Taxiway Overflight
Air Canada Flight 759
Airbus A320-211, C-FKCK
San Francisco, California
July 7, 2017

Incident Report

NTSB/AIR-18/01
PB2018-101561

National
Transportation
Safety Board

NTSB/AIR-18/01
PB2018-101561
Notation 58387
Adopted September 25, 2018

Aircraft Incident Report

Taxiway Overflight
Air Canada Flight 759
Airbus A320-211, C-FKCK
San Francisco, California
July 7, 2017

National
Transportation
Safety Board

490 L'Enfant Plaza, S.W.
Washington, DC 20594

National Transportation Safety Board. 2018. *Taxiway Overflight, Air Canada Flight 759, Airbus A320-211, C-FKCK, San Francisco, California, July 7, 2017*. NTSB/AIR-18/01. Washington, DC.

Abstract: This report discusses the July 7, 2017, incident involving Air Canada flight 759, an Airbus A320-211, Canadian registration C-FKCK, which was cleared to land on runway 28R at San Francisco International Airport, San Francisco, California, but instead lined up with parallel taxiway C. Four air carrier airplanes were on taxiway C awaiting clearance to take off from runway 28R. The incident airplane descended to an altitude of 100 ft above ground level and overflew the first airplane on the taxiway. The incident flight crew initiated a go-around, and the airplane reached a minimum altitude of about 60 ft and overflew the second airplane on the taxiway before starting to climb. None of the 5 flight crewmembers and 135 passengers aboard the incident airplane were injured, and the incident airplane was not damaged. Safety issues identified in this report include the need for consistent flight management system autotuning capability within an air carrier's fleet, the need for more effective presentation of flight operations information to optimize pilot review and retention of relevant information, the need for airplanes landing at primary airports within Class B and Class C airspace to be equipped with a system that alerts pilots when an airplane is not aligned with a runway surface, the need for modifications to airport surface detection equipment systems to detect potential taxiway landings and provide alerts to air traffic controllers, the need for a method to more effectively signal a runway closure to pilots when at least one parallel runway remains in use, and the need for revisions to Canadian regulations to address the potential for fatigue for pilots on reserve duty who are called to operate evening flights that would extend into the pilots' window of circadian low. As a result of this investigation, the National Transportation Safety Board makes safety recommendations to the Federal Aviation Administration and Transport Canada.

For more detailed background information on this report, visit https://www.ntsb.gov/investigations/SitePages/dms.aspx and search for NTSB incident ID DCA17IA148. Recent publications are available in their entirety on the Internet at http://www.ntsb.gov. Other information about available publications also may be obtained from the website or by contacting:

National Transportation Safety Board
Records Management Division, CIO-40
490 L'Enfant Plaza, SW
Washington, DC 20594
(800) 877-6799 or (202) 314-6551

Copies of NTSB publications may be downloaded at no cost from the National Technical Information Service's National Technical Reports Library at https://ntrl.ntis.gov/NTRL/ (this product is product number PB2018-101561). For additional assistance, contact:

National Technical Information Service (http://www.ntis.gov/)
5301 Shawnee Rd.
Alexandria, VA 22312
(800) 553-6847 or (703) 605-6000

Contents

Figures

Tables

Abbreviations

AC	advisory circular
ACA759	Air Canada flight 759
ACARS	aircraft communication addressing and reporting system
agl	above ground level
ASDE	airport surface detection equipment
ASR	air safety report
ASRS	aviation safety reporting system
ASSC	airport surface surveillance capability
ATC	air traffic control
ATCT	air traffic control tower
ATIS	automatic terminal information service
CAST	Commercial Aviation Safety Team
CFR	*Code of Federal Regulations*
CRM	crew resource management
CVR	cockpit voice recorder
DAL521	Delta Air Lines flight 521
EDT	eastern daylight time
EGPWS	enhanced ground proximity warning systems
FAA	Federal Aviation Administration
FDR	flight data recorder

FMC	flight management computer
FMGS	flight management guidance system
FMS	flight management system
IFR	instrument flight rules
ILS	instrument landing system
LNAV	lateral navigation
LUAW	line up and wait
MCDU	multifunction control and display unit
msl	mean sea level
NCT	Northern California terminal radar approach control
nm	nautical mile
NOTAM	notice to airmen
NTSB	National Transportation Safety Board
PAL115	Philippine Airlines flight 115
PDT	Pacific daylight time
PFD	primary flight display
RAAS	runway awareness and advisory system
RNAV	area navigation
SAFO	safety alert for operators
SEA	Seattle-Tacoma International Airport
SFO	San Francisco International Airport

TSB	Transportation Safety Board of Canada
UAL1	United Airlines flight 1
UAL863	United Airlines flight 863
UAL1118	United Airlines flight 1118
VMC	visual meteorological conditions
YYZ	Toronto/Lester B. Pearson International Airport

Executive Summary

On July 7, 2017, about 2356 Pacific daylight time (PDT), Air Canada flight 759, an Airbus A320-211, Canadian registration C-FKCK, was cleared to land on runway 28R at San Francisco International Airport (SFO), San Francisco, California, but instead lined up with parallel taxiway C.[1] Four air carrier airplanes (a Boeing 787, an Airbus A340, another Boeing 787, and a Boeing 737) were on taxiway C awaiting clearance to take off from runway 28R. The incident airplane descended to an altitude of 100 ft above ground level and overflew the first airplane on the taxiway. The incident flight crew initiated a go-around, and the airplane reached a minimum altitude of about 60 ft and overflew the second airplane on the taxiway before starting to climb. None of the 5 flight crewmembers and 135 passengers aboard the incident airplane were injured, and the incident airplane was not damaged.[2] The incident flight was operated by Air Canada under Title 14 *Code of Federal Regulations* (*CFR*) Part 129 as an international scheduled passenger flight from Toronto/Lester B. Pearson International Airport, Toronto, Canada. An instrument flight rules flight plan had been filed. Night visual meteorological conditions prevailed at the time of the incident.

The flight crewmembers had recent experience flying into SFO at night and were likely expecting SFO to be in its usual configuration; however, on the night of the incident, SFO parallel runway 28L was scheduled to be closed at 2300. The flight crew had opportunities before beginning the approach to learn about the runway 28L closure. The first opportunity occurred before the flight when the crewmembers received the flight release, which included a notice to airmen (NOTAM) about the runway 28L closure. However, the first officer stated that he could not recall reviewing the specific NOTAM that addressed the runway closure. The captain stated that he saw the runway closure information, but his actions (as the pilot flying) in aligning the airplane with taxiway C instead of runway 28R demonstrated that he did not recall that information when it was needed. The second opportunity occurred in flight when the crewmembers reviewed automatic terminal information system (ATIS) information Quebec (via the airplane's aircraft communication addressing and reporting system [ACARS]), which also included NOTAM information about the runway 28L closure. Both crewmembers recalled reviewing ATIS information Quebec but could not recall reviewing the specific NOTAM that described the runway closure.

The procedures for the approach to runway 28R required the first officer (as the pilot monitoring) to manually tune the instrument landing system (ILS) frequency for runway 28R, which would provide backup lateral guidance (via the localizer) during the approach to supplement the visual approach procedures. However, when the first officer set up the approach, he missed the step to manually tune the ILS frequency. The captain was required to review and verify all programming by the first officer but did not notice that the ILS frequency had not been entered.

The captain stated that, as the airplane approached the airport, he thought that he saw runway lights for runway 28L and thus believed that runway 28R was runway 28L and that

[1] All times in this executive summary are PDT unless otherwise noted.

[2] Similarly, no crewmembers and passengers aboard the airplanes on taxiway C were injured, and none of those airplanes were damaged.

taxiway C was runway 28R. At that time, the first officer was focusing inside the cockpit because he was programming the missed approach altitude and heading (in case a missed approach was necessary) and was setting (per the captain's instruction) the runway heading, which reduced his opportunity to effectively monitor the approach. The captain asked the first officer to contact the controller to confirm that the runway was clear, at which time the first officer looked up. By that point, the airplane was lined up with taxiway C, but the first officer presumed that the airplane was aligned with runway 28R due, in part, to his expectation that the captain would align the airplane with the intended landing runway.

The controller confirmed that runway 28R was clear, but the flight crewmembers were unable to reconcile their confusion about the perceived lights on the runway (which were lights from airplanes on taxiway C) with the controller's assurance that the runway was clear. Neither flight crewmember recognized that the airplane was not aligned with the intended landing runway until the airplane was over the airport surface, at which time the flight crew initiated a low-altitude go-around. According to the captain, the first officer called for a go-around at the same time as the captain initiated the maneuver, thereby preventing a collision between the incident airplane and one or more airplanes on the taxiway. However, at that point, safety margins were severely reduced given the incident airplane's proximity to the ground before the airplane began climbing and the minimal distance between the incident airplane and the airplanes on taxiway C.

The flight crewmembers stated, during postincident interviews, that the taxiway C surface resembled a runway. Although multiple cues were available to the flight crew to distinguish runway 28R from taxiway C (such as the green centerline lights and flashing yellow guard lights on the taxiway), sufficient cues also existed to confirm the crew's expectation that the airplane was aligned with the intended landing runway (such as the general outline of airplane lights—in a straight line—on taxiway C and the presence of runway and approach lights on runway 28R, which would also have been present on runway 28L when open). As a result, once the airplane was aligned with what the flight crewmembers thought was the correct landing surface, they were likely not strongly considering contradictory information. The cues available to the flight crew to indicate that the airplane was aligned with a taxiway did not overcome the crew's belief, as a result of expectation bias, that the taxiway was the intended landing runway.

The flight crewmembers reported that they started to feel tired just after they navigated through an area of thunderstorms, which radar data indicated was about 2145 (0045 eastern daylight time [EDT]). The incident occurred about 2356, which was 0256 EDT according to the flight crew's normal body clock time; thus, part of the incident flight occurred during a time when the flight crew would normally have been asleep (according to postincident interviews) and at a time that approximates the start of the human circadian low period described in Air Canada's fatigue information (in this case, 0300 to 0500 EDT). In addition, at the time of the incident, the captain had been awake for more than 19 hours, and the first officer had been awake for more than 12 hours. Thus, the captain and the first officer were fatigued during the incident flight.

Cockpit voice recorder (CVR) information was not available for this incident because the data were overwritten before senior Air Canada officials became aware of the severity of this incident. Although the National Transportation Safety Board (NTSB) identified significant safety issues during our investigation into this incident, CVR information, if it had been available, could have provided direct evidence about the events leading to the overflight and the go-around. For example, several crew actions/inactions during the incident flight demonstrated breakdowns in crew resource management (CRM), including both pilots' failure to assimilate the runway 28L closure information included in the ATIS information, the first officer's failure to manually tune the ILS frequency, and the captain's failure to verify the tuning of the ILS frequency. However, without CVR information, the NTSB could not determine whether distraction, workload, and/or other factors contributed to these failures.

The NTSB identified the following safety issues as a result of this incident investigation:

- **Need for consistent flight management system (FMS) autotuning capability within an air carrier's fleet.** The FMS Bridge visual approach to runway 28R was the only approach in Air Canada's Airbus A320 database that required manual tuning for a navigational aid, so the manual tuning of the ILS frequency was not a usual procedure for the flight crew. Identifying other approaches that require an unusual or abnormal manual frequency input and developing an autotune solution would help preclude such a situation from recurring. Further, the instruction on the approach chart to manually tune the ILS frequency was not conspicuous during the crew's review of the chart. An action to mitigate this situation for other approaches would be to ensure sufficient salience of the manual tune entry on approach charts.

- **Need for more effective presentation of flight operations information to optimize pilot review and retention of relevant information.** The way information is presented can significantly affect how information is reviewed and retained because a pilot could miss more relevant information when it is presented with information that is less relevant. Although the NOTAM about the runway 28L closure appeared in the flight release and the ACARS message that were provided to the flight crew, the presentation of that information did not effectively convey the importance of the runway closure information and promote flight crew review and retention. Multiple events in the National Aeronautics and Space Administration's aviation safety reporting system database showed that this issue has affected other pilots, indicating that all pilots could benefit from the improved display of flight operations information.

- **Need for airplanes landing at primary airports within Class B and Class C airspace to be equipped with a system that alerts pilots when an airplane is not aligned with a runway surface.** A cockpit system that provides an alert if the system predicts a landing on a surface other than a runway would provide pilots with additional positional awareness information. Although the Federal Aviation Administration (FAA) has not mandated the installation of such a system, the results of a simulation showed that such technology, if it had been installed on the incident airplane, could have helped the flight crew identify its surface misalignment error earlier in the landing sequence, which could have resulted in the go-around being performed at a safer altitude (before the airplane was dangerously close to other airplanes). Flight safety would be enhanced if airplanes landing at primary airports within Class B and Class C airspace were equipped with such a cockpit system and/or a cockpit system that alerts when an airplane is not aligned with the specific runway for which it has been cleared.

- **Need for modifications to airport surface detection equipment (ASDE) systems (ASDE-3, ASDE-X, and airport surface surveillance capability [ASSC]) to detect potential taxiway landings and provide alerts to air traffic controllers.** The SFO air traffic control tower was equipped with an ASSC system, which was not designed to predict an imminent collision involving an arriving airplane lined up with a taxiway; thus, the ASSC system did not produce an alarm as the incident airplane approached taxiway C. If an airplane were to align with a taxiway, an automated ASDE alert could assist controllers in identifying and preventing a potential taxiway landing as well as a potential collision with aircraft, vehicles, or objects that are positioned along taxiways. An FAA demonstration in February 2018 showed the potential effectiveness of such a system.[3]

- **Need for a method to more effectively signal a runway closure to pilots when at least one parallel runway remains in use.** A runway closure marker with a lighted flashing white "X" appeared at the approach and departure ends of runway 28L when it was closed. The runway closure marker was not designed to capture the attention of a flight crew on approach to a different runway, and the marker did not capture the attention of the incident flight crew as the airplane approached the airport while aligned with taxiway C. Increased conspicuity of runway closure markers, especially those used in parallel runway configurations, could help prevent runway misidentification by flight crews while on approach to an airport.

- **Need for revisions to Canadian regulations to address the potential for fatigue for pilots on reserve duty who are called to operate evening flights that would extend into the pilots' window of circadian low.** The flight crew's work schedule for the incident flight complied with the applicable Canadian flight time limitations and rest requirements; however, the flight and duty time and rest requirements for the captain (a company reserve pilot) would not have complied with US flight time limitations and rest requirements (14 *CFR* Part 117). Transport Canada indicated that its current flight and duty time regulations have been in effect since 1996. Transport Canada also indicated that it released a draft of proposed new flight and duty time regulations in 2014 and issued revised draft regulations in 2017. According to Transport Canada, the proposed regulations would better address the challenge of fatigue mitigation for pilots on reserve duty who are called to operate evening flights extending into their window of circadian low. However, Transport Canada has not yet finalized its rulemaking in this area.[4]

[3] On March 2, 2011, the NTSB recommended that the FAA "perform a technical review of Airport Surface Detection Equipment—Model X to determine if the capability exists systemwide to detect improper operations such as landings on taxiways" (A-11-12). The NTSB also recommended that the FAA, "at those installation sites where the technical review recommended in Safety Recommendation A-11-12 determines it is feasible, implement modifications to Airport Surface Detection Equipment—Model X to detect improper operations, such as landings on taxiways, and provide alerts to air traffic controllers that these potential collision risks exist" (A-11-13). As discussed in section 2.5.2, the NTSB classified these recommendations "Closed—Unacceptable Action" on September 14, 2011.

[4] Title 14 *CFR* Part 117, "Flight and Duty Limitations and Rest Requirements: Flightcrew Members," described the window of circadian low as 0200 through 0559 (body clock time zone).

The NTSB determines that the probable cause of this incident was the flight crew's misidentification of taxiway C as the intended landing runway, which resulted from the crewmembers' lack of awareness of the parallel runway closure due to their ineffective review of NOTAM information before the flight and during the approach briefing. Contributing to the incident were (1) the flight crew's failure to tune the ILS frequency for backup lateral guidance, expectation bias, fatigue due to circadian disruption and length of continued wakefulness, and breakdowns in CRM and (2) Air Canada's ineffective presentation of approach procedure and NOTAM information.

As a result of this investigation, the NTSB makes safety recommendations to the FAA and Transport Canada.

1. Factual Information

1.1 History of Flight

On July 7, 2017, about 2356 Pacific daylight time (PDT), Air Canada flight 759 (ACA759), an Airbus A320-211, Canadian registration C-FKCK, was cleared to land on runway 28R at San Francisco International Airport (SFO), San Francisco, California, but instead lined up with parallel taxiway C.[1] Four air carrier airplanes (a Boeing 787, an Airbus A340, another Boeing 787, and a Boeing 737) were on taxiway C awaiting clearance to take off from runway 28R. The incident airplane descended to an altitude of 100 ft above ground level (agl) and overflew the first airplane on the taxiway.[2] The incident flight crew initiated a go-around, and the airplane reached a minimum altitude of about 60 ft and overflew the second airplane on the taxiway before starting to climb. None of the 5 flight crewmembers and 135 passengers aboard the incident airplane were injured, and the incident airplane was not damaged.[3] The incident flight was operated by Air Canada under Title 14 *Code of Federal Regulations* (*CFR*) Part 129 as an international scheduled passenger flight from Toronto/Lester B. Pearson International Airport (YYZ), Toronto, Canada. An instrument flight rules (IFR) flight plan had been filed. Night visual meteorological conditions (VMC) prevailed at the time of the incident.[4]

The captain and the first officer reported for duty about 1640 and 1610 (1940 and 1910 eastern daylight time [EDT]), respectively. They met at the gate and discussed that the flight's departure would be delayed because the airplane to be used for the flight would be arriving at YYZ late (due to weather in the Toronto area).[5] They also discussed the expected weather en route and reviewed the flight release (also referred to as a dispatch release), which contained pertinent information for the flight, including notice to airmen (NOTAM) information for SFO.

One of the NOTAMs in the dispatch release indicated that runway 28L would be closed from 2300 that night to 0800 the next morning. During postincident interviews, both flight crewmembers provided different accounts regarding their awareness of the runway closure.[6] During interviews about 1 week after the incident, the captain stated that he saw the NOTAM about the runway 28L closure in the flight release, and the first officer stated that he did a "quick

[1] (a) All times in this report are PDT unless otherwise noted. (b) This report also refers to ACA759 as the incident airplane and the incident flight. (c) Title 49 *Code of Federal Regulations* 830.2 defined an incident as "an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations."

[2] All altitudes in this report are agl unless otherwise indicated.

[3] Similarly, no crewmembers and passengers aboard the airplanes on taxiway C were injured, and none of those airplanes were damaged.

[4] Supporting documentation referenced in this report can be found in the public docket for this incident, accessible from the National Transportation Safety Board's (NTSB) Accident Dockets web page by searching DCA17IA148. Other NTSB documents referenced in this report, including reports and summarized safety recommendation correspondence, are accessible from the NTSB's Aviation Information Resources web page (www.ntsb.gov/air).

[5] Flight 759 was originally scheduled to push back from the gate at 1755 (2055 EDT), take off at 1809 (2109 EDT), and land at 2303 (0203 EDT).

[6] The NTSB interviewed the incident captain on July 14 and the incident first officer on July 18, 2017. The NTSB also interviewed both incident flight crewmembers on August 10, 2017.

scan" of the NOTAMs in the flight release but could not recall whether he had seen the runway 28L closure NOTAM and whether he and the captain had discussed the closure information at the gate. The first officer also stated that he realized, after the incident flight landed, that runway 28L had been closed. During an interview about 1 month after the incident, the captain stated that he and the first officer had discussed the runway 28L closure while at YYZ but that they did not place much emphasis on that information because, at that time, the flight was scheduled to land at SFO before the runway would be closed. (The National Transportation Safety Board [NTSB] notes that the flight was originally scheduled to land at SFO at 2303, 3 minutes after runway 28L was scheduled to be closed.)

The airplane pushed back from the gate at YYZ at 1825 (2125 EDT), 30 minutes later than originally scheduled. The captain was the pilot flying, and the first officer was the pilot monitoring. Flight data recorder (FDR) data showed that the throttles were advanced to the takeoff power setting about 1858 (2158 EDT) and that the autopilot was engaged shortly after takeoff and remained engaged until just before the final approach to SFO.[7] The flight crewmembers reported that the departure, climb, cruise, and descent phases of flight were uneventful except for an area of thunderstorms about midway through the flight.[8] The crewmembers also reported that they started to feel tired just after they navigated through the thunderstorms, which radar data indicated was about 2145 (0045 EDT).

Before the airplane began its descent into the terminal area, the first officer obtained automatic terminal information service (ATIS) information Quebec via the airplane's aircraft communication addressing and reporting system (ACARS) and printed the information.[9] (Air Canada records indicated that, about 2321, the airplane was sent the ACARS message with the ATIS information.) Among other things, ATIS information Quebec indicated, "Quiet Bridge visual approach in use," "landing runway 28R," and "NOTAMS…runways 28L, 10R closed." (SFO lighting logs indicated that the lights on runway 28L were turned off about 2312.) ATIS information Quebec also indicated that the runway 28L approach lighting system and the runway 28L/10R centerline lights were out of service. During postincident interviews, the flight crewmembers recalled reviewing ATIS information Quebec but could not recall whether they saw the ATIS-reported information about the runway 28L closure.

