF CLEARANCE CANCELLED;
> B. after the aircraft has started to roll —
> ABORT TAKEOFF.
>
> 337.1 Note:
> An aborted takeoff is an emergency procedure employed in situations where to continue would present a grave hazard to the aircraft. A controller-initiated abort of takeoff should be viewed as an extreme measure to be used only where there is no clear alternate course of action.[6]

The controller was familiar with these required phrases, which had been covered during initial training. The controller had never been required to use either of these phrases.

The NAV CANADA *Hamilton Air Traffic Control Tower Unit Operations Manual* requires[7] that a blocked-runway indicator (Figure 1) be placed by a controller over the appropriate runway header on the EXCDS display, to serve as a visual reminder when the runway is occupied or unavailable. Aircraft are not to be cleared for take-off or landing on a particular runway when a blocked-runway indicator occupies that position on the display, and this display in addition to the entire runway surface is to be viewed as part of the controller's scan before such a clearance is issued. EXCDS recordings for 4 hours surrounding the occurrence showed that aircraft

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6 NAV CANADA, *Air Traffic Control Manual of Operations* (ATC MANOPS), Section 337: Cancellation of Take-Off Clearance.

7 NAV CANADA, *Unit Operations Manual: Hamilton Air Traffic Control Tower*, (original 15 February 2007, Amendment no. 13-02), section 35.3.

departed on runways that had a “blocked runway” depiction at least 3 other times, although in all 3 cases, the runway was not in fact physically occupied.

Repeated exposure to a warning or reminder can result in the user becoming habituated to the warning, in turn resulting in the failure of the reminder to attract the attention of the operator.[8] More specifically, the practice of authorizing aircraft to arrive or depart on a runway for which a blocked-runway indicator is showing serves to desensitize the controller to the importance of the blocked-runway indicator. This desensitization reduces the effectiveness of the indicator as a defence and increases the risk of aircraft being authorized to use a runway that is unavailable.

Call sign confusion

Call sign confusion is a major cause of instances in which an aircraft crew takes a clearance that is not intended for them and can lead to unintended control actions by air traffic controllers arising from visual or auditory confusion of aircraft call signs.[9]

Flightcraft regularly schedules several flights with similar call signs to depart from CYHM around the same time. Near the time of the occurrence, KFA271, KFA273, and KFA275 were all scheduled to depart CYHM and all destined for CYWG.

NAV CANADA procedures specify that controllers should warn pilots of similar call signs on the frequency. The Hamilton Tower *Unit Operations Manual* (UOM) indicates that a form is available to report similar sounding idents (SSIs) and that the form should be used to report instances in which there was “potential or actual confusion due to aircraft with similar sounding idents in the same airspace at the same time.”[10]

The most effective defence against call sign confusion is to eliminate the incidence of similar call signs on the frequency at a given time.[11] The European Organisation for the Safety of Air Navigation (EUROCONTROL) has developed software that analyzes flight schedules to identify potential conflicts and offer a call sign similarity service to operators.[12]

NAV CANADA’s practice is to notify operators of call signs that have been shown to lead to confusion. This practice has resulted in changes to individual flight numbers. In addition, NAV CANADA has raised the issue with stakeholders during customer consultation forums,

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8 M.S. Wotalter and K.R. Laughery, Warnings and Hazard Communications, in: G. Salvendy (ed.), *Handbook of Human Factors and Ergonomics*, 3rd Edition (Hoboken, NJ: John Wiley and Sons, 2006), p. 901.

9 EUROCONTROL, *European Action Plan for Air Ground Communications Safety*, Edition 1.0 (May 2006), p. 5.

10 NAV CANADA, *Unit Operations Manual: Hamilton Air Traffic Control Tower*, (original 15 February 2007, Amendment no. 13-02), section 81.

11 European Organisation for the Safety of Air Navigation (EUROCONTROL), Call Sign Confusion – EUROCONTROL’s Call Sign Similarity Tool helps improve flight safety (05 November 2012), available at http://www.eurocontrol.int/news/call-sign-confusion-eurocontrols-call-sign-similarity-tool-helps-improve-flight-safety (last accessed on 25 November 2014).