[7] The airplane was equipped with a Honeywell solid-state FDR, model 980-4700-042, that was required by 14 *CFR* 129.20 to record 34 parameters and 25 hours of data. The FDR recording contained about 108 hours of data, including 5 hours 15 minutes from the incident flight. The FDR recording for the incident flight began about 1835 (2135 EDT). The airplane was also equipped with a Honeywell solid-state cockpit voice recorder (CVR), model 980-6022-001, but the data from the incident flight were overwritten before Air Canada was notified about this incident. (This CVR model was designed to record 2 hours of operational data, which was consistent with the requirements of 14 *CFR* 129.5 and International Civil Aviation Organization Annex 6 for CVRs to retain the information recorded during at least the last 2 hours of their operation.) Section 1.6.4 discusses notification events for this incident.

[8] During a postincident interview, the captain stated that it was "stressful" navigating through the area of thunderstorms.

[9] Air Canada allowed flight crews to obtain ATIS information using ACARS or VHF communications.

ATIS information Quebec also included weather information.[10] Given this information and the reported landing runway in use, the captain briefed Air Canada's Flight Management System (FMS) Bridge visual approach procedure to SFO runway 28R.[11] The FMS Bridge visual approach to runway 28R, coded as the area navigation (RNAV) 28R approach, was a commercial airline overlay chart (a Jeppesen chart customized for Air Canada) based on the Quiet Bridge visual approach procedure to runway 28R.[12]

Air Canada's FMS Bridge visual approach procedure to runway 28R required pilots of Airbus A319/A320/A321 airplanes to manually enter (tune) the instrument landing system (ILS) frequency into the airplane's flight management computer (FMC) to provide backup lateral guidance (via the localizer) to the runway.[13] The FMS Bridge visual approach to runway 28R was the only approach in Air Canada's Airbus A320 database that required manual tuning for a navigational aid.[14] As part of his pilot monitoring duties, the first officer would have used the multifunction control and display unit (MCDU) to program required settings, but he did not enter the ILS frequency into the radio/navigation page. The first officer reported, during a postincident interview, that he "must have missed" the radio/navigation page and was unsure how that could have happened. Also, the captain did not verify, during the approach briefing, that the ILS frequency had been entered, and neither flight crewmember noticed that the ILS frequency was not shown on the primary flight displays (PFD).[15] FDR data showed that the ILS frequency was not tuned and that no frequency had been entered.

As part of the approach briefing, Air Canada's procedures required the flight crew to discuss any threats associated with the approach. The captain stated that they discussed as threats the nighttime landing, the traffic, and the busy airspace. The captain also reported that he and the first officer discussed that "it was getting late" and that they would need to "keep an eye on each other." The first officer stated that the threats were the mountainous terrain, the nighttime

[10] ATIS information Quebec included the automated surface observing system weather information recorded at 2256. The ATIS information indicated the following: wind was from 310° at 12 knots, visibility was 10 statute miles, sky was clear, temperature was 17°C (63°F), dew point was 9°C (48°F), and altimeter was 29.93 inches of mercury. The automated surface observing system weather information at 2356 (the time of the incident) indicated the following: wind was from 290° at 9 knots, visibility was 10 statute miles, sky was clear, temperature was 16°C (61°F), dew point was 9°C (48°F), and altimeter was 29.92 inches of mercury.

[11] The approach briefing is the first item on Air Canada's pre-descent checklist.

[12] Figure 9 in section 1.6.6 shows the approach chart.

[13] According to the Federal Aviation Administration's (FAA) *Aeronautical Information Manual*, section 1-1-9, ILS ground equipment consists of two "highly directional transmitting systems," one of which is the localizer, which provides course guidance to the runway centerline. Air Canada's chart for the FMS Bridge visual approach to runway 28R showed the ILS frequency (111.7) in the plan view. The Jeppesen chart for the ILS or localizer approach to runway 28R showed 111.7 as the localizer frequency.

[14] Honeywell, the manufacturer of the Air Canada A320 FMS, stated, in e-mails dated July 19, 2018, that the procedure for this approach was created by United Airlines and that Air Canada used United Airlines' database for its operations. The database did not include a frequency for the FMS to autotune for the approach procedure, and Air Canada's policy was to make changes to the database only if information (such as waypoints and altitude restrictions) was not correct. Because the information that United Airlines developed for this approach did not include a frequency for autotuning, manual tuning of the ILS was required.

[15] For ILS information to appear on the PFDs, one of the incident flight crewmembers would have had to select the "LS" buttons on the glareshield, but neither crewmember mentioned selecting this button during the approach. Air Canada's procedures for the FMS Bridge visual approach to runway 28R did not indicate that a flight crew was required to take this action.

conditions, and both flight crewmembers' alertness. The captain and the first officer could not recall whether they discussed the runway 28L closure during the approach briefing.

FDR data showed that, about 2324, the selected altitude for the autopilot changed from the cruise altitude (flight level 360) to 8,000 ft mean sea level (msl), which was the crossing altitude for the first waypoint on the approach. When the airplane began its descent about 2327, the autopilot lateral navigation mode remained as "NAV [navigation]," and the vertical navigation mode changed to "DES [descent]." According to Airbus, this configuration was consistent with the autopilot operating in a managed descent profile.[16]

According to air traffic control (ATC) voice recordings, at 2330:42, the flight crew checked in with the Northern California terminal radar approach control (NCT) approach controller on the DYAMD 3 (RNAV) standard terminal arrival route to SFO.[17] At that time, the airplane was descending from an altitude of 27,000 ft msl.

After the flight crew's initial contact with NCT, the controller issued instructions to join the FMS Bridge visual approach to runway 28R after reaching the final waypoint on the standard terminal arrival route. FDR data showed that, as the airplane descended through an altitude of about 14,500 ft msl at 2336:30, the altitude selected parameter changed to 10,944 ft msl. At 2338:01, the autopilot lateral navigation mode changed from "NAV" to "HDG [heading]" with no recorded corresponding change in the vertical navigation mode. According to Airbus, this configuration and the change in selected altitude were consistent with the autopilot operating in an open descent profile.[18] The flight crewmembers did not discuss the descent mode during the approach briefing, but the first officer reported, during a postincident interview, that he perceived that the descent mode had switched from a managed to an open descent.[19] The first officer also stated that he was uncomfortable with the approach being flown in the open descent mode and that he did not say anything to the captain because the procedure was allowed.[20]

At 2346:08, the controller instructed ACA759 to turn right direct to the TRDOW waypoint and join the FMS Bridge visual approach to runway 28R, and the flight crew acknowledged this

[16] Air Canada's *A319/A320/A321 Aircraft Operating Manual,* volume 1, section 4, "Standard Operating Procedures," indicated that, for the managed descent mode, an airplane is guided along the FMS lateral and vertical flight plan and speed profile. For more information about this descent mode, see section 1.6.1.

[17] The NTSB determined the time and content of air/ground transmissions referenced in this report using certified FAA audio recordings of NCT and SFO air traffic control tower communications.

[18] Air Canada's *A319/A320/A321 Aircraft Operating Manual* indicated that, for the selected descent mode (also referred to as the open descent mode), an airplane is guided by targets that the pilot flying selects and enters into the flight control unit. For more information about this descent mode, see section 1.6.1. According to FDR data, between the altitudes of 8,040 and 1,456 ft msl, the airplane could have been operating in either the open descent mode or the managed descent mode without altitude constraints.

[19] In an e-mail dated March 23, 2018, the captain stated the following about the descent mode: "The descent initially was flown in selected [open mode] to catch up with the profile…[in] part due to the [air traffic] controller taking us out of the normal approach and due to radar vectoring. Once I was comfortable that the airplane, and the automation was caught up with the FMC, and the profile, the rest of the approach was flown in Managed mode as per the profile published on the approach plate." The NTSB notes that situations that might warrant the use of the open descent mode include vectoring off the approach (which occurred during the incident flight), maintaining a specific altitude that is above the glidepath until reaching a specific intersection, and descending to a certain altitude that is below the projected calculated glidepath.

[20] According to Air Canada, the procedure was allowed until reaching the final waypoint on the approach.

instruction.[21] At 2346:19, the controller asked the crewmembers if they had the airport or bridges in sight; the flight crew replied that the bridges were in sight. At 2346:30, the controller cleared the airplane for the approach and, at 2350:48, instructed the flight crew to contact the SFO air traffic control tower (ATCT).

At 2351:07, the flight crew contacted the SFO ATCT and advised that the airplane was on the FMS Bridge visual approach to runway 28R. Four seconds later, the tower controller issued a landing clearance for runway 28R.[22] The flight crew acknowledged the landing clearance at 2351:18. FDR data showed that the landing gear was selected to the down position at 2352:46.

Air Canada's FMS Bridge visual approach procedure to runway 28R indicated that pilots of Airbus A319/A320/A321 airplanes were to do the following: "at or before F101D [the final waypoint on the approach], disengage autopilot and continue as per Visual Approaches [standard operating procedures]." FDR data showed that the autopilot was disconnected at 2353:28 when the airplane was at an altitude of 1,300 ft and that the flight directors were disengaged at 2354:02 when the airplane was at an altitude of 1,200 ft. The airplane passed F101D at 2354:28, when the airplane was at an altitude of about 1,100 ft, and the captain made the required 14° right turn to align the airplane with runway 28R but instead aligned the airplane with taxiway C.

During a postincident interview, the first officer reported that, during the approach, he was looking inside the cockpit to accomplish his tasks as the pilot monitoring. For example, after the autopilot was disconnected, the first officer set the missed approach altitude and heading in case a missed approach was necessary; the first officer stated that he had to look at the approach chart to obtain that information. Also, the first officer reported that the captain had asked him to set the heading bug (indicator) to the runway heading. The first officer stated that he had difficulty finding the heading information on the approach chart, so he had to reference the airport chart.[23] The captain reported that he saw lights across what he thought was the runway 28R surface. The captain asked the first officer to find out whether the runway was clear, at which time the first officer looked outside the cockpit. The first officer stated that the captain's request occurred between the time that the airplane passed F101D (at an altitude of about 1,100 ft) and the time that the airplane descended to an altitude of 600 ft.

The ATC voice recording indicated that, at 2355:45, the flight crew made the following transmission to the controller: "Just want to confirm, this is Air Canada seven five nine, we see some lights on the runway there, across the runway. Can you confirm we're cleared to land?"[24] At that time, the airplane was passing through an altitude of 300 ft. During a postincident interview, the controller stated that, just before the query about the status of runway 28R, he had visually scanned the runways from the departure to approach ends. The controller also stated that, in

[21] Once the airplane joined the approach, the autopilot lateral navigation mode changed to "NAV."

[22] The tower controller was working all positions in the ATCT at that time. Section 1.4.1 discusses ATCT staffing on the night of the incident.

[23] FDR data indicated that the missed approach altitude and the runway heading were set at 2355:00.

[24] The captain stated, during a postincident interview, that it took "a while" for the first officer to contact the controller because of "chatter" on the tower frequency. The ATC voice recording showed that, during the 61 seconds before the flight crew's query to the controller, there were ongoing communications between the tower and airplanes on the ground.

response to the query, he checked the radar display and the airport surface surveillance capability (ASSC) display and then rescanned runway 28R. Regarding the ASSC display, the controller reported that he saw the ACA759 data symbol just to the right of the runway centerline, which he stated was normal for the FMS Bridge visual approach to runway 28R.

At 2355:52, 1 second after the flight crew completed its transmission, the controller replied, "Air Canada seven five nine confirmed cleared to land runway two eight right. There's no one on runway two eight right but you."[25] About that time, the airplane was passing through an altitude of 200 ft and was 2,300 ft (0.38 nautical mile [nm]) from the seawall that protected the airfield from San Francisco Bay.[26] At 2355:58, the flight crew acknowledged the transmission; about that time, the airplane was 500 ft (0.08 nm) from the seawall. Figure 1 shows ACA759's track before reaching the seawall along with the extended centerlines for runway 28R and taxiway C.

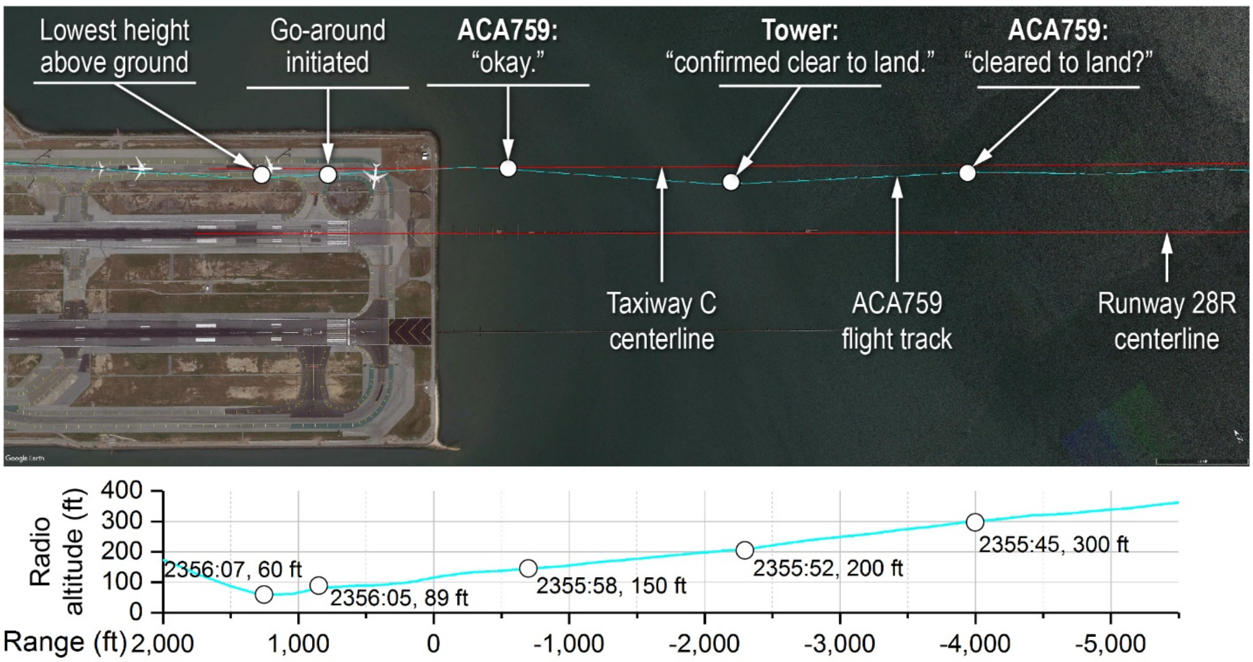


Figure 1. ACA759 track over SFO.

Note: (a) This figure shows a plot of data and does not depict information that was available to the pilots and controller. (b) The range shown at the bottom of the figure is the distance from/beyond the airport seawall.

[25] At this time, the ACA759 data symbol (which showed only the airplane's call sign) disappeared from the ASSC display because the airplane was no longer in the system's depiction area (coverage cone). The ASSC display showed the ACA759 data symbol again 12 seconds later, at 2356:04. For more information about the ASSC system, see section 1.4.2.

[26] The seawall was about 650 ft from the runway 28R displaced threshold and about 400 ft from the paved surface of taxiway C. Because taxiway C did not have a defined threshold (the taxiway curved when intersecting runway 28R), the seawall located before the approach ends of runways 28R and 28L was used to reference distances during the incident airplane's approach to taxiway C.

The ATC voice recording also indicated that, at 2355:59, another pilot stated on the tower frequency, "where is that guy going?"[27] The voice on the transmission was later identified as that of the captain from the first airplane on taxiway C, United Airlines flight 1 (UAL1). About that time, ACA759 was still 500 ft (0.08 nm) from the airport seawall and at an altitude of 150 ft while lined up with taxiway C. At 2356:03 (after ACA759 crossed the seawall), ACA759 overflew UAL1 at an altitude of 100 ft; about the same time, the UAL1 captain stated, over the tower frequency, "he's on the taxiway." About the same time as the UAL1 captain's second transmission, the flight crew from the second airplane on taxiway C, Philippine Airlines flight 115 (PAL115), turned on that airplane's landing gear and nose lights, illuminating a portion of the taxiway and the UAL1 airplane.

FDR data showed that, at 2356:05, the throttles on ACA759 were advanced, and the airplane's engine power and pitch increased. At that time, the airplane was at an altitude of about 89 ft.[28] During a postincident interview, the captain stated that, as the airplane was getting ready to land, "things were not adding up" and it "did not look good," so he initiated a go-around.[29] The captain reported that he thought that he saw runway lights for runway 28L and believed that runway 28R was runway 28L and that taxiway C was runway 28R.[30] During a postincident interview, the first officer reported that he thought that he saw runway edge lights but that, after the tower controller confirmed that the runway was clear, he then thought that "something was not right"; as a result, the first officer called for a go-around because he could not resolve what he was seeing. The captain further reported that the first officer's callout occurred simultaneously with the captain's initiation of the go-around maneuver.

The airplane continued descending, reaching a minimum altitude of about 60 ft at 2356:07 as the airplane overflew PAL115. One second later, once the engines and elevators had fully transitioned to their go-around position, the airplane began to climb. During the 3 seconds between the time that the flight crew initiated the go-around and the airplane began climbing, ACA759 had flown about 700 ft (0.12 nm) from the location over the taxiway where the go-around was initiated.

[27] The controller stated, during a postincident interview, that the transmission seemed "out of context." The ATC voice recording indicated that, 2 seconds after this transmission, the controller stated to himself, "who is…talk?"

[28] The NTSB performed an airplane performance study for this incident (see section 1.5.1), and some FDR-recorded altitudes were adjusted according to the results of the study. For example, the airplane's altitude when the throttles were advanced was adjusted from the FDR-recorded radio altitude (which indicates the airplane's height above the ground) of about 84 ft. Also, the airplane's FDR-recorded minimum altitude of 59 ft (at 2356:07) was adjusted.

[29] Air Canada's *Flight Operations Manual* provided the criteria regarding when a go-around should be initiated. These criteria included "landing will not be accomplished within the touchdown zone" and "landing will not be accomplished on the runway centerline." The captain stated, during a postincident interview, that he thought that the go-around maneuver began when the airplane was at an altitude of about 400 ft and was 0.5 nm from the runway. The NTSB determined the initiation of the go-around (at an altitude of 89 ft and 0.26 nm beyond the seawall) by the throttle lever angles, which increased from 22.5° to 42°; the engine N1 (fan speed), which increased from 57 to 94%; and the corresponding sidestick input as the throttles were advanced.

[30] Between the time of the runway 28L closure and ACA759's approach, nine airplanes flew the FMS Bridge visual approach and made uneventful landings on runway 28R. (Four airplanes were on taxiway C during that time, as described in this section.) The pilots of the flight that immediately preceded ACA759 reported confusion regarding the identification of the runway 28R surface, as discussed in section 1.1.1.

At 2356:09, the controller instructed the ACA759 flight crew to go around.[31] The ACA759 flight crew acknowledged this instruction 2 seconds later as the airplane overflew the third airplane on the taxiway, United Airlines flight 863 (UAL863), at an altitude of 200 ft. Immediately afterward, ACA759 overflew the fourth airplane on the taxiway, United Airlines flight 1118 (UAL1118) at an altitude of 250 ft. Both incident pilots reported (during postincident interviews) that they did not see any airplanes on the taxiway. Table 1 shows the events between ACA759's landing clearance and overflight of taxiway C according to the airplane performance study conducted for this incident.

Table 1. Timeline of events.

Event	Time	Distance from airport seawall	Airplane altitude (agl)
Tower: Cleared to land 28R.	2351:11	-11.5 nm	3,500 ft
Landing gear down	2352:46	-7.7 nm	2,000 ft
Autopilot off	2353:28	-6.0 nm	1,300 ft
Flight directors off	2354:02	-4.8 nm	1,200 ft
Passed F101D and lined up with taxiway C	2354:28	-3.6 nm	1,100 ft
ACA759: Confirm runway clear.	2355:45	-4,000 ft, -0.66 nm	300 ft
Tower: Confirmed clear to land.	2355:52	-2,300 ft, -0.38 nm	200 ft
ACA759: Okay.	2355:58	-500 ft, -0.08 nm	150 ft
UAL1 pilot: Where is that guy going?	2355:59	-500 ft, -0.08 nm	150 ft
UAL1 pilot: He's on the taxiway.	2356:03	+450 ft, +0.07 nm	100 ft
Passed over UAL1	2356:03	+450 ft, +0.07 nm	100 ft
Throttles advanced for go-around	2356:05	+850 ft, +0.11 nm	89 ft
Passed over PAL115	2356:07	+1,250 ft, +0.21 nm	60 ft
Began climb	2356:08	+1,550 ft, +0.26 nm	89 ft
Tower: Go around.	2356:09	+1,700 ft, +0.28 nm	130 ft
Passed over UAL863	2356:11	+2,200 ft, +0.36 nm	200 ft
Passed over UAL1118	2356:12	+2,600 ft, +0.43 nm	250 ft

Note: The airplane's distance from the seawall is expressed in feet and nautical miles for distances less than 1 nm.

At 2356:12, the controller advised the ACA759 flight crew, "it looks like you were lined up for [taxiway] Charlie," and instructed ACA759 to fly a heading of 280° and climb to 3,000 ft msl. The flight crew acknowledged the heading and altitude instructions at 2356:18. At 2356:23, ACA759's landing gear was raised; 5 seconds later, the autopilot was engaged. At 2356:44 and 2356:55, the controller instructed the flight crew to contact NCT, and the crew acknowledged the instruction at 2357:00. During the downwind leg for ACA759's second approach, the first officer asked the captain if they should set the ILS frequency, and the captain agreed. The second approach to SFO was uneventful, and ACA759 made a successful landing on runway 28R about 0011 on July 8. The captain and first officer completed their duty periods at 0032.

[31] (a) The controller stated that, when ACA759 was about 1/10 mile on short final, he noticed that the airplane looked "extremely strange" regarding its proximity to taxiway C and the airplanes on the taxiway and then made the decision to have ACA759 go around. (b) The flight crewmembers indicated, during postincident interviews, that they did not hear specific transmissions on the tower frequency between the controller's verification that the runway was clear and his go-around instruction.

1.1.1 Preceding Arrival on Runway 28R

The airplane that preceded the incident airplane into SFO, a Boeing 737 operated as Delta Air Lines flight 521 (DAL521), landed on runway 28R about 4 minutes before the incident occurred. During postincident interviews, both DAL521 flight crewmembers reported that, after visually acquiring the runway environment, they questioned whether their airplane was lined up for runway 28R.[32] The DAL521 captain stated that he could see lights (but no airplanes) on taxiway C and that those lights gave the impression that the surface could have been a runway.[33] The DAL521 first officer reported seeing a set of lights to the right of runway 28R but that he "could not register" what those lights were. The DAL521 first officer also reported that there were "really bright" white lights on the left side of runway 28R (similar to the type used during construction), but both he and the captain knew that runway 28L was closed.

The DAL521 flight crewmembers were able to determine that their airplane was lined up for runway 28R after cross-checking the lateral navigation (LNAV) guidance. The DAL521 captain stated that, without lateral guidance, he could understand how the runway 28R and taxiway C surfaces could have been confused because the lights observed on the taxiway were in a straight line and could have been perceived as a centerline. The DAL521 crewmembers confirmed that their airplane was lined up correctly when they visually acquired the painted "28R" marking on the paved surface of the runway; they estimated that their airplane was at an altitude of 300 ft at that time.[34]

The DAL521 captain and first officer provided written statements to Delta Air Lines (dated July 13 and 12, 2017, respectively) that were subsequently provided to the NTSB. The DAL521 captain stated, "had the runway sequenced flashing lights been on it would have defined the landing runway or had we flown the ILS [approach] we would have had precision course guidance which would have eliminated the illusion that we were not lined up on runway 28R." The DAL521 first officer stated, "the PF [pilot flying] stayed on the LNAV guidance all the way to the runway which mitigated the confusion we experienced from the lighting and non-normal airport configuration at SFO that night."[35] Both flight crewmembers indicated that, after landing, they heard a radio communication about an airplane lined up with the taxiway followed by the tower controller's instruction for the airplane to go around, and the first officer indicated that he saw an aircraft lined up on the taxiway initiating a go-around. The DAL521 first officer also indicated that he called the ATCT about 40 to 50 minutes after the incident and suggested that, to assist pilots

[32] Similar to the ACA759 flight crew, the DAL521 flight crew flew the FMS Bridge visual approach to runway 28R.

[33] The ASSC system showed that, as DAL521 approached the runway, UAL1, PAL115, UAL863, and UAL1118 were on the taxiway (in about the same positions as when ACA759 approached the runway).

[34] The airplane performance study showed that, when the incident airplane reached an altitude of 300 ft, the airplane was 4,000 ft (0.66 nm) from the seawall, so the DAL521 airplane was most likely about the same distance from the seawall when the DAL521 flight crew visually acquired the painted "28R" on the runway.

[35] The DAL521 first officer also stated the following: "The construction lights were so bright we could not determine the location of the inboard runway, 28L. So I initially thought the construction was on a taxiway and we might be lined up on Rwy 28L and the taxiway on the right could be Rwy 28R."

with runway identification, flight crews should "fly ILS approaches to RWY 28R" or the tower should "turn on the lights for RWY 28L."[36]

1.1.2 Airplanes on Taxiway C

The flight crews of the four airplanes that were on taxiway C at the time of the incident provided written statements to the NTSB. The captain of the first airplane, a Boeing 787 operated as UAL1, stated that he had a clear view of arriving traffic. The UAL1 captain also stated that he first saw ACA759 when it was about 1 to 2 miles away because ACA759's landing lights were pointed directly at the UAL1 airplane. He thought that ACA759 would correct its course and align with the runway. When that did not occur, he transmitted "where is that guy going" and "he's on the taxiway" on the tower frequency, and the controller directed the incident airplane to go around.

The flight crewmembers of the second airplane, an Airbus A340 operated as PAL115, stated that, when ACA759 was on short final, it became evident that the airplane was lined up with taxiway C. The PAL115 crewmembers also reported that they switched on their airplane's landing gear lights and nose lights so that the ACA759 flight crewmembers could recognize that they had aligned the airplane with a taxiway. The PAL115 crewmembers further stated that the controller's go-around instruction was issued after ACA759 had overflown their airplane.

The captain of the third airplane, a Boeing 787 operated as UAL863, stated that he turned on all airplane lights before the ACA759 flight crew performed a go-around. The UAL863 first officer stated that "a lot of lights" were on runway 28L and that he noticed an "X" on runway 28L.[37] The UAL863 first officer also stated that it "quickly became obvious" that ACA759 was lining up with the taxiway. One of the UAL863 relief first officers (who was in the cockpit at the time) stated that "the tower controller should not have been the only controller working the entire airport" because it took him a few seconds to respond to the UAL1 pilot's transmissions.

The captain of the fourth airplane, a Boeing 737 operated as UAL1118, stated that he lost sight of ACA759 when it was at an altitude of about 500 to 600 ft because of his airplane's position behind a Boeing 787. The captain also stated that, although the ACA759 flight crew "made a serious mistake that went unchecked for way too long," it was also important to note that the tower controller "was performing way too many functions…Ground, Tower, and at times ops vehicles."

1.2 Personnel Information

1.2.1 The Captain

The captain, age 56, held a Canadian airline transport pilot (aeroplane) license with a multiengine land rating. The captain's most recent pilot's license, dated October 2, 2015, included a type rating for the EA32, which is the Canadian flight crew type rating designation for

[36] During a postincident interview, the controller stated that, after ACA759 landed, a pilot from a Delta Air Lines flight called the tower to report a problem differentiating runway 28R from taxiway C.

[37] The incident flight crewmembers stated that they did not see a lighted "X" on runway 28L to indicate that it was closed. Similarly, neither DAL521 pilot recalled seeing a lighted "X" to indicate that runway 28L was closed.

Airbus A320-series airplanes. The captain also held a category 1 medical certificate dated December 20, 2016, with a limitation that required him to wear glasses.[38] The captain reported that he was wearing his glasses at the time of the incident.

The captain was employed by Canadian Airlines between 1988 and 2000 and Air Canada since 2000 (after the two airlines merged). He had been a captain on the A320 since 2007. According to Air Canada records and information provided by the captain, he had accumulated about 20,000 hours of total flight experience, including about 7,063 hours in the A320, about 4,797 hours of which were as an A320 pilot-in-command. He had flown about 166, 56, 11, and 6 hours in the 90, 30, and 7 days and 24 hours, respectively, before the incident. The captain's last line check occurred on March 8, 2017, and his last recurrent ground training occurred on January 20, 2017. The captain had no previous accident or incident history, and company training records showed that he had not failed any pilot checkrides.

The captain reported that he had been to SFO "lots of times," including once or twice during the 4 months before the incident. The captain recalled that, on previous flights into SFO, runways 28L and 28R were both illuminated, and he stated that he had never seen runway 28L "dark." The incident flight was the first time that the captain and the first officer had flown together.

72-Hour History

The captain stated that he went to sleep between 0030 and 0100 EDT on July 5, 2017, and awoke between 0700 and 0800 EDT. He was off from work that day. On July 6, the captain went to sleep about 0000 EDT and awoke about 0800 EDT. The captain was a reserve pilot for Air Canada, and his reserve duty period on July 6 began at 0500 EDT. He reported for duty between 1600 and 1700 EDT and flew to LaGuardia Airport, New York, New York, and then back to YYZ. He went off duty at 2313 EDT (15 minutes after the flight arrived at the gate) and then cleared customs, took a train to the airport parking lot, walked to his car, and drove home. He stated that the flight from New York, because of its arrival time, affected his sleep cycle "a little bit." The captain went to sleep between 0200 and 0300 EDT on July 7 and awoke about 0745 EDT. The captain considered himself to be "fairly rested" during the 3 nights before the incident flight.

The captain's reserve duty period began at 1113 EDT on July 7. About 1149 EDT, crew scheduling called the captain to notify him of a round-trip flight assignment from YYZ to SFO.[39] The captain did not take any naps that day and reported for duty by 1940 EDT. The captain considered himself to be rested before the flight but reported that he started feeling fatigued midway through the flight, just after the airplane maneuvered through an area of thunderstorms. At the time of the incident, the captain had been awake for more than 19 hours. Table 2 shows the captain's sleep schedule during the 72 hours before the incident.

[38] The Transportation Safety Board of Canada reviewed both flight crewmembers' medical certificates as part of this investigation and found that the captain and the first officer reported no medications, medical conditions, or sleep disorders as part of their category 1 medical examinations. In addition, neither flight crewmember reported any medications, medical conditions, or sleep disorders during postincident interviews.

[39] The return flight, from SFO to YYZ, departed on July 8 at 1649 (1949 EDT) and arrived at 2135 (0035 EDT on July 9).

Table 2. Captain's self-reported sleep schedule.

Date	Bedtime (EDT)	Awakening time (EDT)	Sleep opportunity
July 4 to 5	Between 0030 and 0100	Between 0700 and 0800	6 to 7.5 hours
July 5 to 6	0000	0800	8 hours
July 6 to 7	Between 0200 and 0300	0745	4.75 to 5.75 hours

The captain stated that he normally obtained between 6 and 7 hours of sleep each night and felt rested after that amount of sleep. He consistently went to bed after 0000 EDT and considered himself to be neither a morning nor an evening person. The captain thought that it was "hard to get into a rhythm" when traveling because of difficulty winding down and falling asleep immediately after flights. The captain reported that he did not take any prescription or nonprescription medicine, use tobacco products or illicit drugs, and consume alcohol in the 72 hours before the incident. The captain also reported no issues with his health and had no changes to his health, financial situation, or personal life within the 12 months before the incident that would have affected his performance on the day of the incident.

1.2.2 The First Officer

The first officer, age 42, held a Canadian airline transport pilot (aeroplane) license with a multiengine land rating. The first officer's most recent pilot's license, dated November 30, 2015, included a type rating for the EA32 (the Canadian flight crew type rating designation for Airbus A320-series airplanes). The first officer also held a category 1 medical certificate dated May 12, 2017, with no limitations.

The first officer had been employed by Air Canada since December 2007. According to Air Canada records and information provided by the first officer, he had accumulated about 10,000 hours of total flight experience, including about 2,343 hours in the A320 as second-in-command. He had flown about 148, 70, 18, and 6 hours in the 90, 30, and 7 days and 24 hours, respectively, before the incident. The first officer's last line check occurred on April 25, 2017, and his last recurrent ground training occurred on December 29, 2016. The first officer had no previous accident or incident history.

The first officer reported that he had twice attempted to upgrade to A320 captain. Air Canada records showed that the first officer passed his command line operational evaluation training on February 6 and 7, 2017, and that he did not pass his qualifying oriented evaluation training on March 1 and 16, 2017. According to the simulator instructors and check airmen who conducted the first officer's upgrade attempts, the first officer had occasional difficulty maintaining situational awareness and did not perform in accordance with required Transport Canada standards.[40] Air Canada's director of safety and training stated that the first officer subsequently completed requalification training for the first officer position. The instructor who administered this training stated that the first officer performed "above average."

[40] A check airman who flew with the incident first officer (when he was attempting to upgrade to captain) stated that, during a flight, the incident first officer did not anticipate a potential flap overspeed event and respond to an increase in thrust that would have caused a flap overspeed. The instructor stated that he had to intervene before a flap overspeed occurred.

72-Hour History

The first officer was off duty on July 4, 2017, and reported that he had a “proper” night’s sleep then. On July 5, the first officer awoke about 0800 EDT and took a nap in the afternoon for 90 minutes. He was a flight crewmember (the pilot flying) that night for a flight to SFO, which landed at 2305 (0205 EDT on July 6).[41] The first officer went to sleep about 0400 EDT and awoke about 1000 EDT. He took a 1-hour nap in the afternoon and flew back to YYZ that night. The flight arrived on July 7 about 0030 EDT, and the first officer went to sleep about 0300 EDT. He awoke about 0900 EDT, took a 90-minute nap about 1300 EDT, and reported for duty at 1910 EDT (30 minutes before the scheduled report time). The first officer stated that both he and the captain began to feel “very tired” between 2330 and 0000 (0230 and 0300 EDT on July 8).[42] At the time of the incident, the first officer had been awake for more than 12 hours. Table 3 shows the first officer’s sleep schedule during the 72 hours before the incident.

Table 3. First officer’s self-reported sleep schedule.

Date	Bedtime (EDT)	Awakening time (EDT)	Sleep opportunity
July 4 to 5	Unknown	Unknown	Unknown
July 5 to 6	0400	1000	6 hours plus 1-hour nap (7 hours)
July 6 to 7	0300	0900	6 hours plus 1.5-hour nap (7.5 hours)

The first officer thought that he needed 8 hours of sleep each night to feel rested and considered himself to be a “pretty heavy sleeper.” He also considered himself to be a “normal day person” and stated that he typically felt tired about 2300 EDT. He normally took a nap in the afternoon for about 90 minutes on the days that he was scheduled for a nighttime flight. The first officer reported that he slept well during naps and felt rested afterward.

The first officer reported that he did not take any prescription or nonprescription medicine in the 72 hours before the incident that would have affected his performance. The first officer also reported that he did not use tobacco products or illicit drugs and that his last alcohol consumption before the incident was dinnertime on either July 3 or 4. He further reported no issues with his health and had no changes to his health, financial situation, or personal life within the 12 months before the incident that would have affected his performance on the day of the incident.

1.3 Airplane Information

The incident airplane, shown in figure 2, was owned by GE Capital Aviation Services, which leased the airplane to Air Canada. The airplane’s transport-category airworthiness certificate was dated January 17, 1992. The airplane was powered by two CFM56-5A1 engines and had 2 flight crew seats, 1 jumpseat, 5 cabin crew seats, and 154 passenger seats. The airplane’s last inspection before the incident occurred on June 25, 2017, at which time the airplane had accumulated a total of 82,427 hours of flight time.

[41] SFO lighting logs showed that runway 28L closed at 2323 on July 5.

[42] As indicated in section 1.1, the flight crewmembers also reported feeling tired just after they maneuvered the airplane through the thunderstorms.

Source: Air Canada.

Figure 2. Incident airplane.

1.4 Airport Information

SFO was located 8 miles southeast of San Francisco at an elevation of 13 ft msl. The airport was owned and operated by the city and county of San Francisco and was certificated under 14 *CFR* Part 139. SFO had four runways (two sets of parallel runways) designated as 10L/28R, 10R/28L, 1R/19L, and 1L/19R, as shown in figure 3. Runway 10L/28R was 11,870 ft long and 200 ft wide. Runway 10R/28L was 11,381 ft long and 200 ft wide. Runway 28R was equipped with a localizer that was aligned with the 284° runway heading. Taxiway C, which was to the right of runway 28R (as viewed from the approach end of the runway), was 12,330 ft long and 75 ft wide.

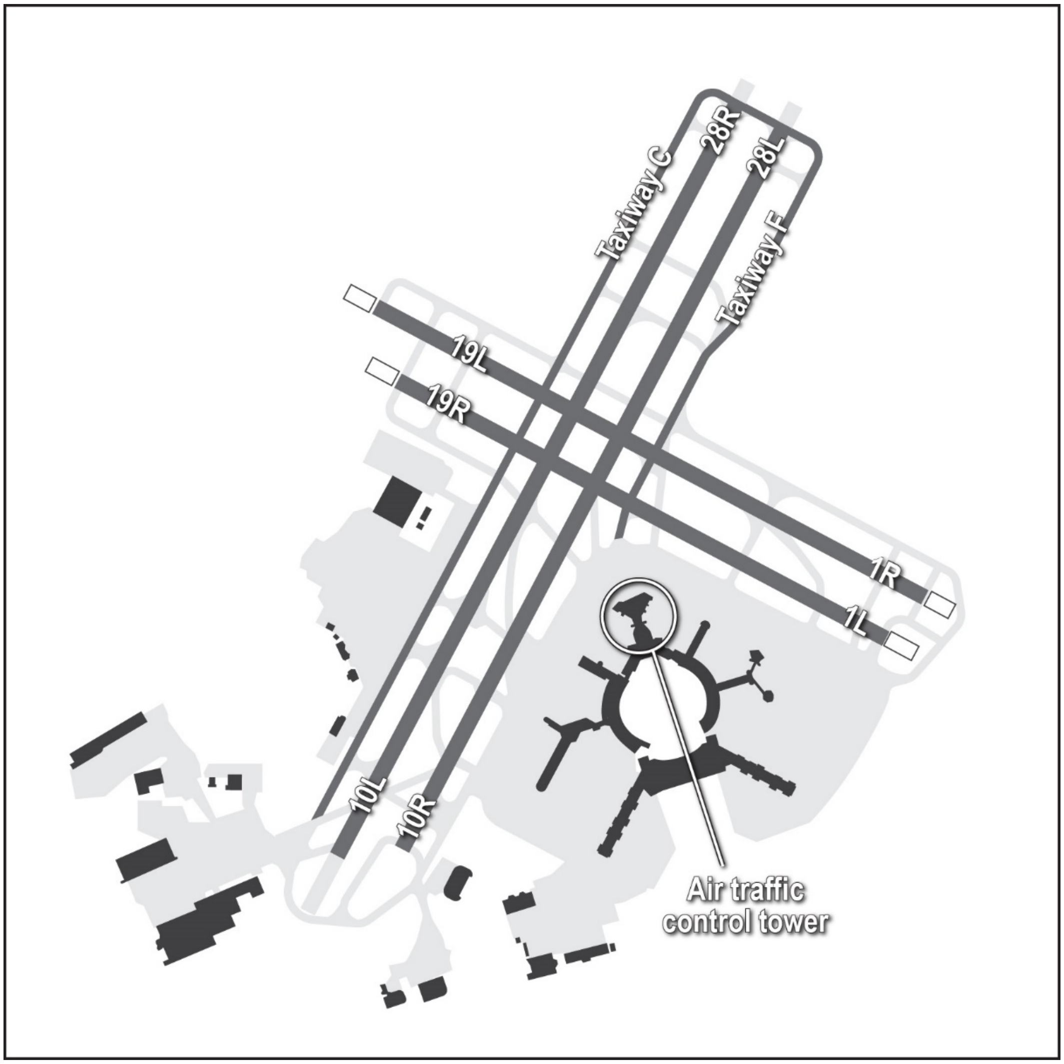


Figure 3. SFO layout map.

The SFO inspection log showed the runway, taxiway, signage, and lighting inspections surrounding the time of the incident. On July 7, 2017, runway 28R was inspected at 1550, runway 28L was inspected at 1609, and all taxiways were inspected at 2108. On July 8, the airport signage was inspected at 0211, and the airport lighting was inspected at 0339. No discrepancies were noted for any of these inspections.

Title 14 *CFR* 139.311, "Marking, Signs, and Lighting," stated that "each certificate holder must provide and maintain lighting systems for air carrier operations when the airport is open at night." The regulation required runway and approach lighting that met specifications for takeoff and landing minimums. The regulation also required that taxiways have one of four lighting systems, one of which was centerline lights.

The airport light status (on/off) and intensity were controlled from the ATCT. Runway 28R was equipped with white runway edge lights, white centerline lights, white touchdown zone lights, and an approach lighting system with white centerline sequenced flashing lights (ALSF-2).[43] Runway 28R was also equipped with a four-light precision approach path indicator with a 3° glidepath that was located on the left side of the runway. Taxiway C was equipped with green centerline lights that were spaced at 50-ft intervals (± 5 ft), blue taxiway edge lights located at the intersections with runway 28R to highlight the edge of the intersections, and flashing yellow in-pavement guard lights located where taxiway C intersected runway 1R/19L (which ran perpendicularly to runways 28L and 28R and taxiway C).[44] Figure 4 shows an illustration of the lighting on runway 28R and taxiway C. On the night of the incident flight, the runway and taxiway centerline lights were set at step 1 (out of 5).