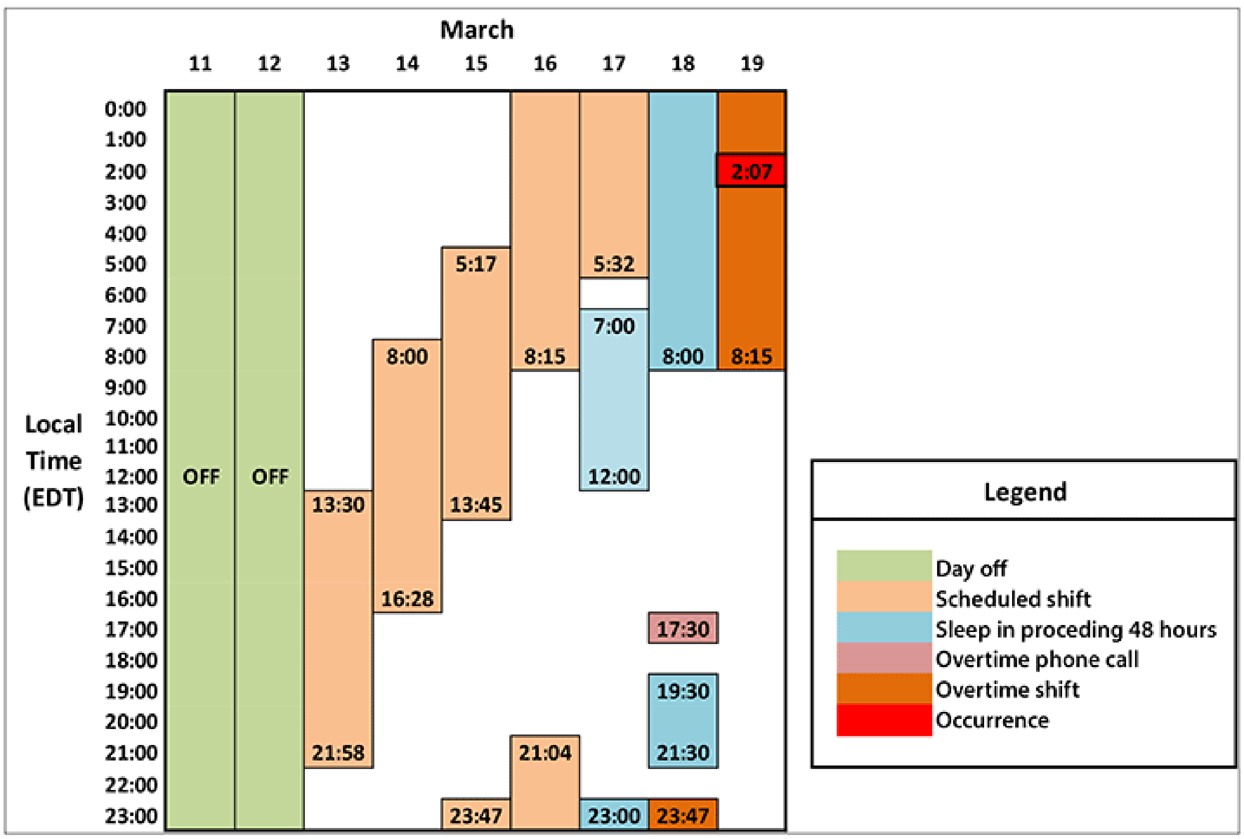
12 European Organisation for the Safety of Air Navigation (EUROCONTROL), Call Sign Similarity (CSS) Service, available at http://www.eurocontrol.int/services/call-sign-similarity-css-service (last accessed on 25 November 2014).

encouraging operators to take steps to proactively identify and eliminate potentially confusing call signs.