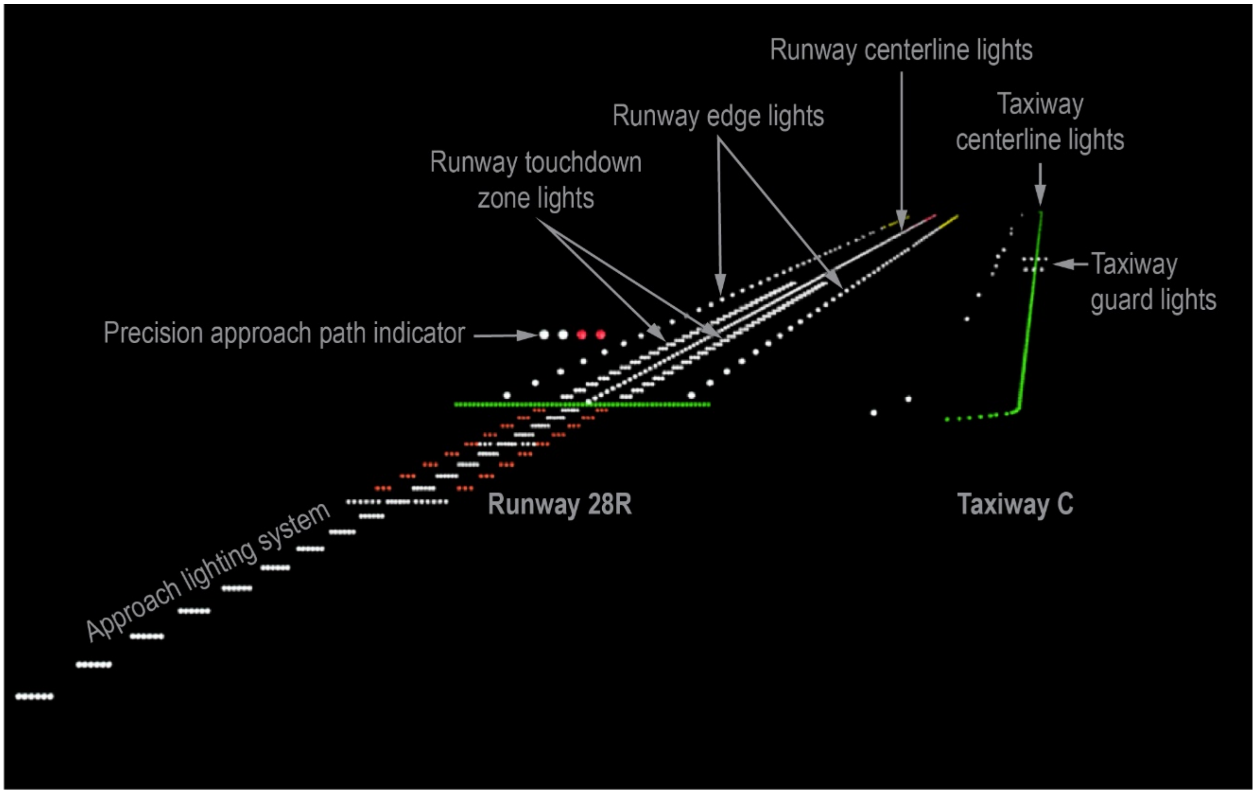


Figure 4. Illustration of SFO's lighting configuration.

Note: The green runway threshold lights (for runway 28R) are also shown.

Figure 4 also shows the ALSF-2 approach lighting system installed on runway 28R. The approach lighting system had a total of 24 white centerline bar lights that were spaced at 100-ft

[43] (a) An approach lighting system is a ground reference aid for pilots when making an approach to a runway. (b) The runway centerline lights were white until the last 3,000 ft of the runway. From 3,000 to 1,000 ft, the color of the lights alternated between red and white. For the last 1,000 ft, all of the lights were red. (c) The runway edge lights transitioned from white to amber for the last 2,000 ft of the runway.

[44] (a) During postincident interviews, the flight crewmembers recalled seeing specific color cues, including the green taxiway centerline lights, while on approach to SFO. (b) The taxiways at YYZ had green centerline lights that were spaced at 15-m (about 50-ft) intervals, retroreflective markers on the straight edges of the taxiways, and blue edge lights around turns and at intersections.

intervals and faced the direction of approaching aircraft, and 15 of the white centerline bar lights extended into San Francisco Bay. Sequenced flashing lights (strobes) were positioned on the 15 centerline bar lights that were farthest from the runway to create, when the sequenced flashing lights were turned on, the appearance of a rapidly moving light toward the runway.[45] During postincident interviews, the tower controller who handled the incident flight stated that, on the night of the incident, the approach lighting system was on, and the DAL521 captain stated that the sequenced flashing lights were not on.

The purpose of the construction project on runway 10R/28L at the time of the incident was to resurface the runway and replace existing light fixtures with improved lighting.[46] The project started in February 2017 and was expected to last about 10 months.[47] The work required the closure of the runway each night and during some weekends. At the time of the incident, 28 portable light plants were located around the construction zone.[48] A runway closure marker (a white flashing lighted "X") was placed at the approach and departure ends of runway 28L when the runway was closed. The lighted "X" was 20.5 ft by 20.5 ft and flashed on for 2.5 seconds and then off for 2.5 seconds, which was consistent with Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5345-55A, "Specification for L-893, Lighted Visual Aid to Indicate Temporary Runway Closure."[49] The flashing light associated with the "X" on runway 28L could be seen on an SFO security video that captured the incident. (See section 1.5.1 for information about the video).

One of the controllers at the SFO ATCT stated, during a postincident interview, that he had noticed an increase in pilot requests to adjust the lights for runway 28R due to the construction on runway 28L. According to the SFO acting air traffic manager, after the incident, controllers at the SFO ATCT were directed to (1) increase the intensity of the approach lights by one step if the adjacent arrival runway is closed and (2) when construction is ongoing, ask the pilots of the first arriving airplane after dark if the construction lighting is distracting.

---

[45] Controllers normally select a lighting setting based on the weather conditions. On the night of the incident, the weather was VMC, so the sequenced flashing (strobe) lights would not have been on (unless a pilot requested them).

[46] The replacement lighting included new runway-to-taxiway lead-on/lead-off lights, takeoff hold lights, and runway entrance lights.

[47] The runway 10R/28L project was completed on December 18, 2017.

[48] Each light plant extended up to 30 ft and included four elliptical light fixtures that used 1,000-watt halide light bulbs.

[49] The L-893 runway closure marker currently in use in the national airspace system was intended for short-term closures. This marker resulted from a research project conducted at the FAA Technical Center, the results of which were published in a January 1987 technical report. According to the report, the development of a lighted visual aid to denote closed runway surfaces included the following performance criteria: (1) the visual aid should be conspicuous when viewed from the air with and without other runway visual aids illuminated, (2) the visual aid should be visible from any point 0.5 mile from the runway threshold, (3) the visual aid should be suitable for night operations down to a visibility of 3 miles, and (4) the message presented by the visual aid should be intuitively understood (Marinelli 1987). Various lighted visual aids were considered during this research project, and a lighted "X" was selected for evaluation. A similar lighted visual aid had been in operational use at SFO at that time, which "reinforced results" from the FAA Technical Center's evaluation. The NTSB is not aware of any further FAA research for the L-893 runway closure markers (after their implementation) except for assessing the use of light-emitting diode bulbs.

1.4.1 Air Traffic Control Tower Staffing

The SFO ATCT operated 24 hours a day. At the time of the incident, the ATCT was staffed with two controllers who were assigned to the midnight shift (2230 to 0630). The controller handling the incident flight had been an FAA controller since December 2008 and had been working at the SFO ATCT since 2013. He was qualified and current on all positions at SFO and was designated as a controller-in-charge.[50] The controller had also worked a daytime shift on July 7 from 0530 to 1330. The controller reported that he took a 45-minute nap in between the morning and midnight shifts and that he felt rested for his shifts.[51] The controller also stated that he had "no problems" adjusting to the midnight shift.

The controller reported to the tower at 2230 on July 7 and initially worked the ground control position. (The other controller assigned to the midnight shift was initially working the local control position.) The front-line manager had briefed both controllers about the closure of runway 28L at 2300. About 2349, all ATCT positions and frequencies had been combined, and one controller worked the positions in the tower cab while the other controller took a recuperative break in the building.[52] The controller who worked all positions configured his workstation to hear the SFO local control (tower) frequency and NCT interphone communications through his headset and the SFO ground control frequency over the workstation speaker.[53]

According to SFO ATCT personnel interviewed after the incident, the decision to combine positions to a single controller was made by the controllers on duty based on the anticipated traffic/workload and weather.[54] The SFO acting air traffic manager indicated that SFO traffic generally begins to lessen after 0000 and tapers off significantly after 0100.

[50] Both controllers who were on duty during the midnight shift were qualified as controllers-in-charge. The controller who handled the incident flight was designated as the controller-in-charge for that shift. The SFO acting air traffic manager stated, during a postincident interview, that two controllers-in-charge were normally staffed for the midnight shift.

[51] According to information that the controller provided during a postincident interview, he received 8 hours of sleep on the night of July 6 through 7.

[52] FAA Order JO 7210.3Z, *Facility Operation and Administration*, stated that "breaks to recuperate are provided to enable employees to engage in activities necessary to rejuvenate themselves in order to effectively manage fatigue." (FAA Order JO 7210.3Z, which was in effect at the time of the incident, was replaced by JO 7210.3AA on October 12, 2017.) SFO ATCT personnel indicated that recuperative breaks during the midnight shift were longer than the breaks that were normally provided during other shifts.

[53] The NCT and SFO ATCT letter of agreement, titled "Coordination and Control Procedures," stated that "each facility must advise when going to a single person midnight operation," but the SFO ATCT did not provide that notification to NCT on the night of the incident. The NTSB could not determine, from the available evidence, whether this situation was a recurring issue at the ATCT or occurred only on the night of the incident. NCT was not using single-person operations during the time surrounding the incident.

[54] The two controllers assigned to the midnight shift evaluated the pending traffic on the flight schedule monitor, the depicted traffic in the national airspace system, and the expanded radar view of traffic within 40 miles of SFO and decided that it was safe to combine all positions. Also, NCT had provided the ATCT with the authority to automatically release IFR departures from SFO, which indicated a less complex traffic situation. The controller who took the recuperative break stated that there had been a "sharp decline" in the amount of traffic displayed before the ATCT positions were combined.

The controller who handled the incident flight stated that traffic was "normal" before the incident and that he was not overly busy.[55] At the time that ACA759 called to confirm whether runway 28R was clear for landing, the controller was handling another air carrier's tug operator, but he checked the radar monitor and the ASSC display and rescanned runway 28R before advising the flight crew that the runway was clear. The controller recalled that two other air carrier pilots had contacted him just before he heard the "where is that guy going?" transmission. The controller was unsure about who made this transmission, but he checked the ASSC display and saw that the ACA759 data symbol no longer appeared. The controller stated that he had never seen an airplane's data symbol disappear when the airplane was on final approach. The controller also stated that he was not initially concerned that the ACA759 data symbol had disappeared from the ASSC display because he had observed the airplane from the tower cab window.

About that time, the controller heard the transmission indicating that an airplane was over the taxiway. The controller stated that he had never seen an airplane line up with taxiway C and that there was no indication that ACA759 was misaligned until he observed the airplane looking "extremely strange" on short final, which was about the time when he decided to instruct the flight crew to perform a go-around.[56] The controller stated that, about 0125 on July 8, he entered a mandatory occurrence report into the SFO ATCT's data analysis and reporting system; this report was required when an airplane goes around within 0.5 mile from a landing threshold. After the incident, the controller continued working all positions until 0300, at which time the other controller assigned to the midnight shift returned to the tower cab.

The controller who handled the incident airplane reported that, while working single-person operations on the night of the incident, he applied line up and wait (LUAW) procedures for other traffic.[57] FAA Order JO 7110.65W, *Air Traffic Control*, which prescribes ATC procedures, indicated that LUAW procedures should be used to position an airplane for an imminent departure when a takeoff clearance cannot immediately be issued because of traffic.[58] Paragraph 10-3-8 of FAA Order JO 7210.3Z stated that, when applying LUAW procedures, the "local control position must not be consolidated/combined with any other non-local control position. For example, local control must not be consolidated/combined with the front-line manager/controller-in-charge (CIC) position, clearance delivery, flight data, ground control, cab coordinator, etc." The order also stated that, during LUAW operations, "the front line manager/CIC position should not be combined with any other position."

During a postincident interview, the SFO acting air traffic manager stated that, if LUAW procedures were needed to efficiently move traffic, then traffic was "too busy to combine

[55] The controller also stated that he would not combine positions unless he was comfortable and had some predictability about the tasks that he would need to perform. The controller further stated that, if the traffic had become too busy or complex, he would have asked the other on-duty controller to return to the tower cab to assist.

[56] The distance and angle (parallax) of the tower cab relative to the approach end of runway 28R and taxiway C would have made it difficult for the controller to discern that the airplane was aligned with the taxiway instead of the runway. Parallax is the change in apparent position due to the viewing angle.

[57] During a postincident interview, the controller stated, "when aircraft were on a 5-mile final and compressing [the distance between two aircraft was decreasing], it was hard to fit in a departure from runway 1, without using LUAW."

[58] FAA Order JO 7110.65W, which was in effect at the time of the incident, was replaced by JO 7110.65X on September 12, 2017.

positions." The SFO acting air traffic manager also stated that, after the incident, ATCT management issued guidance indicating that the ground control and local control positions could not be combined before 0015.[59] In addition, the SFO acting air traffic manager stated that ATCT management had been reemphasizing the correct application of LUAW procedures.

1.4.2 Air Traffic Control Tower Equipment

The SFO ATCT was equipped with an ASSC system, which was one of three types of airport surface detection equipment (ASDE) systems in the national airspace system. FAA Order JO 7110.65W described the use and purpose of ASDE as follows:

> Surveillance equipment specifically designed to detect aircraft, vehicular traffic, and other objects, on the surface of an airport, and to present the image on a tower display. Used to augment visual observation by tower personnel of aircraft and/or vehicular movements on runways and taxiways.

Also, the order indicated that the ASSC system used surface movement radar, multilateration, and the Automatic Dependent Surveillance-Broadcast system.[60]

According to FAA Order JO 7110.65W, the ASSC system included a safety logic system software enhancement that "predicts the path of aircraft landing and/or departing, and/or vehicular movements on runways." The order stated that "visual and aural alarms are activated when the safety logic projects a potential collision." Specifically, the system was designed to provide an alert for "an actual situation involving two real safety logic tracks (aircraft/aircraft, aircraft/vehicle, or aircraft/other tangible object) that safety logic has predicted will result in an imminent collision." The order also stated that the system could generate false and nuisance alerts and could result in an "Invalid Non-Alert," which involves "a situation in which the safety logic software did not issue an alert when an alert was required, based upon the design specifications."

According to the FAA, at the time of the incident, the ASSC system was available at SFO and Cleveland Hopkins International Airport, Cleveland, Ohio (FAA 2018a).[61] The ASSC display in the SFO ATCT presented aircraft and vehicle positions over a map of the airport's runways, taxiways, and approach corridors. The ASSC display included a two-dimensional presentation of

[59] (a) At the time of the incident, the SFO ATCT's standard operating procedures described staffing requirements between 0630 and 2200 but did not provide such requirements between 2200 and 0630 the next day. (b) In June 2018, the NTSB asked the SFO ATCT when the 0015 time became effective and what factors were used to determine this time. The SFO ATCT operations manager responded that the 0015 time became effective on July 8, 2017 (the day after the incident) and that normal traffic patterns, runway closures, administrative duties, and fatigue guidance were considered in determining the 0015 time.

[60] According to the order, the other two ASDE systems were ASDE-3, a surface movement radar, and ASDE-X, which used an X-band surface movement radar, multilateration, and the Automatic Dependent Surveillance-Broadcast system. The three ASDE systems functioned similarly, but the ASSC had some capabilities that the other two ASDE systems did not have, including the ability to display extended runway centerlines and expand the capture box (block of airspace) area.

[61] According to the FAA, six additional airports were scheduled to receive the ASSC system during the next few years.

the runway centerlines, which extended out to about 2.5 nm. Figure 5 shows the ASSC display at 2356:21 on the night of the incident.

Source: FAA.

Figure 5. ASSC display at SFO.

Note: (a) The top of the figure shows the extended runway centerlines for runway 28R and 28L, and the bottom of the figure shows the airport movement areas. (b) The NTSB added labels to the figure to emphasize pertinent information.

The SFO ATCT controller who was taking a recuperative break at the time of the incident stated that the ASSC system assisted ground controllers in identifying airplanes and their locations and preventing runway incursions. He also stated that local controllers used the system as an "extra set of eyes" to assist with scanning and situational awareness. This controller also stated that the ASSC system provided airplane location information starting about the time that an airplane was on a 2-mile final approach. Another SFO ATCT controller stated that the ASSC system could be programmed to display runway and taxiway closures.

In February 2018, the FAA conducted tests at Seattle-Tacoma International Airport (SEA), Seattle, Washington, to determine if the ASDE-X system at the airport could detect and predict taxiway landings with only a negligible number of nuisance or false alarms.[62] NTSB staff observed the tests and participated in the discussion of the test results.

[62] On December 19, 2015, a Boeing 737 airplane operated by Alaska Airlines landed on a taxiway instead of the intended runway at SEA. The crew and passengers were not injured, and the airplane was not damaged. The incident occurred during daytime VMC. For more information about this incident, see NTSB incident number DCA16IA036.

For the tests, the system was configured to apply the same parameters that are used to predict a landing on a closed runway.[63] The tests included four different taxiway landing scenarios (one of which was similar to the circumstances of the SFO incident), and an FAA flight check airplane flew several approaches for each scenario. The tests showed that the ASDE-X system predicted the potential taxiway landing and provided an alarm when the airplane was within 20 seconds or 3,000 ft of landing. The ASDE-X alarm occurred with enough time for ATC personnel to respond. No false alarms occurred during any of the approaches and taxiway landing scenarios, including those involving parallel taxiway B, which is located 407 ft to the left of runway 16L (centerline to centerline). According to information that the FAA provided to the NTSB on September 13, 2018, a software enhancement, the taxiway arrival prediction capability, was implemented at SEA in May 2018, and the FAA has a schedule to evaluate the remaining ASDE-X-equipped airports and implement the software enhancement, where feasible, by the end of fiscal year 2020.

1.5 Tests and Research

1.5.1 Airplane Performance Study

The NTSB conducted an airplane performance study for this incident to determine the lowest altitude over the taxiway that ACA759 reached before the initiation of the go-around and the estimated distance between ACA759 and the second airplane on taxiway C (PAL115, which was below ACA759 when it reached its lowest altitude). To conduct the study, the NTSB used FDR data; radar data from the airport surveillance radar-9 at Metropolitan Oakland International Airport, Oakland, California; and video from a security camera at an SFO terminal.[64]

The security video showed ACA759 on final approach to the airport, as shown in figure 6. The reflection of the airplane's lights could be seen on the water in San Francisco Bay. Three of the four airplanes on taxiway C (UAL1, PAL115, and UAL863) are visible in the figure.

---

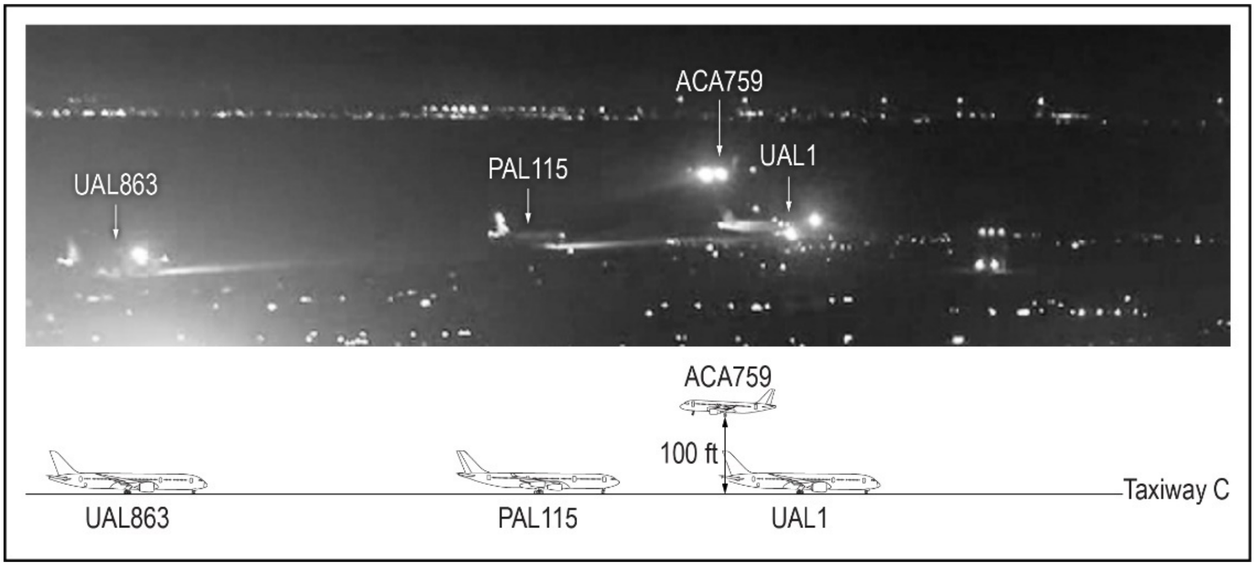
[63] All of the ASDE systems could be configured to predict a potential landing on a closed runway and provide alerts if this hazard was detected.