Tower staffing

CYHM tower is a 24-hour facility. During the week prior to the occurrence shift, the controller had worked 5 regularly scheduled shifts, with start times that varied from early morning to late night (Figure 3). On the controller's first scheduled day off, 18 March 2013, an unscheduled overtime shift arose, and the controller was called at 1730 and given the option to work that shift. The controller initially declined; however, in response to a second phone call, once informed that no one else had volunteered, the controller accepted. The overtime shift was to begin at 2347. In an effort to be rested, the controller obtained 2 hours of sleep before the shift began.

Figure 3. The controller's schedule



The controller began the overtime shift as planned and assumed responsibility for the combined air–ground position at approximately 2348. It was agreed that the other controller would remain in the building and return to assume responsibility for the combined position at approximately 0230.

The Hamilton Tower UOM provides the following guidance for controllers with respect to the opening and closing of control positions:

> 19. OPENING AND CLOSING CONTROL POSITIONS
>
> When there are two controllers on duty, meal and relief breaks may be given to operational personnel by combining operating positions provided;
>
> a) Current and anticipated workload permits; and
> b) The controller remains in the building and can easily be recalled.[13]

The controller had been in position and working alone for approximately 2 hours and 20 minutes when the occurrence happened.

Situational factors, such as time on task, can influence an individual's ability to attend to the important cues in his or her operating environment. The likelihood of an individual distinguishing a cue (differentiating signal from noise) has been shown to be affected by the salience of the cue, the frequency with which the cue is observed, and the amount of time for which the individual has been performing the task, with increased time on task being associated with decrements in vigilance.[14]

Controller workload

The workload and work complexity for the first 2 hours, as characterized by the controller, was light, but increased to a moderate-to-high workload with increased complexity for the next 20 minutes. During this 20-minute period, although there were no arrivals, 4 aircraft taxied for departure and required clearance amendments or runway changes due to weather. Although the other controller was available for recall, the occurrence controller did not assess the workload as being busy enough to warrant such a recall.

Both excessive workload and low levels of workload can result in decrements to controller performance. Overload can result in excessive demand on working memory and decrements in situational awareness, due to an inability to attend to all of the relevant information in the operating environment. This inability can lead to task shedding. Low levels of workload can produce similar effects by different means, since low levels of stimulation will result in vigilance decrements, which reduce the amount of attention to the operating environment. The importance of considering periods of low task demands has been described as follows: "In many environments, it is the low levels of workload that, when coupled with boredom, fatigue, or sleep loss, can have negative implications for human performance."[15]

Fatigue

Sleep-related fatigue results from a lack of sufficient restorative sleep or from circadian rhythm effects and results in an increased propensity for sleep and reduced cognitive performance.

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13 NAV CANADA, *Unit Operations Manual: Hamilton Air Traffic Control Tower*, (original 15 February 2007, Amendment no. 13-02), section 19.

14 C.D. Wickens and J.G. Hollands, *Engineering Psychology and Human Performance*, 3rd Edition (New Jersey: Prentice Hall, 2000), pp. 34–38.

15 Ibid., p. 470.

Most people need 7–8 hours of sleep every 24 hours[16] to manage fatigue and maintain performance at satisfactory levels. Obtaining less than this amount of sleep will result in the accumulation of a sleep debt, either in the short term (acute sleep debt) or gradually over time (chronic sleep debt). Greater sleep debts will result in greater performance-related effects of fatigue. Similarly, prolonged periods of continuous wakefulness will result in effects on performance and a greater propensity for sleep.

Decreases in cognitive performance can be observed at specific times during the day due to the body's natural propensity for sleep at night. This circadian rhythm trough normally occurs at night for daytime workers, and during this period, the risks of fatigue and degraded performance are increased. When an individual regularly works at night or crosses time zones, circadian rhythms will self-adjust at a rate of approximately one hour per day. As such, a shift worker who works only 1 or 2 night shifts will remain for practical purposes anchored to his or her local time, with the greatest propensity for sleep at night.

Schedules that rotate in a counter-clockwise fashion (i.e., where shift start times get progressively earlier) require the shift worker to sleep at progressively earlier times, when it can be more difficult to fall asleep, and the sleep obtained may be of lower quality. As a consequence, counter-clockwise schedules are more likely to lead to fatigue than clockwise rotating schedules.

The controller reported feeling fatigued at the time of the occurrence, and occasionally had difficulty getting adequate sleep during this type of shift rotation.

Review of controller's work schedule

A review was conducted of the controller's work schedule for the 70 days preceding the occurrence. The typical shift rotation was from evening (1534 to 0002) or early evening (1330 to 2158), to swing (1002 to 1830), or day (0800 to 1628) to early day (0517 to 1345) to midnight (2347 to 0815) to early midnight (2104 to 0532).

The following characteristics of the schedule were notable with respect to the possible effects of fatigue on controller performance:

- The shift pattern consisted mostly of daytime work between the hours of 0515 and 2400 local time. The controller worked 13 night shifts outside of these hours during the 70-day period, and most of the night shifts occurred in pairs. As such, the controller would remain anchored to sleeping during the night, with the greatest circadian trough occurring in the early morning hours.
- The shift rotation was counter-clockwise, meaning that the controller would be sleeping and waking at progressively earlier times.
- The controller had 10 hours off between finishing the early day shift at 1345 and starting the first midnight shift at 2347. Assuming a 45-minute commute each way to work, plus time for meals, personal hygiene, and any family and social responsibilities, the controller does not have an 8-hour opportunity for sleep between these 2 shifts. This shift pattern was observed 6 times during the 70 days preceding the occurrence.

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[16] See for example: A. Anch, C. Browman, M. Mitler, and J. Walsh, *Sleep: A Scientific Perspective* (New Jersey: Prentice-Hall, 1988).

- An early day shift (beginning at 0517) preceded each of these short change periods. The early start time of this shift decreases the likelihood that the controller would obtain a full night's sleep prior to the start of the early day shift.

A quantitative analysis using the controller's 70-day shift pattern was completed using the Fatigue Avoidance Scheduling Tool (FAST). FAST is biomathematical software that provides estimates of human performance at specific points within sleep–wake patterns.[17] The entire 70-day work schedule leading up to the occurrence was analyzed, using an assumption of 7 hours sleep per day. The predicted sleep was then corrected to ensure that the controller's 3 confirmed sleep periods were reflected in the sleep–wake history.

Based on known fatigue risk factors and the predicted sleep, the quantitative analysis showed low predicted effectiveness occurred during a large proportion of the night shifts. The following risk factors were noted:

- Obtaining less than 8 hours of sleep in the previous 24 hours (sleep loss)
- Accumulation of a sleep debt greater than 8 hours (sleep loss)
- Time of day (circadian rhythm trough) and being out of phase (circadian rhythm de-synchronization).

A qualitative analysis of the pattern of work / rest during this period identified the same risk factors and likely impact on performance.

Flight crew

Records indicate that the flight crew was certified and qualified for the flight in accordance with existing regulations.

The captain had approximately 6000 hours of total flight time, including 3000 hours on the Boeing 727, 800 hours of which were as pilot-in-command. In addition to this time, he had 2000 hours of experience as a second officer, which is not logged as flight time. The captain had been continually employed by Flightcraft since 2001.

The first officer had approximately 2200 hours of total flight time, including 800 hours on the Boeing 727. In addition to this time, he had 2000 hours of experience as a second officer. The first officer had been continually employed by Flightcraft since 2007.

The second officer had approximately 2250 hours of total flight time. In addition to this time, he had 2000 hours of experience as a second officer and had been continually employed by Flightcraft since 2009.

All 3 crew members had been off work for the preceding 2 days or longer, and checked in for duty 1.5 hours before the occurrence. Flight crew fatigue was not considered to be a factor.

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[17] Detailed scientific information about FAST and about the underlying Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model and its validation are available in: S. Hursh, D. Redmond, M. Johnson, et al., Fatigue models for applied research in warfighting, *Aviation, Space, and Environmental Medicine*, 75(3 Suppl) (2004), pp. A44–A53.

None of the crew members could recall another instance in their careers when they were issued an instruction to abort take-off, other than in a training scenario in the simulator.