[64] The radar, which was about 10 nm from the incident location, updated data every 4.5 seconds.

Source: SFO.

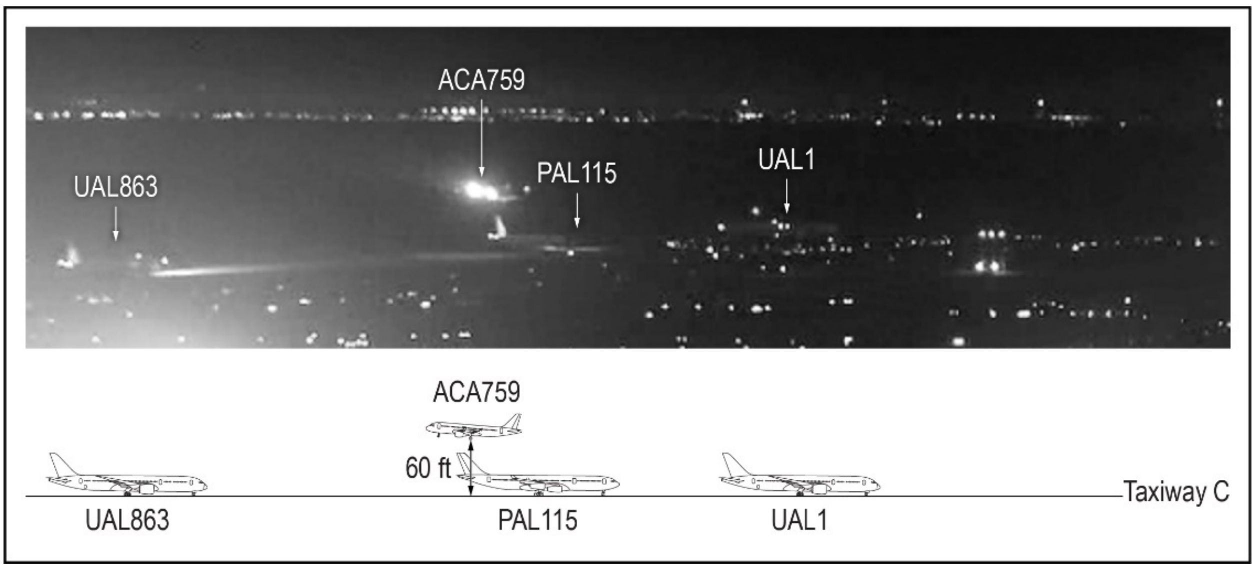
Figure 6. ACA759 on final approach to SFO.

The security video also showed ACA759 passing over the airport seawall and then passing over UAL1 on taxiway C, as shown in figure 7. About this time, the PAL115 flight crew turned on that airplane's landing lights, which illuminated the taxiway between PAL115 and UAL1 as well as the tail and side of the UAL1 airplane. In addition, the security video showed the fuselage of PAL115, which was illuminated by the ACA759 landing lights, and ACA759 descending to its lowest altitude as the airplane passed over PAL115. At that point, the attitude of the ACA759 airplane changed from nose down to nose up, as shown in figure 8. Subsequent frames of the security video showed ACA759 gaining altitude over the taxiway and passing over UAL863 and UAL1118. (UAL863 is shown in figures 7 and 8, but UAL1118 is not shown in those figures).



Source for top image: SFO.

Figure 7. ACA759 passing over UAL1 (top) and relative locations of airplanes (bottom).



Source for top image: SFO.

Figure 8. ACA759 passing over PAL115 (top) and relative locations of airplanes (bottom).

Note: The PAL115 airplane, an A340, has a reported height of 55 ft. Although ACA759's radio altimeter recorded the height above the ground of the bottom of the landing gear to be 60 ft, the security video showed more distance between the airplanes than the radio altimeter measurement. Specifically, the security video showed that the separation distance between the ACA759 fuselage and the PAL115 vertical stabilizer was 13.5 ft, as explained further in this report section.

The performance study considered the incident airplane's pressure altitude and radio altitude, which the FDR recorded, when determining altitude points. Pressure altitude was used for altitudes that were higher than 2,000 ft. Radio altitude—the height of the airplane above the ground directly below—was used for altitudes that were 2,000 ft and lower.[65] The adjusted radio altitude reflected the bottom of the airplane's landing gear above the ground; the landing gear extended 5 ft below the airplane's fuselage.

The lowest adjusted radio altitude, which occurred when ACA759 passed over PAL115, was determined to be 60 ft, which was the height of the bottom of the landing gear above the ground. To confirm this altitude, the NTSB examined the image from the security camera video that showed ACA759 passing over PAL115 (figure 8). In that image, the vertical stabilizer of the PAL115 airplane (an A340) was well illuminated. The NTSB used known dimensions of an A340 vertical stabilizer to scale the image, measured the closest point between the two airplanes, and determined that measurement to be 13.5 ft. Because the security camera image of the airplanes was relatively small and pixilated, this measurement was estimated to be between 10 and 20 ft to account for the inherent uncertainty. In addition, this measurement assumed that ACA759 was directly above PAL115; the lateral separation could not be determined from the image of ACA759 passing over PAL115. The A340 airplane (including the vertical stabilizer) was reported to be 55 ft tall, so the altitude of the ACA759 fuselage as it passed over PAL115 would have been between 65 and 75 ft, which was consistent with the 60-ft adjusted radio altitude plus the 5-ft distance between the bottom of the landing gear and the bottom of the fuselage.

The airplane performance study also determined the track of ACA759 while it approached SFO and was over taxiway C, as discussed in section 1.1 and shown in table 1.

1.5.2 Enhanced Ground Proximity Warning System Simulation

According to Honeywell, Air Canada installed Honeywell Mark V enhanced ground proximity warning systems (EGPWS) on the company's fleet of A320 airplanes. According to Honeywell's *Mark V and Mark VII EGPWS Pilot's Guide*, the EGPWS incorporated several terrain alerting and display features.

The EGPWS guide also described other features, including the runway awareness and advisory system (RAAS) option, which provides "alerts and advisories that increase crew situational awareness during operations on and around airports." Another option was the SmartLanding system, which, according to Honeywell, "provides visual and aural annunciations that supplement flight crew awareness of…select RAAS advisories." At the time of the incident,

[65] According to Airbus, the radio altimeter should be set so that it reads 0 ft at airplane touchdown with an estimated average pitch of 6°. After ACA759's final touchdown on runway 28R (after the second approach and landing), the radio altimeter recorded a value of -2 ft. For the airplane performance study, the radio altimeter measurement was adjusted +2 ft (the approximate height of the main landing gear wheels above the ground). No adjustments were made for the pitch of the airplane. In addition, the image of ACA759 and PAL115 when they were at their closest point was relatively small in the video frame, so the measurements were approximations. Thus, the altitudes derived in the study had uncertainty associated with them.

the EGPWS installed in Air Canada's A320-200 fleet, including the incident airplane, did not include the RAAS or the SmartLanding system options.[66]

The NTSB asked Honeywell to conduct a simulation to determine if an EGPWS with the SmartLanding system would have alerted the incident flight crew about the potential taxiway landing. The simulation was run using a Mark V EGPWS in Honeywell's laboratory in Redmond, Washington. Honeywell set the taxiway landing alert threshold at a radio altitude of 250 ft, which was the default setting, and incorporated parameters from the incident airplane's FDR.[67] The aural taxiway landing alert, "Caution Taxiway, Caution Taxiway," was designed to annunciate between a radio altitude of 250 and 150 ft. The simulation showed that the incident flight crew would have received the aural taxiway landing alert when the airplane was at a radio altitude of 235 ft and was 2,600 ft (0.43 nm) from the airport seawall. According to the results of the airplane performance study, the incident airplane reached that altitude just before the tower controller confirmed that runway 28R was clear.

The NTSB notes that Honeywell's systems are examples of available systems designed to augment a pilot's positional awareness during in-flight and ground operations; Garmin also has such a system available, and Rockwell Collins has a system in development. The three Honeywell systems described in this section all provide the alert "approaching [runway number]" before landing.

1.6 Organizational Information

1.6.1 Descent, Approach, and Arrival Information

Air Canada's *A319/A320/A321 Aircraft Operating Manual*, volume 1, section 4, "Standard Operating Procedures," provided flight crews with information on preparing for the descent to the destination airport. The manual stated that descent preparation should be completed before the top of the descent. The manual also stated that the pilot monitoring was to "set navaids as required" on the "RAD NAV [radio/navigation]" page (referenced with the MCDU) and "check idents on…PFDs (ILS)." The manual further stated that the pilot flying was to review all MCDU programming by the pilot monitoring, including entries on the radio/navigation page.

Air Canada's *A319/A320/A321 Aircraft Operating Manual*, volume 2, section 22-30, "Auto Flight – Flight Guidance," stated that the open descent mode maintains a target speed/Mach number with the autopilot/flight director pitch mode while autothrust (if activated) maintains idle thrust (unless the flight crew maintains idle thrust manually). Volume 1, section 4 of the manual, "Standard Operating Procedures," described a selected approach (also referred to as an open

[66] (a) Honeywell's *Mark V and Mark VII EGPWS Pilot's Guide* indicated that RAAS required a GPS source. At the time of the incident, Air Canada operated 42 A320-200 airplanes, some of which were equipped with a GPS; the incident airplane was not equipped with a GPS. A June 2018 e-mail from Air Canada to the NTSB indicated that all of the airplanes in the company's A320-200 fleet had been equipped with a GPS. (b) Honeywell also offered another optional feature, the SmartRunway system, which was designed to alert flight crews to an impending taxiway landing as well as an impending taxiway takeoff.

[67] The FDR did not record true track, true heading, and vertical speed parameters, which were necessary for the simulation, so Honeywell derived those parameters using the magnetic heading, magnetic variation, drift angle, and/or pressure altitude that the FDR recorded.

approach) as “Autopilot or Flight Director systems directed by pilot selected commands” and a managed approach as “Autopilot or Flight Director systems directed by FMGS [flight management guidance system] capabilities.”[68] The FMGS-generated information on the electronic flight instrument system included the flight plan, the airplane’s position and lateral deviation from the flight plan, the approach, and raw data from tuned navigational aids.

Air Canada’s *Flight Operations Manual,* section 8.9.10.1, “Arrival Preparation,” stated that, before briefing the arrival and approach, a flight crew should obtain the current ATIS, review applicable NOTAMs, and program the FMS/FMGS with the required data and cross-check the entries with the appropriate charts. Section 8.9.10.3, “Arrival and Approach Briefing,” provided flight crews with information on briefing the approach and arrival into an airport. The manual stated that the purpose of the arrival and approach briefings, which the pilot flying was required to perform for all approaches (including visual approaches), was “to enhance situational awareness and clarify expectations.” The manual also addressed the threat briefing, indicating the following:

> Beginning with the Pilot Monitoring (PM)…and ending with the Pilot Flying (PF), each crew member should identify any relevant threats that are anticipated during descent, arrival, approach, landing and taxi-in that pertain to their role, as well as strategies to mitigate them.

Air Canada’s Threat Briefing Reference Card indicated that a threat briefing was expected to be performed as part of the approach briefing. The card also indicated that the threat briefing was to be performed by both the pilot flying and the pilot monitoring. The card included examples of threats involving the airplane, operations, ATC, the runway, adverse weather, the operating environment, and the flight crew.[69] “NOTAMS” was listed under the “Operations” heading, “Lighting” was listed under the “Runway” heading, and “Alertness” was listed under the “Flight Crew” heading.

Air Canada’s *A319/A320/A321 Aircraft Operating Manual*, volume 1, section 4, “Standard Operating Procedures,” provided flight crews with guidance about crew coordination during the approach. The manual stated the following:

> The PM must maintain a high level of vigilance in monitoring aircraft position, attitude and configuration and pay close attention to instrument indications. The PF must monitor position through both external references and by reference to NAV systems, including DME [distance measuring equipment] and NAV Display. Use automation functions to the greatest extent possible. Good crew communication is important.

Air Canada’s *A319/A320/A321 Aircraft Operating Manual*, volume 1, section 11, “Approach,” provided flight crews with stabilized approach criteria for various approaches. For

[68] A managed descent is also directed by the FMGS. Most of the Air Canada pilots who were interviewed after the incident stated that they would have flown the FMS Bridge visual approach to runway 28R as a managed descent due to the altitude restrictions and the associated increased workload. Also, the incident first officer stated that he flew a managed descent during the flight into SFO 2 nights before the incident.

[69] The threat briefing card further indicated that the threats included on the card were not “an exhaustive list of all possible threats” and that the flight crew was responsible for briefing any additional threats that might be present.

visual approaches, the manual provided the following criteria: "lateral tracking as close as possible to the extended runway centerline or published inbound course" and "vertical tracking on approximately a 3 degree glide path and using visual approach slope indicators…if available."[70] The manual also stated that the pilot flying and the pilot monitoring should closely monitor flight parameters and that the pilot monitoring should call out any deviation that exceeded the established parameters. Air Canada's *Flight Operations Manual*, section 8.11.9.3, "Go-Around," stated that a go-around should be initiated if "stable approach parameters cannot be met and maintained inside the appropriate gates" (1,000 and 500 ft above airport elevation).[71]

1.6.2 Crew Resource Management

Air Canada provided its pilots with a crew resource management (CRM) manual that included, among other subjects, communication, situational awareness, planning, decision-making, workload management, active monitoring, and threat and error management. A separate document, the company's CRM competency guide, addressed each pilot's responsibilities in the areas of situational awareness, decision-making and problem solving, workload management, professional management, and active monitoring and threat and error management procedures. In the area of situational awareness, the guide indicated that a captain was to "recognize and effectively respond to indications of reduced situational awareness from other crew members." In the area of active monitoring and threat and error management procedures, the guide indicated that the pilot monitoring was to "communicate all errors, omissions, and differences in situational awareness and ambiguities to the PF assertively." Also, in the area of active monitoring and threat and error management procedures, all pilots were to "detect deviations from the desired aircraft trajectory and take appropriate action."

Air Canada provided CRM training during new hire, recurrent, and command upgrade training. The incident captain reported that the training was conducted in a classroom setting with mostly lectures and some scenarios. In 2016, Air Canada revised its CRM training to reflect a threat and error management model. This model focused on the following four levels (from top to bottom) of threat management:

- Proactive—the flight crew briefs and mitigates threats before they are encountered.
- Reactive—an unexpected threat has occurred that the crew must recognize and respond to. If the crew manages the threat, then no error occurs.
- Errors and error management—the crew has mismanaged the threat, and a procedural, communication, or handling error has occurred. If the crew traps the error, safety margins will be maintained.

[70] Postincident interviews and airplane track data suggested that the flight crew used the precision approach path indicator located to the left of runway 28R for glidepath information. FDR data showed that, after the airplane passed F101D (at an altitude of about 1,100 ft), the airplane's glidepath was between 2.1° and 3.2°.

[71] As discussed in section 1.1, other criteria for initiating a go-around were "landing will not be accomplished within the touchdown zone" and "landing will not be accomplished on the runway centerline."

- Undesired aircraft state—a flight crew-induced aircraft state has occurred that clearly reduces safety margins and results in a safety-compromised situation.

The captain's and the first officer's CRM skills were highly rated by other pilots who had flown with them. Although a check airman expressed concern about the first officer's situational awareness (as indicated in section 1.2.2), the check airman described the first officer's overall CRM as "good."

1.6.3 Fatigue Information

Air Canada's *Flight Operations Manual* provided information regarding the development of fatigue and fatigue management. Section 4.12.3, "Circadian Basics," stated that humans "have an internal circadian clock that regulates physiological and behavioural functions on a 24-hour basis" and that "the clock coordinates daily cycles of sleep/wake, performance, physiology, mood, and other functions." The manual also discussed circadian disruption by stating that "the circadian clock cannot adjust immediately when a person suddenly changes schedule (e.g., by flying into a new time zone or changing to a new work/rest schedule)." The manual further stated that flying into a new time zone produces "a challenge to the circadian clock" because "it can take several days or weeks for the clock to get into step with the new local time." In addition, the manual stated that, between 0300 and 0500 (body clock time zone), "physiological sleepiness peaks, and virtually all aspects of alertness and performance slow and can be reduced."

Section 4.12.5, "Preventive Strategies," stated that "naps can acutely improve alertness and performance, and even short naps can provide benefits." The manual also stated that "a nap reduces the duration of continuous wakefulness before a work period, and can be particularly beneficial before a period of night work, when the challenge of working through the circadian low point is also a factor."

Section 4.12.6, "Operational Countermeasures," discussed strategies for pilots to counteract fatigue while on duty. The section noted that such countermeasures, which included controlled rest (a planned cockpit rest period to improve subsequent performance and alertness) were "meant to temporarily enhance alertness and performance…so that operational safety and efficiency are maintained." Regarding controlled rest, the manual advocated the use of "strategic naps" in appropriate circumstances and indicated that "napping is the only operational countermeasure that addresses one of the major physiological causes of fatigue – the need for sleep – and reverses it."[72]

1.6.4 Event Reports

Air Canada's *Flight Operations Manual*, section 12.2, "Definitions, Procedures, and Report," stated the following: "Any aircraft accident, incident, emergency, or other safety related event which may require investigation, monitoring or tracking shall be reported to Dispatch as soon as possible. In addition, the flight crew should file an ASR [air safety report] when time

[72] Air Canada officials stated, during postincident interviews, that the company's controlled rest policy is generally used by overseas flight crewmembers who do not have a relief crewmember. Air Canada requests that crewmembers who use the controlled rest policy file a fatigue report.

permits."[73] (ASRs are voluntary.) The section provided examples of reportable safety events, including unusual or abnormal aircraft handling; significant navigation errors or technical navigation problems; breach of air regulations, ATC irregularities, or a near miss; an unstable approach; a go-around; and any other hazard that poses a direct threat to flight safety.

Chapter 3 of the manual, "Safety Management System," section 2.5.1, stated that an ASR is "an electronic or paper medium through which employees are able to identify hazards, incidents, and accidents which impact the operational safety of Air Canada." The section also stated that ASRs are "de-identified and accessible by all levels of management who are required to regularly review, provide feedback, and monitor the progress of analysis and investigations."

During postincident interviews, the first officer stated that he and the captain met about 1100 on the morning after the incident to discuss the facts of the incident for the ASR, and the captain stated that he contacted company flight dispatch later that day to report the event.[74] Air Canada records showed that the captain reported the event to dispatch about 1608 (1908 EDT) on July 8. The dispatcher who spoke with the captain stated that he reported that the airplane was lined up with the wrong runway and that a go-around ensued.[75] The dispatcher also stated that the captain's report sounded "innocuous" and that, because of the late notification (16 hours after the incident), he did not think that the event was serious.

The captain stated that he also spoke with the duty pilot to report that he had aligned the airplane with a taxiway and performed a go-around.[76] The captain indicated that the duty pilot asked him whether the localizer was tuned, and the captain replied that it was not tuned for the first approach but was tuned for the second approach. According to Air Canada's vice president of safety, after the flight crew notified the duty pilot of the incident, the senior director of line operations determined that the flight crew would be allowed to operate the flight from SFO to YYZ (using a different airplane than the incident airplane) and then "would be held out of service" after arriving at YYZ later that day. Air Canada's director of corporate safety, investigations, and research stated that the incident airplane had flown about 40 hours before Air Canada senior officials became aware of the severity of the incident and realized that data from the airplane needed to be retrieved.[77] Air Canada's safety department was not consulted on the decision to keep

---

[73] (a) Air Canada's *Flight Operations Manual*, section 8.16, "Post Flight," stated that flight crews should brief company dispatch after a flight about any "significant operational factors." (b) At the time of the incident, Air Canada did not define "as soon as possible" regarding the pilot's responsibility to report events to dispatch. In a May 2018 revision to its *Flight Operations Manual*, Air Canada defined "as soon as possible" as "to accomplish promptly or as soon as time permits." This and other postincident actions taken by Air Canada are discussed in appendix B.

[74] The captain stated that he did not report the incident to company dispatch shortly after it occurred because he was "very tired" and it was "very late."