Human performance on the flight deck

Recognition-Primed Decision (RPD) is a decision-making model[18] that was developed to explain how people make quick, effective decisions when faced with complex situations. Decisions are based on what is perceived about the world, which in turn is based on what is being attended to. Individual control of attention resources is a balancing act between maintaining operational efficiency, by attending to items that are expected, and being open to new or conflicting data that may challenge the operational assumptions that form the current mental model.

Decision making is usually based on the first mental model that fits the recognized data. This basis enables rapid decision making in situations that demand prompt responses. Attention mechanisms that encourage scanning[19] behaviors and identification of new data are critical to ensuring that decisions are made on the basis of the most operationally relevant mental model.

For scanning behavior to be effective, new data must be detectable (over background noise) and recognizable. That is, the new information must be received, considered, and either dismissed as irrelevant or integrated into an updated mental model of operational status. Rejection or integration of new information is a cognitive task that takes time to complete. The more difficult to detect or the more incomplete the new information is, the greater the likelihood that it will not be integrated into a new mental model.

Rejected take-offs are a rare event, estimated to occur approximately once every 3000 take-offs.[20] High-speed rejected take-offs initiated by ATC are rarer still, accounting for less than 1% of that total. Generally, these ATC instructions are due to controller realization of a real or potential conflict with very serious consequences. These conflicts are occasionally visible to the flight crew, such as a vehicle encroaching on the runway; more commonly, however, the conflicting traffic is unknown to the flight crew.

The naturally higher workload during departure, perceived receipt of take-off clearance, and clear sightlines of the runway, combined with the lack of visual cues such as spotting the traffic, served to bias the crew's expectation toward a typical, uneventful take-off.

On 11 March 2013, a similar occurrence,[21] albeit under different circumstances, occurred during an approach into Toronto–Lester B. Pearson International Airport (CYYZ). In this occurrence, ATC issued instructions to the approaching aircraft to pull up and go around. The flight crew did not hear the first transmission and only heard a portion of the second instruction to go

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18 G.A. Klein, The Recognition-Primed Decision (RPD) model: Looking back, looking forward, in: eds. C.E. Zsambok and G. Klein, *Naturalistic Decision Making* (1997), pp. 285–292.

19 Scanning in this context means actively searching through the individual's entire sensory environment, and is not necessarily limited to visual input.

20 Federal Aviation Administration (FAA), Advisory Circular No. 120-62: Takeoff Safety Training Aid: Announcement of Availability (09 December 1994).

21 TSB Aviation Investigation Report A13O0045

around. The crew did not interpret the instruction as applying to them, and expecting a typical non-eventful landing, continued the approach.

TSB Watchlist

The TSB Watchlist makes public a list of those issues posing the greatest risk to Canada's transportation system.

The risk of collisions on runways has been on the Watchlist since 2010. The Board remains concerned that until better defences are implemented, such as improved procedures and enhanced collision warning systems, this risk will continue.

TSB Laboratory reports

The following TSB Laboratory report was completed and is available on request:

- LP058/2013 – FDR Download

Analysis

The investigation determined that all of the individuals involved in the occurrence were adequately qualified, trained, and licensed. All of the vehicles and equipment were operating as designed, and mechanical failures were not considered to be a factor.

Therefore, the analysis will focus on the underlying reasons why the controller issued the take-off clearance, why the aircraft began the take-off roll, and why the instruction to abort take-off initially went unrecognized.

The controller's work schedule for the 70 days prior to the occurrence was a counter-clockwise rotation, meaning that progressively earlier start times are encountered as shift times change. Counter-clockwise shift schedules contribute to fatigue, since they require the individual to sleep at earlier times when it can be more difficult to fall asleep, making it more difficult to obtain quality sleep. In addition, many counter-clockwise shift schedules, including the controller's schedule, provide short recovery times between shifts that limit the opportunity for sleep.

The scheduling practices in use at Hamilton Tower typically result in the controller transitioning from an early morning shift to a midnight shift. This early morning start, followed by the short shift change with only 10 hours off duty, serves to limit the ability to obtain sleep. In combination with the known effects of a circadian trough, the Fatigue Avoidance Scheduling (FAST) analysis predicted significant performance decrements, particularly during the first midnight shift.

The controller occasionally had difficulty getting adequate sleep during this type of shift rotation and, at the time of the occurrence, which coincided with a circadian trough, reported feeling fatigued. The controller had slept for 8 hours in the 24 hours preceding the occurrence and had slept for 16 hours in the preceding 48 hours. The accuracy of details regarding the controller's actual sleep outside of this window is uncertain.

Given that the recent sleep should have lessened the effects of acute or chronic fatigue, and given the uncertainty regarding the previous sleep history, the existence of fatigue at the time of the occurrence could not be concluded. However, the controller reported feeling fatigued.

On the night of the occurrence, the 2 controllers working had determined that the occurrence controller would work the combined air–ground position from the beginning of the shift at 2345 until approximately 0230. This meant that the controller would be in position for close to 3 hours before being relieved.

In the 20 minutes preceding the occurrence, controller workload had increased as 4 aircraft taxied for departure. Although the second controller on duty was available for immediate recall, the occurrence controller did not assess the workload as being busy enough to request assistance.

This period of increased workload and complexity took place at a time when the controller had been in position for over 2 hours and coincided with a period of circadian low. Given the possible vigilance decrements associated with increased time on task, and the known effects of circadian lows on performance, the practice of working the combined air–ground position at night for extended periods of time in order to provide lengthy controller breaks increases the risk of controller errors.

The controller made a call sign error, possibly as a result of workload and fatigue factors, in requesting validation for the departure of KFA273. The 2 aircraft call signs that the controller confused were both those of aircraft destined for Winnipeg and scheduled to depart 20 minutes apart. The risk of call sign confusion was therefore present for every sector between Hamilton and Winnipeg. The fact that this call sign similarity is often a nightly occurrence desensitizes controllers and pilots to its potential impact and reduces the effectiveness of the defences in place to address this issue.

While viewing the extended computer display system (EXCDS) display, which needed to be manipulated during the validation request, the blocked-runway indicators located directly below the aircraft's strip went unnoticed. The controller caught the call sign error while beginning a transmission to KFA273, informed the aircraft to stand by, and then corrected the error with the area control centre (ACC). The controller then issued a take-off clearance to KFA273. In doing so, and possibly distracted by the need to make the previous correction, the controller again did not detect the blocked-runway indicator while preforming the routine scan. Similarly, the practice of authorizing aircraft to arrive or depart on a runway for which a blocked-runway indicator is showing indicates a desensitization of the controller to the importance of the blocked-runway indicator, eliminating its effectiveness as a defence and increasing the risk of aircraft being authorized to use a runway that is unavailable.

As the controller was completing the clearance, a visual scan of the runway surface detected the vehicles, and the controller paused and informed the aircraft to stand by. The *Air Traffic Control Manual of Operations* (ATC MANOPS) phraseology was not used to cancel the take-off clearance. It could not be determined whether using correct phraseology would have altered the outcome.

The controller paused after the words "cleared take-off Runway 30" were spoken. After this brief pause and without releasing the push-to-talk button (PTT), the controller then stated "actually standby" rather than the required phraseology ("Take-off clearance cancelled"). During the pause, the pilot not flying (PNF) on KFA273 assumed that the transmission was complete, depressed the aircraft's PTT and read back the clearance. When the controller eventually released the tower PTT, only the tail end of this transmission, which included the aircraft's call sign, was heard. As call signs alone are often used to acknowledge receipt of a transmission, the controller assumed that the aircraft understood the instruction to stand by and did not expect it to take off.

The flight crew, having not heard the portion of the transmission informing them to stand by, assumed that everything was normal, and began their take-off procedure.

The controller then instructed the vehicles to exit the runway, briefly glanced at KFA273 to confirm that the aircraft wasn't rolling, and then focused on the Purolator Apron to issue taxi instructions to another Flightcraft aircraft. During this time, KFA273 began the take-off roll outside of the direct field of view of the controller. Immediately after the controller finished the taxi instructions, attention was returned to Runway 30, and the movement of KFA273 was noticed. The controller immediately instructed KFA273 to abort take-off.