[75] The NTSB listened to a recording of the captain's call to dispatch and confirmed that the captain indicated that he aligned the airplane with the "wrong runway."

[76] Air Canada's *Flight Operations Manual*, chapter 3, "Organizational Structure, Publications, and Documentation," stated that the duty pilot was an Air Canada flight operations manager who was responsible "for all operational and administration decisions during times when other managers are not available." The duty pilot acted on behalf of Air Canada flight operations senior management.

[77] FDR data showed that the incident airplane departed SFO at 0747 (1047 EDT) on July 8 and arrived at Pierre Elliott Trudeau International Airport, Montreal, Canada, the same day at 1245 (1545 EDT). Because the airplane continued to fly after the incident occurred, CVR data from the incident flight were overwritten, and the FDR recorded more than 41 hours of data during eight flights after the incident flight.

the incident airplane in service and have the flight crew continue with the planned flight to YYZ, even though the safety department was generally included on such decisions.[78]

During a postincident interview, the captain stated that the duty pilot asked him to file an ASR. The captain indicated that he had filed an ASR on July 8, but Air Canada's director of corporate safety, investigations, and research stated that no safety report was on file when he learned about the event through an e-mail from the Transportation Safety Board of Canada (TSB) about 2200 EDT on July 9.[79] (This director stated that the ASR had been "sitting in the system" and was received on either July 10 or 11. The director further stated that company tablets were used to send ASRs and that the reports could only be transmitted if a tablet was connected to Wi-Fi.)

The Air Canada A320 assistant chief pilot stated, during a postincident interview, that she and other Air Canada officials met with the incident flight crew on July 10. According to the A320 assistant chief pilot, the flight crewmembers stated that they performed a go-around at an altitude of about 400 feet and that they did not realize that the airplane was aligned with a taxiway until "very late in the approach." She also stated that the crewmembers were then told that ACA759 had overflown airplanes on a taxiway and that the crewmembers' responses were "shock" and "surprise."

In addition, the SFO acting air traffic manager reported that he and other ATCT personnel interviewed the incident captain at 1140 on July 8. During that conversation (which was not recorded), the acting air traffic manager notified the captain of the possible pilot deviation. According to FAA Order JO 7210.632, *Air Traffic Organization Occurrence Reporting*, this notification is provided when an "employee providing air traffic services determines that pilot actions affected the safety of operations." The order also indicated that this notification was to be part of the air traffic mandatory occurrence report and that the flight crew should be notified "as soon as operationally practical."[80]

1.6.5 Plan Continuation and Expectation Bias Training

On April 1, 2017, Air Canada implemented part of its training on plan continuation and expectation bias, which was presented to company pilots during annual recurrent training.[81] This training comprised an 8-minute video, titled "Understanding Gut Feel." The video explained that a gut feeling was "a sense of knowing things before we can consciously know them, or communicate them, or even explain them." The video also explained that a gut feeling signaled that "something about this moment is different or strange, something has changed, and this

[78] The NTSB could not determine, on the basis of the available evidence, why Air Canada's safety department was not consulted on these decisions, but the company's flight operations department had the authority to make such decisions without contacting the safety department.

[79] The NTSB learned about this incident from the FAA on July 9 at 1630 EDT (see appendix A) and notified the TSB about the incident at 1840 EDT the same day.

[80] The FAA order further indicated that this notification was "intended to provide the involved flight crew with an opportunity to make note of the occurrence and collect their thoughts for future coordination with Flight Standards regarding enforcement actions or operator training."

[81] Air Canada developed this training after collaborating with a human factors contractor (who was hired a few years before the incident) to help improve the company's performance.

something, yet to be discovered, poses a potential threat." The video further explained that this "signaling usually lasts for only 3 to 4 seconds before we either check it out or talk ourselves out of what it is trying to tell us," which "complicates our ability to translate the messages from the gut."

The video presented a basic strategy for listening to gut feelings when evaluating a situation, as expressed by the acronym "LIVE": listen (to signals), investigate (what has changed or is different), validate (test and confirm a theory about what is different), and express (communicate the concern to others). The video added that, once a person begins listening to gut feelings, that person will become "much more aware and connected" to a working environment.

The incident flight crewmembers had not received this training at the time of the incident because both had completed their most recent training (during the 2016/2017 training cycle) before the video became available (as part of the 2017/2018 training cycle). Air Canada indicated that the incident flight crewmembers would receive the training during their next annual recurrent training.

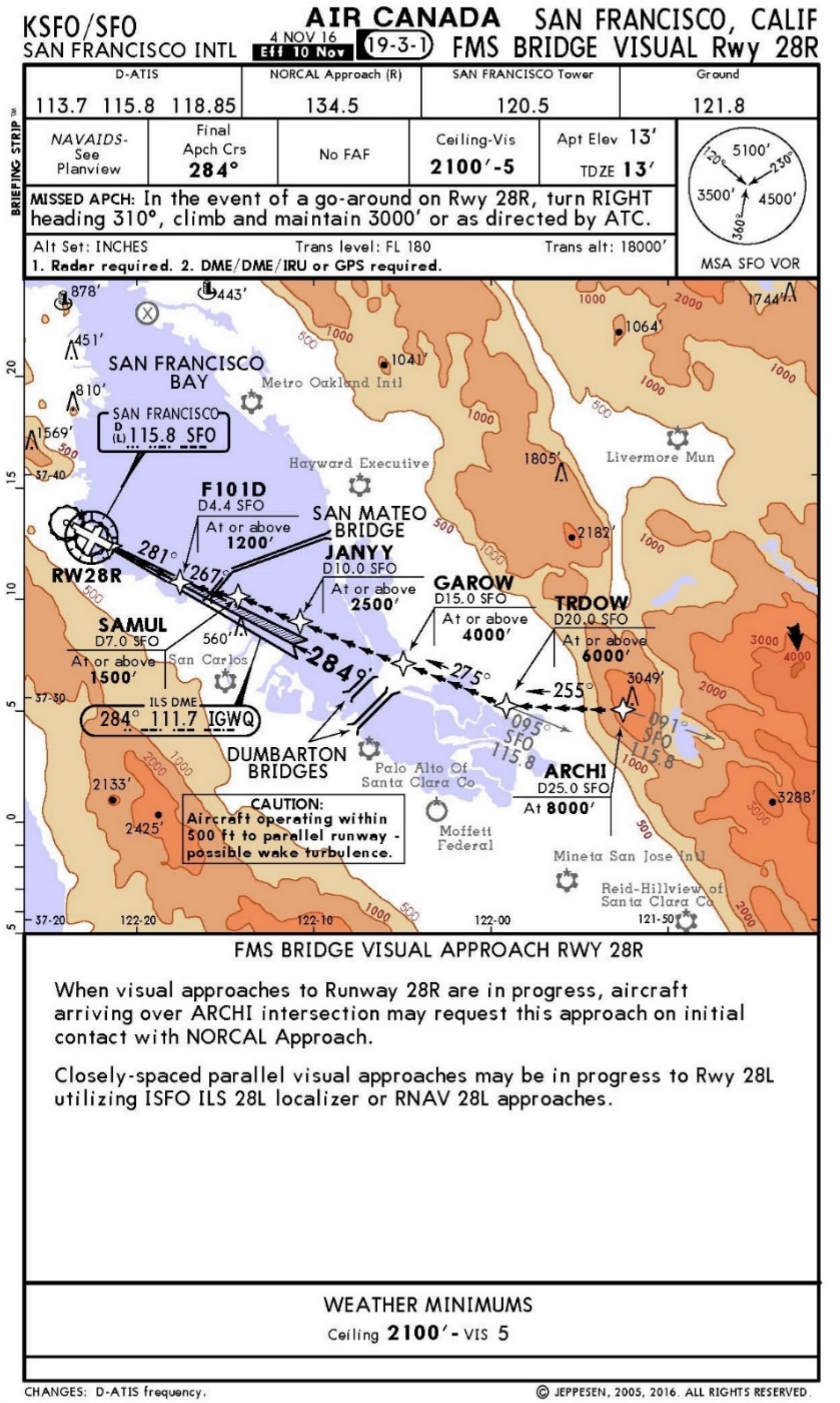
As part of its plan continuation and expectation bias training, Air Canada planned to introduce a 49-slide PowerPoint presentation during the 2018/2019 training cycle to (1) help company pilots understand why experienced professional pilots make errors and (2) examine mitigation strategies to overcome plan continuation and expectation bias. The NTSB's review of the planned presentation found that it defined plan continuation bias as "unconscious cognitive bias to continue [an] original plan in spite of changing conditions" and expectation bias as "when someone expects one situation, she or he is less likely to notice cues indicating that the situation is not quite what it seems." The slides presented two case studies, one in which a flight crew was affected by plan continuation bias, which led to a loss of situational awareness, and one in which a flight crew was affected by expectation bias, which led to crew confusion. The slides also presented countermeasures (which were company CRM competencies) to prevent plan continuation and expectation bias.

1.6.6 Flight Information

Air Canada's FMS Bridge visual approach to runway 28R, the NOTAM information that Air Canada provided in the ACA759 flight release to notify the flight crew about the runway 28L closure, and the display of the ATIS information transmitted to the flight crew about 2321 are shown in figures 9 through 11, respectively.[82] The NTSB added a highlighted box with a dashed

[82] The first officer stated that Air Canada had recently transitioned from paper flight releases to digital flight releases that were accessed on company tablets. The first officer also stated that he would circle or highlight important items on paper flight releases but that the company tablets in use at the time of the incident did not have that capability. (The NTSB notes that the presentation of approach chart information was the same in the paper and electronic versions.) After the incident, Air Canada developed a means for its flight crews to highlight areas or make notes on digital flight releases.

outline to each of these figures to emphasize information related to the circumstances of this incident.



KSFO/SFO **AIR CANADA** SAN FRANCISCO, CALIF

4 NOV 16 (19-3-1A) Eff 10 Nov SAN FRANCISCO INTL

FMS BRIDGE VISUAL APPROACH RWY 28R (RNAV 28R)

The FMS Bridge Visual Approach is coded as the RNAV 28R Approach. Selecting this procedure will display the entire approach procedure, including missed approach guidance.

The FMS Bridge Visual Approach must be requested on initial contact with NORCAL Approach.

Embraer
Select the RNAV 28R approach from the database. Manually tune and preview the ILS 28R. Intercept the FMS Bridge Visual in LNAV and descend via the profile.

A319/320/321
Anticipate crossing ARCHI at 8,000'. Select the RNV28R approach from the database. Tune the ILS 28R. Intercept the FMS Bridge Visual track in NAV and descend via the profile. At or before F101D, disengage autopilot and continue as per Visual Approaches (SOP).

The FMS Bridge Visual Approach is a visual approach procedure. Crews are responsible for traffic watch. ATC may amend the FMS procedure or impose additional restrictions during the approach. Clearance may also be issued to follow the FMS path or intercept the final approach course prior to receiving clearance for the approach. When doing this, the controller should use the following phraseology: 'PROCEED DIRECT ARCHI, MAINTAIN EIGHT THOUSAND, INTERCEPT FINAL APPROACH COURSE or INTERCEPT FMS APPROACH COURSE'

NOT FOR NAVIGATION

CHANGES: None.

Source: Air Canada.

Figure 9. Approach procedure (two pages).

Note: The NTSB added the highlighted box with a dashed outline (on the second page of the approach procedure) for emphasis. The approach chart is 8.5 inches long and 5.5 inches wide.

ACA 0759 CYYZ/KSFO 08.JUL.2017/0055z [printed: 07JUL/2313z]

```
SFO  10.Apr.2017 0700z - 30.Nov.2017 1200z DA4069/17
SFO 04/069 SFO OBST CRANE (ASN 2016-AWP-2357-NRA) 373703N1222260W
(0.4NM WSW SFO) 251FT (240FT AGL) FLAGGED AND LGTD
1704100700-1711301200
.
TEMP WAT CHARTS NOT REQD.

SFO  24.Mar.2017 2254z - 16.Dec.2017 1200z DA3212/17
SFO 03/212 SFO OBST CRANE (ASN 2016-AWP-2987-NRA) 373724N1222352W
(1.1NM WNW SFO) 251FT (245FT AGL) FLAGGED AND LGTD
1703242254-1712161200
.
TEMP WAT CHARTS NOT REQD.

SFO  21.Mar.2017 1939z - 31.Jul.2017 1300z 1A975/17
TAXILANE M CL LGT U/S

SFO  03.Feb.2017 1340z - 03.Aug.2022 1340z DA2027/17
SFO 02/027 SFO OBST CRANE 2016-AWP-3218-NRA 373648N1222258W (1500FT
W APCH END RWY 01L) 133FT (125FT AGL) FLAGGED AND LGTD
1702031340-2208031340
.
TEMP WAT CHARTS NOT REQD

SFO  03.Feb.2017 1340z - 03.Aug.2022 1340z DA2025/17
SFO 02/025 SFO OBST CRANE 2016-AWP-3216-NRA 373650N1222318W (1500FT
W APCH END RWY 01L) 133FT (125FT AGL) FLAGGED AND LGTD
1702031340-2208031340
.
TEMP WAT CHARTS NOT REQD

SFO  04.Nov.2016 0934z - PERM 1A2850/16
APRON TAXILANE H1 CLSD

SFO  11.Oct.2016 2035z - 11.Apr.2018 2300z DA10047/17
SFO 10/047 SFO OBST CRANE (ASN 2016-AWP-2427-OE) 373536N1222306W
(1.6NM SSW SFO) 100FT (61FT AGL) LGTD 1610112035-1804112300
.
TEMP WAT CHARTS NOT REQD

SFO  07.Jul.2016 1857z - 10.Nov.2017 0100z DA7029/17
SFO 07/029 SFO OBST CRANE (ASN 2016-AWP-1309-OE) 373960N1222356W
(3.1NM NNW SFO) 372FT (298FT AGL) FLAGGED AND LGTD
1607071857-1711100100
.
TEMP WAT CHARTS NOT REQD

SFO  11.Feb.2016 1446z - 01.Aug.2017 2300z DA2057/17
SFO 02/057 SFO OBST CRANE (ASN 2016-AWP-74-NRA) 373644N1222308W
(0.6NM SW SFO) 158FT (150FT AGL) FLAGGED AND LGTD
1602111446-1708012300
.
TEMP WAT CHARTS NOT REQD

SFO  19.Sep.2007 1546z - UFN CN815/07  - CO NOTAM
THE DESTINATION AND/OR ALTERNATE AIRPORT IS A GROUP II FAA SPECIAL
QUALIFICATION AIRPORT. THE CAPTAIN MUST MEET CERTAIN REQUIREMENTS TO
OPERATE INTO THIS AIRPORT - SEE FOM 5.4.5.2 OR JEPPESEN AIR CANADA
"AIRPORT QUALIFICATION" PAGE.

Runway
**NEW**SFO  08.Jul.2017 0600z - 08.Jul.2017 1500z DA7026/17
SFO 07/026 SFO RWY 10R/28L CLSD 1707080600-1707081500

**NEW**SFO  08.Jul.2017 0600z - 08.Jul.2017 1500z DA7025/17
SFO 07/025 SFO RWY 01R/19L CLSD 1707080600-1707081500

**NEW**SFO  08.Jul.2017 0600z - 08.Jul.2017 1500z 1A2281/17
RWY 10R/28L CLSD

**NEW**SFO  08.Jul.2017 0600z - 08.Jul.2017 1500z 1A2280/17
RWY 01R/19L CLSD

SFO  02.Jun.2017 1357z - 21.Jul.2017 1500z 1A1951/17
RWY 28L ALS U/S
```

© Smart4Aviation   Page 8 of 27

Source: Air Canada.

Figure 10. NOTAM showing runway 28L closure.

Note: (a) The NTSB added the highlighted box with a dashed outline for emphasis. (b) The information on this page of the flight release appeared under the gray highlighted heading "DESTINATION" on the previous page of the flight release. (c) The highlighted NOTAM was issued by the FAA; the third "NEW" NOTAM, which contains the same information as the FAA (domestic) NOTAM, was issued by the International Civil Aviation Organization. (d) Paper flight release information is 11 inches long and 8 inches wide.

07/08/2017 06:21:11
QU DDLXCXA
ATSACXA 080621
DAI
AN C-FKCK
- /ATSACXA.TI2/KSFO ARR ATIS Q
0556Z SFO ATIS INFO Q 0556Z. 31012KT 10SM CLR 17/09 A2993 (TWO NINER NINER THREE)
QUIET BRIDGE VA IN USE. LNDG RWYS 28R. DEPG RWYS 1L. NOTAMS... RWYS 28L, 10R
CLSD. RWYS 1R, 19L CLSD. TWY J CLSD, TWY S1 CLSD. TWY F CLSD BETWEEN TWY L, RWY
1L, TWY F1 CLSD BTWN TWY L, RWY 1L. RY 28L ALS OTS, RY 28L/10R CL LGTS OTS
MULTIPLE CRANES UP TO 275 FEET, WEST AND SOUTH OF SFO AIRPORT. ASSC IN USE AC TVT
TRNSPNDR WITH MODE C ON ALL TYS AND RWYS. READBACK OF ALL RWY HOLDING
INSTRUCTIONS IS REQUIRED. ALL ACFT ARE RQRD TO INCL ACFT CLSGN IN ALL RDBKS AND<
ACKMTS. ...ADVS YOU HAVE INFO Q.281B

Figure 11. ATIS information Quebec.

Note: (a) The NTSB added the highlighted box with a dashed outline for emphasis. (b) This display of ATIS information, which was based on the raw text provided by Air Canada, represents what the flight crew would have seen on the ACARS screen. Nonpertinent items from the raw text, such as coding at the end of each line, have been deleted. The docket for this incident contains the raw ATIS information text. (c) ACARS information is printed on a paper roll that is 4.25 inches wide. The length varies according to the information to be printed.

1.7 Additional Information

1.7.1 Wrong Surface Landings Video

In August 2018, the FAA announced its new video highlighting wrong surface landings and provided pertinent data as part of the announcement (FAA 2018b). The FAA's data showed that 85% of wrong surface landings involved general aviation aircraft (with the remainder involving commercial aircraft). The data also showed that parallel runways accounted for 75% of wrong surface landings. In addition, the video (dated July 25, 2018) indicated that 85% of wrong surface landings occurred at level 9 or lower ATCT facilities.[83]

1.7.2 Safety Alert for Operators

On August 18, 2017, the FAA issued Safety Alert for Operators (SAFO) 17010, "Incorrect Airport Surface Approaches and Landings," to provide "some best practices for approaching and landing on the correct airport surface." The best practices described in the SAFO included

[83] Small ATCT facilities are classified as levels 4 through 6, and medium ATCT facilities are classified as levels 7 through 9. The SFO ATCT was considered to be a level 10 facility.

- performing a stabilized approach, which "is critical to pilots and flightcrews for maintaining situational awareness of the external environment";
- using technology, including ILS and RNAV published approaches or FMS RNAV aids "to support pilot and flightcrew decisions";
- employing CRM, which is "imperative because it leverages the skills of all crew-members…and delineates job functions and the expectation of support";
- using available resources, which include reviewing airport lighting, reviewing and discussing NOTAMs, and monitoring ATIS information; and
- being ready to go around, including understanding the reasons why a go-around might be warranted and, if necessary, taking that action "early, particularly during a time of confusion."

The SAFO indicated that the SFO incident highlighted the importance of these best practices. In the SAFO, the FAA strongly urged directors of operations, directors of safety, directors of training, and chief pilots to collaborate to

- emphasize existing procedures to ensure approaches to and landings on the correct airport surface,
- provide information to flight crewmembers about recent incorrect surface landing events and the importance of proactively reducing that hazard,
- ensure that all training refers to best practices that support approaches to and landings on the approved runway, and
- emphasize the need for crew rest and vigilance when a work schedule "takes a crewmember outside of his or her normal day."

1.7.3 Canadian Fatigue Regulations

Canada's flight and duty time and rest requirements have been in effect since 1996. Transport Canada's "Guidance Material Concerning Flight Time and Flight Duty Time Limitations and Rest Periods," indicated the following about pilots on reserve duty:

> When a flight crew member is on reserve, an air operator must provide the flight crew member with the opportunity to obtain at least 8 consecutive hours [of] sleep in any 24 hours by one of the 3 methods indicated in the standard. When that flight crew member is contacted and required to report for duty during the period of reserve duty, the flight crew member is no longer considered to be on reserve but on duty…. This means that at anytime during the reserve period, a flight crew member can be required to start a 14 hour duty period…. A flight crew member therefore must remain rested while on reserve such that they are able to cope with a full duty day if called.

Air Canada Pilots Association and Safer Skies, which comprises five unions in Canada, have been advocating for stricter rest requirements and flight time limitations to address pilot fatigue, including fatigue in reserve duty pilots. In 2010, the Canadian Aviation Regulatory Advisory Council Working Group began an effort to update Canada's regulations relating to fatigue (*Canadian Aviation Regulations* 700.16, "Flight Duty Time Limitations and Rest Periods.") In 2014, Transport Canada released a draft of proposed new regulations and, in 2017, revised the draft regulations, but no changes to regulations relating to fatigue have been implemented.