At the time of the instruction to abort take-off, KFA273 had just reached 80 knots. The PNF announced the speed, and the pilot flying (PF) confirmed. At the same time, a chart on the PF's pedestal fell and briefly distracted the crew. Apart from the brief distraction, the crew considered the take-off to be proceeding normally, as expected, and their forward view of the runway ahead presented no indication otherwise.

That which is expected is a central factor that drives attention behavior and, as a result, cues that indicate that the situation is not as expected may not attract attention away from anticipated tasks. The implication is that situations will appear normal or familiar unless that which is "out of the ordinary" is of sufficient magnitude to attract attention and subsequent analysis.

The cockpit environment was relatively noisy. The abort call was simultaneous with other sensory input, unexpected due to its rarity, and without supporting cues such as visual sighting of the obstacle. As a result, it was not sufficiently compelling to alter the crew's mental model of the situation, or of their expectation of an uneventful take-off, and initially went unnoticed.

As the aircraft began to crest the middle section of the runway, the crew began to notice unusual lights, and the PNF then recognized that the abort take-off call, issued 9 seconds earlier, had been intended for them. The crew rejected the take-off and brought the aircraft to a stop at a safe distance from the vehicles.

Although the crew did consider the increased brake temperature following the rejected take-off (RTO), the brake-cooling schedule was not consulted and, as a result, the aircraft departed with an increased risk of brake overheating or tire fuse plug release.

This occurrence and the similar occurrence in CYYZ (A13O0045) suggest that if air traffic control transmissions, when issued with the intention of alerting flight crews of extremely hazardous conditions or of giving instruction to crews to avoid those conditions, are incomplete, not heard, or insufficiently compelling to alter the crew's preconceived perception of the situation, then the risk is increased that the transmission will go unheeded.

As the TSB Watchlist points out, and as this occurrence demonstrates, there is an ongoing risk of aircraft colliding with vehicles or other aircraft on the ground at Canadian airports. The TSB is concerned that this risk will continue until improved procedures and enhanced collision warning systems are implemented at Canada's airports.

Findings

Findings as to causes and contributing factors

1. The blocked-runway indicator on the controller's extended computer display system display went unnoticed or unheeded, resulting in a take-off clearance being issued to KFA273 when the runway was not clear of vehicles.

2. During issuance of the take-off clearance, vehicles were observed on the runway, and the controller instructed the aircraft to stand by rather than using standard phraseology to cancel the take-off clearance.

3. The flight crew began to read back the take-off clearance before the controller released the push-to-talk button and, in doing so, did not hear the controller's instruction to stand by.

4. The controller's attention was focused on other tasks when KFA273 began the take-off roll, resulting in the aircraft movement going unnoticed for 22 seconds before the instruction to abort take-off was issued.

5. The air traffic control instruction to abort take-off, which was simultaneous with other sensory input and was not sufficiently compelling to alter the crew's mental model of the situation or their expectation of an uneventful take-off, initially went unnoticed. As a result, the rejected take-off was not initiated until 9 seconds after the instruction.

Findings as to risk

1. If personnel scheduling practices include counter-clockwise shift rotations and short shift changes, there is an increased risk of fatigue and performance impairments during night shifts occurring at the end of the shift rotation.

2. If the practice of working the combined air–ground position is employed for extended periods of time at night, there is an increased risk of controller errors due to fatigue.

3. If a blocked-runway indicator is routinely unheeded, there is an increased risk of aircraft being authorized to use a runway that is unavailable.

4. If airlines systematically plan flights with similar call signs to operate in close proximity to one another, there is an increased risk of call sign confusion.

5. If air traffic control transmissions are incomplete, not heard, or insufficiently compelling to alter the crew's preconceived perception of the situation, then the risk is increased that the transmission will go unheeded.

6. If aircraft depart before the advisory times in the brake-cooling schedule, then there is an increased risk of brake overheating or tire fuse plug release.

Safety action

Safety action taken

Kelowna Flightcraft Air Charter Ltd.

As a result of the incident, Flightcraft has undertaken the following:

- Flightcraft Memo 13-008 was issued to all flight crews, discussing air traffic control (ATC)-initiated rejected take-offs and standard terminology.
- During the course of the next recurrent flight training cycle, all pilots were exposed to ATC-initiated rejected take-offs, and these scenarios will be the subject of periodic review in recurrent training exercises.
- The ATC-initiated rejected take-off has been incorporated into the script scenarios of the B727 recurrent pilot proficiency check (PPC).
- Brake-cooling considerations following a rejected take-off are now covered extensively during simulator training.

This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 05 November 2014. It was officially released on 06 January 2014.

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.

Appendices

Appendix A – Communications recorded at Hamilton Tower

Time at beginning of transmission	Time at end of transmission	Frequency	Speaker	Transmission
2:06:34	2:06:36	Hotline[22]	YHM Tower	Satellite Hamilton
2:06:36	2:06:36	Hotline	Toronto ACC	Satellite
2:06:37	2:06:39	Hotline	YHM Tower	Request release Flightcraft 275 Runway 30
2:06:40	2:06:42	Hotline	Toronto ACC	Flightcraft 275 valid 30
2:06:42	2:06:43	Hotline	YHM Tower	Thanks, up in 2.
2:06:57	2:07:01	Tower	YHM Tower	Flightcraft 273, ahh… stand by
2:07:01	2:07:02	Hotline	YHM Tower	Satellite Hamilton
2:07:03	2:07:04	Hotline	Toronto ACC	Yes
2:07:04	2:07:08	Ground	KFA271	Ground Flightcraft 271 at Purolator (Apron) ready to taxi
2:07:05	2:07:09	Hotline	YHM Tower	Ah, just wanted to confirm, did I say Flightcraft 273?
2:07:10	2:07:13	Hotline	Toronto ACC	Ah, I don't know, which one did you say?
2:07:13	2:07:16	Hotline	YHM Tower	Ah I think I might have said 275 but it's 273 for Runway 30
2:07:16	2:07:17	Hotline	Toronto ACC	Flightcraft 273 valid 30
2:07:18	2:07:19	Hotline	YHM Tower	Thanks ST
2:07:21	2:07:31	Tower	YHM Tower	Flightcraft 273 Tower contact Toronto Centre 128.27 airborne, wind 230, 15 gusting 22, from the threshold cleared for take-off Runway 30…actually standby ah….
2:07:28 estimated	2:07:33	Tower	KFA273	…….(stepped on)…… 273
2:07:35	2:07:38	Ground	YHM Tower	Plow 82 Plus 1 Ground exit golf advise holding short Runway 30
2:07:40	2:07:44	Ground	Plow 82	82 exiting golf ahh advise holding short
2:07:48	2:07:50	Ground	YHM Tower	Flightcraft 271 Ground ah confirm ready to taxi

22 Hotline refers to a telephone link that is specially arranged and used for a particular purpose (Canadian Oxford Dictionary, second edition [2004]). In this case, it refers to a direct communication link between Toronto Area Control Centre and CYHM tower.

2:07:51	2:07:52	Ground	KFA271	That's affirmative 271
2:07:53	2:08:02	Ground	YHM Tower	Flightcraft 271 Ground Runway 30 wind 230, 15 gusting 22, altimeter 29.58, taxi Delta your discretion and Bravo hold short Runway 24
2:08:04	2:08:08	Ground	KFA271	Delta Bravo hold short 24 flight 271
2:08:09	2:08:10	Tower	YHM Tower	Flightcraft 273 abort take-off
2:08:13	2:08:14	Tower	Unknown	*Unknown push-to-talk activation*
2:08:33	2:08:35	Tower	KFA273	Flight ah 273 ah we're stopped.
2:08:39	2:08:45	Tower	YHM Tower	Flightcraft 273 Tower roger, ah sorry for that 180 backtrack and line up at the threshold
2:08:49	2:08:53	Tower	KFA273	OK, 180 back, and line up at the threshold Flightcraft 273

Appendix B – Visual depiction of event