2. Analysis

2.1 Introduction

This incident occurred when ACA759 overflew four air carrier airplanes on a taxiway at a low altitude. ACA759 had been cleared to land on runway 28R at SFO, but the flight crew aligned the airplane with parallel taxiway C instead. The flight crew initiated a go-around, which avoided a collision between ACA759 and one or more of the airplanes on the taxiway. None of the crewmembers and passengers aboard the airplanes were injured, and none of the airplanes involved in this event were damaged. ACA759 was operated by Air Canada under IFR and the provisions of 14 *CFR* Part 129.

The following analysis discusses the incident sequence (section 2.2) and evaluates the following:

- reasons for the flight crew's surface alignment error, including the roles of expectation bias and fatigue (section 2.3);
- the reporting of the incident (section 2.4);
- ATC issues, including frequency congestion and the technology available to SFO controllers at the time of the incident (section 2.5); and
- the effectiveness of runway closure markers currently in use in the national airspace system (section 2.6).

After completing a comprehensive review of the circumstances that led to this incident, the investigation established that the following factors did not contribute to the cause of the incident:

Flight crew qualifications. The flight crew was properly certificated and qualified in accordance with Canadian regulations, Air Canada requirements, and 14 *CFR* Part 129.

Flight crew medical conditions. The flight crew held valid and current Canadian medical certificates. The captain and the first officer reported no medications, medical conditions, or sleep disorders during their required medical examinations and during postincident interviews.

Airplane mechanical conditions. The airplane was properly certificated, equipped, and maintained in accordance with Canadian regulations and 14 *CFR* Part 129. No evidence indicated any structural, engine, or system failures.

Airport lighting. Runway 28R (the intended landing runway for the flight) and parallel taxiway C at SFO met the requirements for lighting in 14 *CFR* Part 139. The runway 28R approach lights were on as the incident airplane approached SFO. Title 14 *CFR* 139.311 required taxiways to have one of four types of lighting systems, one of which was centerline lights, which were present and illuminated on taxiway C. The runway and taxiway centerline lights were set at step 1 (out of 5), which was appropriate for the weather conditions on the night of the incident.

Thus, the NTSB concludes that none of the following were factors in this incident: (1) flight crew qualifications, which were in accordance with Canadian and US regulations; (2) flight crew medical conditions; (3) airplane mechanical conditions; and (4) airport lighting, which met US regulations.

2.2 Incident Sequence

2.2.1 Notification of Runway 28L Status

SFO runway 28L was scheduled to close at 2300 on the night of the incident due to construction, and a NOTAM in the flight release for ACA759 provided information about the closure. The captain stated that he and the first officer discussed the runway 28L closure while at the departure gate but that they did not place much emphasis on this information because the captain thought that the flight would land before the runway would be closed.[84] (The NTSB notes that the flight was originally scheduled to land 3 minutes after the runway 28L closure.) However, the airplane pushed back from the gate 30 minutes late due to the delayed arrival at YYZ of the airplane to be used for the flight and took off about 49 minutes later than the scheduled takeoff time. Even though the flight crewmembers knew, during their preflight preparations, about ACA759's delayed departure, no evidence indicated that the crewmembers reconsidered the importance of the NOTAM information at that time or as the airplane approached SFO. For example, as part of the approach briefing, the flight crew was required to perform a threat briefing, but none of the threats that the pilots reportedly briefed related to the runway 28L closure.[85]

Air Canada's standard operating procedures for preparing for an arrival into an airport indicated that the flight crew was, among other things, to obtain the current ATIS and review applicable NOTAMs. ACARS data showed that the flight crew requested ATIS information, and the ACARS message displaying ATIS information Quebec was sent to the airplane about 2321, which was several minutes before the airplane began its descent from cruise altitude; at that time, the crew's workload would likely have been lighter compared with later phases of flight. The ATIS information included a NOTAM indicating that runway 28L was closed, but neither flight crewmember recalled seeing this information. Section 2.3.2 discusses the effect of the runway 28L closure on the flight crew's ability to identify the intended landing surface.

2.2.2 Preparations for the Descent

Air Canada standard operating procedures stated that descent preparation should be completed before the top of the descent and listed the tasks that needed to be completed. The pilot monitoring (in this case, the first officer) was to use the MCDU to reference the radio/navigation page and set navigational aids into the FMC and then check that the ILS identifier shown on the

[84] The captain provided this account during his second postincident interview with the NTSB. This information differed from the account that he provided, and the account that the first officer provided, during their first postincident interviews with the NTSB (see section 1.1).

[85] As previously stated, Air Canada's Threat Briefing Reference Card indicated that NOTAM information was one of the threats expected to be included in a threat briefing.

PFDs was correct.[86] The pilot flying (in this case, the captain) was to review the approach programming in the MCDU and complete an approach briefing, which included verifying that the primary approach aid (ILS) identifier and frequency were properly set.

ATIS information Quebec indicated that the Quiet Bridge visual approach was in use and that arriving airplanes would be landing on runway 28R. The flight crew used Air Canada's FMS Bridge visual approach procedure, which was based on the Quiet Bridge visual approach procedure, for the approach to runway 28R. Air Canada's FMS Bridge visual approach chart consisted of two pages. The first page showed the approach procedure and included the ILS frequency for runway 28R in the plan view. The second page of the approach chart was in text format and indicated that Airbus A319/A320/A321 pilots should tune the ILS for runway 28R, which would provide flight crews with backup lateral guidance (via the localizer aligned with the runway heading) during the approach. This lateral guidance would supplement the visual approach procedures.

The first officer stated that, when he set up the approach in the FMC, he missed the step in the procedure to manually tune the ILS frequency, and FDR data showed that no ILS frequency had been entered for the approach. According to Air Canada personnel, the FMS Bridge visual approach was the only approach in the company's Airbus A320 database that required manual tuning of an ILS frequency, which might have contributed to the first officer's failure to input the frequency (as discussed below). However, the first officer's error should have been caught by the captain as part of his verification of the approach setup during the approach briefing. If cockpit voice recorder (CVR) information had been available for this incident (as discussed further in section 2.4), the NTSB might have been better able to determine whether distraction, workload, and/or other factors contributed to the first officer's failure to manually tune the ILS frequency and the captain's failure to verify that the ILS frequency was tuned. The NTSB concludes that the first officer did not comply with Air Canada's procedures to tune the ILS frequency for the visual approach, and the captain did not comply with company procedures to verify the ILS frequency and identifier for the approach, so the crewmembers could not take advantage of the ILS's lateral guidance capability to help ensure proper surface alignment.

The flight crew of DAL521, which preceded the incident airplane to SFO, was also flying the FMS Bridge visual approach to runway 28R. The DAL521 airplane landed on runway 28R without incident (despite confusion regarding the identification of the runway surface, as discussed in section 1.1.1) because the flight crew used LNAV guidance to align with the runway. The DAL521 captain confirmed that the airplane was aligned with runway 28R as he visually acquired the painted "28R" on the runway surface when the airplane was at an altitude of about 300 ft. The DAL521 captain stated, during a postincident interview, that the runway 28R and taxiway C surfaces could have been confused if the approach was not backed up with lateral guidance.

The incident captain's failure to recognize that the ILS frequency had not been manually tuned suggests insufficient preparation for the approach.[87] The first officer might have missed the

[86] One of the incident flight crewmembers would have had to select the "LS" buttons on the glareshield for ILS information to appear on the PFDs.

[87] The captain's request for the first officer to set the runway heading, as discussed in section 2.2.3, also suggests insufficient preparation for the approach.

step to manually tune the ILS frequency because Air Canada flight crews were not required to take this action for any approach other than the FMS Bridge visual approach, which provided an opportunity for an omission error (flight crew inaction). It is also possible that the first officer missed the information on Air Canada's FMS Bridge visual approach chart about manually tuning the ILS frequency because of the presentation and position of that information. Specifically, the instruction was embedded in the middle of a paragraph on the second (and last) page of the approach chart, as shown in figure 9, which was not optimal for capturing pilot attention because the action item could be overlooked. The instruction to manually tune the ILS frequency for the FMS Bridge visual approach could have been emphasized, for example, as part of a bulleted list, which Air Canada used in other company procedures to draw pilots' attention to relevant information.

The NTSB concludes that the flight crew's failure to manually tune the ILS frequency for the approach occurred because (1) the FMS Bridge visual approach was the only approach in Air Canada's Airbus A320 database that required manual tuning of a navigation frequency, so the manual tuning of the ILS frequency was not a usual procedure for the crew, and (2) the instruction on the approach chart to manually tune the ILS frequency was not conspicuous during the crew's review of the chart. Although the incident flight was operating under 14 *CFR* Part 129, the approach chart that the flight crew used was originally developed by an air carrier operating under 14 *CFR* Part 121. Therefore, the NTSB recommends that the FAA work with air carriers conducting operations under 14 *CFR* Part 121 to (1) assess all charted visual approaches with a required backup frequency to determine the FMS autotuning capability within an air carrier's fleet, (2) identify those approaches that require an unusual or abnormal manual frequency input, and (3) either develop an autotune solution or ensure that the manual tune entry has sufficient salience on approach charts. The NTSB notes that, after the incident, Air Canada revised its procedures so that the FMS Bridge approach to runway 28R would be flown as an instrument approach. (More information about Air Canada's postincident actions can be found in appendix B.)

The NTSB notes that the FAA, as part of its work with the Commercial Aviation Safety Team (CAST), would be in an ideal position to act on Safety Recommendation A-18-23 through the CAST safety enhancement process because of the team's shared interest in mitigating commercial aviation safety issues.[88] Also, according to the FAA, CAST is moving toward "a proactive approach that focuses on detecting risk and implementing mitigation strategies before accidents or serious incidents occur" (FAA 2017).

2.2.3 Initial Approach

Air Canada's procedures allowed pilots to decide whether to descend using the managed or open descent autopilot mode. The first officer reported that the approach was conducted using the open descent mode. With the open descent mode, pitch control maintains the target speed/Mach number, and autothrust maintains idle thrust. The captain reported that he initially flew the approach using the selected descent mode, which, according to Air Canada, was synonymous with the open descent mode. However, the captain also reported that he subsequently flew the approach using the managed descent mode, which guides an airplane to the deceleration point along the

[88] In addition, the FAA has a broader oversight role of ensuring that operational risks are appropriately evaluated under air carriers' safety management systems (14 *CFR* Part 5, "Safety Management Systems").

flightpath that was computed by the FMGS and, unlike the open descent mode, considers speed and altitude constraints.

The NTSB was unable to determine whether the approach was flown using the open or managed descent mode because of the differing statements from the captain and the first officer and the lack of FDR parameters to show flight mode annunciator indications. However, the first officer perceived that the descent was being flown using the open descent mode, which increased his workload during a critical phase of flight because he had to ensure, among other things, that altitude constraints were met. The first officer stated that he thought that it was unusual to use the open descent mode, but he did not notify the captain about his concern because the procedure was allowed (until reaching the final waypoint on the approach, F101D). This and other breakdowns in CRM during the incident flight are discussed in section 2.2.5.[89]

The captain flew the FMS Bridge visual approach to runway 28R with the autopilot engaged until just before F101D. After the airplane reached F101D and the autopilot was disconnected, the first officer began setting the altitude and heading for a missed approach, which diverted his attention from monitoring the approach as the captain aligned the airplane with taxiway C.[90] The NTSB recognizes that the first officer set the missed approach altitude and heading at an appropriate time (given his perception that the airplane was being flown in the open descent mode). However, his attention was further diverted from monitoring the approach when the captain requested that the first officer set the runway heading. The first officer stated that he had difficulty locating the runway heading information on the approach chart and had to find it on another chart, which extended the first officer's heads-down time after the airplane passed F101D.

If the first officer had been monitoring the approach at this point, he might have realized, among other things, that the ILS frequency and identifier and the runway 28R extended centerline were not depicted on his PFD.[91] The NTSB concludes that the first officer's focus on tasks inside the cockpit after the airplane passed the final waypoint reduced his opportunity to effectively monitor the approach and recognize that the airplane was not aligned with the intended landing runway.

2.2.4 Final Approach Segment and Go-Around

The airplane passed F101D at an altitude of about 1,100 ft. Shortly afterward, the captain noticed lights going across what he perceived to be the runway surface. According to the first officer, between that time and the time that the airplane descended to an altitude of 600 ft, the

[89] Other breakdowns in CRM indicated an apparent lack of preparation for the approach, including both flight crewmembers' (1) ineffective review of the runway 28L closure NOTAM before the flight and when ATIS information Quebec was received and (2) lack of discussion about the runway 28L closure during the approach briefing.

[90] Because the first officer perceived that the approach was being flown using the open descent mode, he would not have set the missed approach altitude until the airplane reached its minimum altitude for the descent (1,200 ft msl) or the captain was no longer using the autopilot and flight director for guidance.

[91] Air Canada's stabilized approach criteria for a visual approach included lateral tracking as close as possible to the extended runway centerline or the published inbound course. However, the flight crew could not have verified that the airplane was tracking close to the extended runway 28R centerline given that the extended centerline information would not have been electronically depicted (because the ILS/localizer frequency had not been tuned).

captain requested that the first officer contact the tower controller to verify that the runway was clear. According to the ATC voice recording and the NTSB's airplane performance study, when the flight crew transmitted, "we see some lights on the runway there, across the runway. Can you confirm we're cleared to land?" the airplane was passing through an altitude of 300 ft.

The controller had scanned the runway just before receiving the flight crew's transmission. While receiving the transmission, the controller scanned the ASSC and radar displays to check for conflicts and scanned runway 28R again. The controller confirmed that the airplane was cleared to land and stated that no other airplanes were on the runway. At that point, the airplane was passing through an altitude of 200 ft.

The airplane performance study for this incident showed that ACA759 continued the approach and flew over the first airplane on taxiway C (UAL1) at an altitude of 100 ft and that the flight crew initiated a go-around when ACA759 was at an altitude of 89 ft.[92] The airplane performance study also showed that ACA759 flew over the second airplane on taxiway C (PAL115) at an altitude of 60 ft before the airplane began climbing, which resulted in only 10 to 20 ft of vertical separation between the ACA759 and PAL115 airplanes. The NTSB concludes that the flight crew-initiated, low-altitude go-around over the taxiway prevented a collision between the Air Canada airplane and one or more airplanes on the taxiway. Because of the lack of CVR data for the incident flight, the NTSB could not determine what information the pilots discussed, if anything, before and during the go-around. Nevertheless, the NTSB was able to determine the cues that likely led to the flight crew's recognition of its alignment error and the crew's initiation of the go-around maneuver, as discussed in section 2.3.2.2.

The controller recalled that, when ACA759 was about 1/10 mile on short final, the airplane looked "extremely strange" regarding its location relative to runway 28R, taxiway C, and the airplanes along the taxiway. When the UAL1 captain stated, over the tower frequency, "where is that guy going?" at 2355:59, the controller expressed confusion regarding who had made the transmission.[93] (The UAL1 captain did not identify himself during the transmission.) At that point, the controller, who had just checked runway 28R twice, was likely trying to process what he was seeing and hearing. The controller stated, during a postincident interview, that the transmission seemed "out of context."

The controller had no reason to think that ACA759 was lined up with taxiway C before he observed the airplane looking "extremely strange." The ACA759 flight crew had reported that the airplane was on approach to runway 28R, and the ASSC display had previously predicted that the airplane would be landing on runway 28R. Also, the controller had not previously seen an airplane align with taxiway C. Further, the distance and angle (parallax) of the tower cab relative to the approach end of runway 28R and taxiway C would have made it difficult for the controller to visually recognize that ACA759 was aligned with the taxiway instead of the runway, especially at night and with the lights from the construction on runway 28L and airport vehicle movements.

[92] As previously stated, all altitudes in this report are agl (unless otherwise indicated).

[93] The ATC voice recording indicated that, 2 seconds after the UAL1 captain stated, "where is that guy going?" and 2 seconds before he stated, "he's on the taxiway," the controller stated to himself, "who is…talk?"

When the UAL1 captain stated, 4 seconds after his first transmission, “he’s on the taxiway,” the controller might have realized what had happened with ACA759. Because the flight crew had already begun the go-around maneuver (at 2356:05), the airplane was climbing at the time of the controller’s go-around instruction (2356:09). The controller subsequently told the flight crew that the airplane appeared to have been lined up with taxiway C. The NTSB concludes that the controller responded appropriately once he became aware of the potential conflict. A factor that precluded the controller from determining sooner that a potential conflict existed was the ASSC system’s lack of capability to detect a taxiway landing and provide an alert, as discussed further in section 2.5.2.

2.2.5 Crew Resource Management Breakdown

Air Canada’s CRM manual for pilots and the company’s CRM competency guide addressed, among other subjects, situational awareness, workload management, active monitoring, and threat and error management. Several crew actions/inactions during the incident flight demonstrated breakdowns in CRM, many of which were manifested as noncompliance with Air Canada’s standard operating procedures. These crew actions/inactions included

- the flight crew’s ineffective review of NOTAMs in the flight release;
- the flight crew’s failure to identify the runway 28L closure information within the ATIS information;
- the flight crew’s failure to conduct a complete approach briefing;
- the first officer’s failure to manually tune the ILS frequency and the captain’s failure to verify the tuning of the ILS frequency;
- the first officer’s failure to express concern about the perceived use of the open descent mode; and
- the captain’s request, at the final waypoint (F101D), for the first officer to set the runway heading, which took the first officer by surprise and prolonged his heads-down time while the airplane was aligned with the taxiway.

The captain’s and the first officer’s CRM skills were highly rated by other pilots who had flown with them. Also, a review of Air Canada’s CRM training program indicated that the crewmembers received comprehensive CRM training. Thus, although errors indicating breakdowns in CRM occurred during the incident flight, those errors did not appear to be consistent with both crewmembers’ performance during other flights (except for a check airman’s report of the first officer’s performance during a flight) and the CRM training that the crewmembers received.[94] Possible explanations for the breakdowns in CRM during the incident flight include

[94] A check airman who had flown with the first officer when he was attempting to upgrade to captain expressed concern about the first officer’s situational awareness, as stated in section 1.2.2.

fatigue (discussed in section 2.3.3) and the high workload associated with the approach, but the NTSB could not identify the source of the breakdowns due to the lack of CVR information.

Air Canada's CRM procedures were designed to reflect a threat and error management model. According to the top level of the model, flight crews were expected to proactively brief and mitigate threats before they are encountered. Company procedures required crews to brief potential threats during the approach briefing. Because both flight crewmembers could not recall the runway 28L closure NOTAM in the flight release and did not assimilate the runway 28L closure information included in the ATIS information, they did not identify the runway 28L closure as a potential threat associated with the approach. (If the flight crew had recalled the runway 28L closure information and briefed it as a threat, that action should have made the information more readily accessible for future recall.)

According to the next level of the model, flight crews were expected to respond when an unexpected threat has occurred and manage the threat so that no error occurs. When the captain aligned the airplane with taxiway C, he did not have any lateral guidance to indicate that the airplane was off course because of the first officer's failure to tune the ILS frequency and the captain's failure to verify that the approach was properly set up. Also, the first officer, as the monitoring pilot, was required to communicate all errors and situational awareness concerns to the captain. However, the first officer was heads down when the captain aligned the airplane with the taxiway because of the time that it took the first officer to locate the runway heading information (in response to the captain's instruction to set the runway heading) and the time needed for the first officer to set the missed approach altitude and runway heading. As a result, neither crewmember realized, once the airplane passed the final waypoint, that the airplane was not aligned with the intended landing runway.

The threat and error management model further indicated that, if the flight crew mismanaged the threat, then a procedural, communication, or handling error could occur. If such an error occurs and the crew traps the error, then safety margins will be maintained. Even though the tower controller confirmed that runway 28R was clear, the flight crew recognized that something was not right with the approach about the time that the airplane passed over the seawall. According to the captain, the first officer called for a go-around at the same time as the captain initiated the go-around maneuver, thereby preventing a collision on the taxiway.

Even though the flight crew performed a go-around at that point, safety margins were severely reduced given ACA759's proximity to the ground (below 100 ft) before the airplane began climbing and the minimal distance between ACA759 and the airplanes on taxiway C. Thus, a flight crew-induced aircraft state that compromised safety—the bottom level of the threat and error management model——resulted from ineffective threat and error management. The NTSB concludes that errors that the flight crewmembers made, including their false assumption that runway 28L was open, inadequate preparations for the approach, and delayed recognition that the airplane was not lined up with runway 28R, reflected breakdowns in CRM and led to minimal safety margins as the airplane overflew taxiway C.

2.3 Reasons for Flight Crew's Misalignment With Taxiway C

The flight crewmembers had recent experience flying into SFO at night: the captain reported that he had flown into SFO one or two times during the previous 4 months, and the first officer was the pilot flying on a flight to SFO 2 nights before the incident. The flight crewmembers' training records indicated no issues with identifying airport surfaces, flying stabilized approaches, and flying visual approaches. The incident occurred in night VMC, and no evidence indicated any obstructions or glare in the cockpit that would have affected the flight crew's view outside of the cockpit windows. However, the flight crewmembers were unable to identify the runway 28R surface (despite the presence of approach and runway lighting) and instead aligned the airplane with parallel taxiway C. Also, neither crewmember recognized that the airplane was not aligned with the intended landing runway until the airplane was over the airport surface, at which time the flight crew initiated a low-altitude go-around. Sections 2.3.1 through 2.3.3 discuss reasons for the flight crew's alignment error and the factors that led to the eventual recognition of this error, and section 2.3.4 discusses the mitigation of such errors.

2.3.1 Flight Crew Awareness of Runway Closure

The flight crew had opportunities before the approach to learn about the runway 28L closure. The first opportunity occurred before the flight when the crewmembers received the flight release. Both crewmembers stated that they reviewed NOTAMs in the flight release. However, the first officer stated that he could not recall reviewing the specific NOTAM that addressed the runway 28L closure. Also, even though the captain stated that he saw the runway closure information, his actions in misaligning the airplane demonstrated that he did not recall that information when it was needed, and he thought that runway 28R was runway 28L. The second opportunity occurred in flight during the crewmembers' preparations for the approach to runway 28R. Both crewmembers recalled reviewing ATIS information Quebec, which they received via an ACARS message in the cockpit, but neither crewmember recalled reviewing the specific NOTAM in the ATIS information that described the runway 28L closure.

Because the flight crewmembers either did not review or could not recall the information about the runway 28L closure, they expected to see two parallel runways while on approach to SFO and further expected that they would need to fly the approach to the right-side surface.[95] The flight crew's recent experience flying into SFO would have reinforced these expectations. For example, when the first officer flew into SFO 2 nights before the incident, the airplane used for that flight landed on runway 28R at 2305, which was about 18 minutes before runway 28L was closed. Also, the captain stated that he had never seen runway 28L "dark" and that none of his previous landings at SFO occurred when a runway was closed.

A runway closure marker with a flashing white "X" was placed at the threshold of runway 28L to indicate the runway closure. However, the flashing "X" would not have been in the flight crew's direct field of view because the "X" was oriented toward the runway 28L final

[95] Industry analysis of traffic patterns at SFO showed that airplanes landing on runway 28R tended to stay more to the right of course when runway 28L was open than when it was closed.

approach corridor and the airplane was not aligned with runway 28L.[96] Also, the flash rate might have been too slow to capture the crew's attention.[97] (The conspicuity of the "X" to flight crews on final approach is further discussed in section 2.6.) The NTSB concludes that the flight crewmembers' lack of awareness about the runway 28L closure and the crewmembers' previous experience seeing two parallel runways at SFO led to their expectation to identify two runway surfaces during the approach and resulted in their incorrect identification of taxiway C instead of runway 28R as the intended landing runway.

The NTSB considered the presentation and priority of the runway 28L closure information compared with other information that the flight crew received. The flight release package was 27 pages long and consisted of, among other items, route, weather, and NOTAM information. The NOTAM indicating the runway 28L closure ("**RWY** 10R/28L **CLSD**") appeared on page 8 of the package, which was also the second page of NOTAM information, under the gray highlighted heading "DESTINATION" (which appeared on the previous page). Features of the NOTAM text emphasized the closure information, such as the use of bold font for the words "**RWY**" and "**CLSD**" and a "**NEW**" designation in red font with asterisks before the NOTAM text, as shown in figure 10.[98] However, this level of emphasis was not effective in prompting the flight crewmembers to review and/or retain this information, especially given the NOTAM's location (toward the middle of the release), which was not optimal for information recall. A phenomenon known as "serial position effect" describes the tendency to recall the first and last items in a series better than the middle items (Colman 2006).

The ACARS message providing ATIS information Quebec, as displayed in the cockpit, was 14 continuous lines with all text capitalized in the same font. As shown in figure 11, the NOTAM indicating the runway 28L closure appeared at the end of line 8 and the beginning of line 9. The uniform presentation of the ATIS information could have contributed to the flight crew's oversight of the runway closure information. The flight crew's receipt of ATIS information Quebec via ACARS was consistent with Air Canada's procedure to obtain ATIS information using either ACARS or VHF communications. Thus, effective presentation of information is important for flight crewmembers who obtain ATIS and other information via ACARS. The capability exists to make important information more conspicuous in an ACARS message by, for example, inserting line breaks within the text to group related information.

The NTSB concludes that, although the NOTAM about the runway 28L closure appeared in the flight release and the ACARS message that were provided to the flight crew, the presentation of the information did not effectively convey the importance of the runway closure information and promote flight crew review and retention. Multiple events in the National Aeronautics and Space Administration's aviation safety reporting system (ASRS) database showed that this issue

---

[96] The size of the "X," 20.5 ft by 20.5 ft, would have appeared small along the 200-ft width of runway 28L.

[97] The "X" flashed on for 2.5 seconds and off for 2.5 seconds, equating to a frequency of 0.2 Hz. Although a 0.2-Hz flash at the threshold of runway 28L might be effective at preventing the use of the runway when closed, the frequency might have been too low to have captured the attention of the ACA759 flight crewmembers unless they had explicitly focused their attention on the approach end of runway 28L.

[98] Although the red text would have been visible during the crewmembers' review of the flight release before departure, the low ambient lighting conditions in the cockpit would likely have made the red text less conspicuous.

has affected other flight crews, indicating that all air carriers could benefit from improved information display in flight releases and ACARS messages.[99]

The way information is presented can significantly affect how information is reviewed and retained. Specifically, when pilots review information, their scan and retention of that information is influenced by the pilots' perceived relevance of the information to a task. Thus, it is possible for a pilot to miss more relevant information when it is presented with information that is less relevant. Although human limitations (such as fatigue and time pressure/workload) may affect the review of information, these limitations can be overcome with effective information presentation. For example, items in the middle of a list can be better retained if the information is presented with "intensity" because a sharp, clear, or salient presentation has a better chance of being recalled compared with less visually stimulating information (FAA 2008). Therefore, the NTSB recommends that the FAA (1) establish a group of human factors experts to review existing methods for presenting flight operations information to pilots, including flight releases and general aviation flight planning services (preflight) and ACARS messages and other in-flight information; (2) create and publish guidance on best practices to organize, prioritize, and present this information in a manner that optimizes pilot review and retention of relevant information; and (3) work with air carriers and service providers to implement solutions that are aligned with the guidance. The NTSB notes that one way to ensure that air carriers effectively present and prioritize relevant information in flight releases and ACARS messages would be to develop an industry standard.

2.3.2 Role of Expectation Bias

2.3.2.1 Initial Taxiway Misalignment

Because the flight crewmembers were not aware of the runway 28L closure, they were likely expecting SFO to be in its usual configuration, which would include runway 28L being open for departures and arrivals and airplanes using taxiway F (as shown in figure 3) to reach the departure end of runway 28L. Because of the runway 28L closure on the night of the incident, airplanes were using taxiway C to depart from runway 28R.

The flight crewmembers stated, during postincident interviews, that the taxiway C surface resembled a runway, which they believed was runway 28R. A cue supporting the crewmembers' perception that they were aligned with runway 28R was the lighting from the airplanes on taxiway C. Specifically, the airplanes' wingtip navigation lights would have partially resembled (width-wise) runway edge lighting.[100] Also, the airplanes' flashing red beacon lights would have

[99] The NTSB conducted an ASRS search to identify reports since 2010 related to flight crew confusion resulting from the depiction of ACARS messages and/or predeparture flight plan information. The NTSB found multiple reports of altitude and lateral deviations in which the pilot cited the formatting of information as a related issue, which further indicates that information display improvements are needed for text-based resources. For more information, see exemplar cases (ACNs [accession numbers] 1282309, 1409095, 1414185, 1447318, 1540033, 1544364, and 820437) in the ASRS database (https://asrs.arc.nasa.gov/search/database.html, accessed September 14, 2018).

[100] The second and third airplanes on taxiway C, an Airbus A340 and a Boeing 787, respectively, had wing spans of about 200 ft, which was also the runway 28R width. (The first airplane on taxiway C, a Boeing 787, also had a wing span of 200 ft, but the airplane was oriented perpendicularly to the taxiway. Thus, those wingtip lights would not have created the illusion to the incident flight crewmembers that they had aligned ACA759 with runway 28R.)

been consistent with features associated with approach lighting. Another cue that would have supported the crew's perception was the presence of runway and approach lights on runway 28R, which would also have been present on runway 28L when open. However, the runway and approach lights on runway 28L were off, and the construction lighting that was reported on the runway 28L surface had features that were consistent with ramp lighting.

A psychological concept associated with perception and decision-making that can allow a mistaken assessment to persist is expectation bias, which refers to the manipulation of perceived elements to values consistent with a person's expectation (Bhattacherjee 2001). A similar concept, confirmation bias, results from a tendency to primarily seek out confirming evidence of a belief while spending less effort seeking out negative evidence that can disconfirm the belief (Nickerson 1998). Thus, expectation bias and confirmation bias can cause a person's incorrect belief to persist despite available contradictory evidence. Both biases occur as part of basic information processing, and a person may not be actively aware of such biases at the perceptual level. In this report, the term "expectation bias" also describes the effects of confirmation bias.

Expectation bias is not a new phenomenon in aviation. The NTSB investigated numerous accidents and incidents that involved pilot errors resulting from expectation bias, particularly in night VMC when fewer cues were available to pilots to aid in airport and runway identification. For example, in January 2014, a Boeing 737 landed at the wrong airport in Branson, Missouri, in night VMC. The flight crew expected that the visually identified airport and runway were the intended destination and did not reference cockpit displays to verify the airport and runway. As a result, the airplane landed on runway 12 at M. Graham Clark Downtown Airport instead of runway 14 at Branson Airport. Also, in November 2013, a Boeing 747 landed at the wrong airport in Wichita, Kansas, in night VMC due to the flight crew's expectation that the observed runway lights were from the intended landing runway at McConnell Air Force Base. Instead, the airplane landed at Colonel James Jabara Airport on a runway that was one-half the length of the intended landing runway. For both of these cases, cues that indicated the flight crew's mistaken perception were available; however, those cues were not effectively used because the crewmembers' expectation bias outweighed the available conflicting cues.[101]

For this incident, lighting aids generally associated with runways were not present on taxiway C. Specifically, although the flight crew perceived the taxiway to be the intended runway, the taxiway did not have a precision approach path indicator, touchdown zone lights, full-length edge lights, and approach lights.[102] However, the absence of these normally conspicuous features of a runway would have been difficult for the flight crewmembers to recognize because of their expectation bias and the inherent difficulty detecting omissions in the environment (the latter of which could have been mitigated if the flight crew had briefed the runway 28L closure). In addition, features present along taxiway C were inconsistent with it being a runway. For example, although the presence of centerline lights along the full surface length was a cue that was consistent

[101] For more information, see NTSB incident numbers DCA14IA037 and DCA14IA016, respectively.

[102] Air Canada's stabilized approach criteria for a visual approach included vertical tracking on approximately a 3° glidepath and using a visual approach slope indicator. Postincident interviews and airplane track data suggested that the captain used the precision approach path indicator located to the left of runway 28R for glidepath information, which was intended for airplanes approaching that runway. The availability of this glidepath information while the airplane was aligned with taxiway C would have supported the flight crew's expectation that the airplane was aligned with runway 28R.

with a runway, the taxiway centerline lights were green, as shown in figure 4.[103] (Runway centerline lights are white.) Also, flashing yellow in-pavement guard lights were present on taxiway C (also shown in figure 4), which would not have been present on a runway surface because the guard lights were designed to prevent a taxiing airplane from crossing onto a runway.

During postincident interviews, the flight crewmembers recalled seeing specific color cues, including the green taxiway centerline lights.[104] However, the flight crew continued the approach despite this conflicting cue. Given that the general outline of airplane lights along taxiway C (in a straight line) had likely confirmed the crew's expectation that the right-side surface was a runway, the omission of conflicting color cues in the crew's assessment of the runway environment was consistent with the effects of expectation bias.[105] The captain of DAL521 (the flight that immediately preceded the ACA759 into SFO) provided a similar assessment during postincident interviews. Specifically, the DAL521 captain stated that the airplane lights on taxiway C gave the impression that that surface could have been a runway.[106]

Although multiple cues were available to the flight crew to distinguish runway 28R from taxiway C, sufficient cues also existed to confirm the crew's expectation that the airplane was aligned with the intended landing runway. As a result, once the airplane was aligned with what the flight crewmembers thought was the correct landing surface, they were likely not strongly considering contradictory information. The NTSB concludes that the cues available to the flight crewmembers to indicate that the airplane was aligned with a taxiway were not sufficient to overcome their belief, as a result of expectation bias, that the taxiway was the intended landing runway.

2.3.2.2 Flight Crew Recognition of Misalignment

The captain stated that, while on final approach, he noticed lights going across what he thought was the runway 28R surface; this description is consistent with the in-pavement guard lights on taxiway C. Despite this cue indicating that the airplane was aligned with a taxiway, the captain's expectation bias continued because of his assumption that the lights were associated with an airplane on the runway surface. The captain then asked the first officer to verify with the controller that the runway was clear. When the first officer looked up after prolonged heads-down time during the approach (see section 2.2.3), the airplane was lined up with the taxiway. However, the first officer presumed that the airplane was aligned with runway 28R due, in part, to his expectation that the captain would align the airplane with the runway, and the first officer did not

[103] The NTSB is currently investigating a December 2017 incident involving a Horizon Air Bombardier Q400 that was attempting to land on runway 6 at Pullman-Moscow Regional Airport, Pullman, Washington, at night. The runway was dark because its lights were out of service, and the airplane landed on the taxiway that was parallel to the runway despite the illumination of blue taxiway edge lights, which the flight crew perceived as dim white runway edge lights. For more information, see NTSB incident number DCA18IA081.

[104] Taxiway lighting at YYZ, where the flight crew was based, was similar to the lighting on SFO taxiway C; both airports had green taxiway centerline lights and blue taxiway edge lights.

[105] The airplanes' wingtip navigation lights were red (left wing) and green (right wing), and the runway edge lighting was white.

[106] The DAL521 captain also stated that, because the lights from the airplanes located on taxiway C were in a straight line, the airplane lights could have been perceived as centerline lights, which could confuse a flight crew.

immediately recognize that the surface ahead was not the intended landing runway. When the first officer contacted the controller, the airplane was about 4,000 ft (0.66 nm) from the airport seawall.

As ACA759 continued to approach the airport seawall, the flight crew of the second airplane on taxiway C, PAL115, saw that ACA759 was lined up with taxiway C, and the PAL115 crew turned on that airplane's landing lights to alert the ACA759 crew. Video information showed that PAL115's landing lights illuminated the surface in front of that airplane as well as the tail and side of the first airplane on taxiway C, UAL1. About this time, the UAL1 captain made the first of two transmissions, on the tower frequency, about the position of an airplane above the airport surface; these transmissions were also available cues for the incident flight crew to recognize ACA759's misalignment.[107]

In addition, about this time, ACA759 descended to an altitude at which its landing lights would have illuminated the environment below. The appearance of airplanes on the surface (especially given that the controller had just advised the flight crew that runway 28R was clear) and the lack of runway markings on the surface should have been additional cues indicating that the airplane was not aligned with runway 28R.

During postincident interviews, the captain and the first officer were unable to identify a specific triggering factor in the environment that led to the decision to initiate and call for, respectively, a go-around. However, all of the cues mentioned above occurred within 6 seconds before the initiation of the go-around (2355:59 to 2356:05). That period is consistent with the time for pilots to recognize a cue, make a decision, and execute an action. The NTSB concludes that multiple salient cues of the surface misalignment were present as the airplane approached the airport seawall, and one or more of these cues likely triggered the captain's initiation of a go-around, which reportedly occurred simultaneously with the first officer's call for a go-around.

2.3.3 Role of Flight Crew Fatigue

The flight crew's work schedule for the incident flight complied with the applicable Canadian flight time limitations and rest requirements (as discussed later in this section). Also, as previously stated, there was no evidence of sleep disorders or medical conditions that would have affected the quality of the captain's and the first officer's sleep in the days before the incident.

During the 3 days before the incident, the captain had sleep opportunities of between 4.75 and 8 hours. The captain reported that he needed 6 to 7 hours of sleep to feel rested; thus, he did not likely have a chronic sleep debt, but might have had an acute sleep debt, at the time of the incident. Information about the first officer's sleep opportunities was only available for the 2 days before the incident. During that time, the first officer had sleep opportunities of between 7 and 7.5 hours (including naps). Because the first officer reported that he needed 8 hours of sleep to feel rested, it is possible that he was experiencing a slight acute or chronic sleep debt at the time of the

[107] ACA759 was 500 ft (0.08 nm) from the airport seawall when the UAL1 captain made his first transmission about the position of an arriving airplane. When the UAL1 captain made his second transmission about the position of an arriving airplane, ACA759 was 450 ft (0.07 nm) beyond the seawall. The flight crewmembers recalled, during postincident interviews, that they did not hear specific transmissions on the tower frequency between the controller's verification that the runway was clear and his go-around instruction.

incident. However, other fatigue factors would have more strongly affected both crewmembers during the incident flight.

The incident occurred about 2356, which was 0256 EDT according to the flight crew's normal body clock time. The captain reported that he typically went to sleep after 0000 EDT, and the first officer reported that he typically began to feel tired about 2300 EDT. Thus, part of the incident flight occurred during a time when the flight crew would normally have been asleep. Also, 0256 EDT approximates the start of the human circadian low period described in Air Canada's fatigue information (0300 to 0500 body clock time). Even when a person is well rested, operating during this time of day increases the possibility of performance decrements (Caldwell 1997). Because the crewmembers were awake at a time that was opposite of their normal body clocks, they were more vulnerable to the effects of fatigue, which they reported experiencing after navigating through thunderstorms (about 0045 EDT on July 8) and between 0230 and 0300 EDT (on July 8).

In addition, at the time of the incident, the captain had been awake for more than 19 hours, and the first officer had been awake for more than 12 hours. The first officer took advantage of an opportunity to nap for 1.5 hours before reporting for duty, but the flight crewmembers would likely not have been able to take advantage of controlled rest during the flight because they were dealing with thunderstorms during the first half of the flight and preparing for the approach during the second half of the flight.[108] The NTSB's January 1994 study of flight crew-related major aircraft accidents indicated that fatigue related to lengthy periods of wakefulness could contribute to errors. Specifically, the study found that flight crewmembers who had been awake for more than 11 hours made significantly more procedural and tactical decision errors than those who had been awake for less time (NTSB 1994).

Among the performance decrements resulting from fatigue is the inability to adapt behavior to accommodate new information, which could lead to higher susceptibility for expectation bias and increased difficulty of overcoming expectation bias once it occurs (Harrison and Horne 1999). The NTSB concludes that the captain and the first officer were fatigued during the incident flight due to the number of hours that they had been continuously awake and circadian disruption, which likely contributed to the crewmembers' misidentification of the intended landing surface, their ongoing expectation bias, and their delayed decision to go around.

According to Canadian flight duty time and rest requirements (*Canadian Aviation Regulations* 700.16, "Flight Duty Time Limitations and Rest Periods"), the incident flight crew could have been on duty for 14 hours plus an additional 3-hour extension due to "unforeseen operational circumstances" (the delayed arrival of the inbound airplane due to weather).[109] Thus, the incident captain and first officer could have been on duty until 0940 (1240 EDT) on July 8. The flight crewmembers completed their duty periods at 0032 (0332 EDT) on July 8, which

[108] In addition, no evidence indicated that either pilot filed a fatigue report, which Air Canada requests from flight crewmembers who use the controlled rest policy.

[109] According to *Canadian Aviation Regulations* 700.17, the "maximum flight duty time referred to in…700.16(1) may be exceeded if…the flight is extended as a result of unforeseen operational circumstances" Transport Canada's "Guidance Material Concerning Flight Time and Flight Duty Time Limitations and Rest Periods," S740.17, indicated that "unforeseen operational circumstances" relate to circumstances, including weather, that result in delays to a planned schedule.

complied with Canadian regulations, but the regulations would have allowed the crewmembers to remain on duty for another 9 hours.

The NTSB compared the Canadian flight time and rest requirements with those required by 14 *CFR* Part 117, "Flight and Duty Limitations and Rest Requirements: Flightcrew Members." This comparison showed that the incident first officer's flight and duty time and rest requirements would have complied with the provisions of Part 117.[110] However, the flight and duty time and rest requirements for the captain, as a company reserve pilot, would not have complied with Part 117 regardless of whether he would have been considered to have been on long- or short-call reserve.[111] (Although Part 117 addressed long- and short-call reserve, Canadian regulations did not make this distinction.) In addition, once assigned a flight, Canadian reserve pilots do not have any limitations on flight and duty time beyond those for line pilots.[112]

For pilots on long-call reserve, 14 *CFR* 117.21(d) indicated that a flight crewmember must receive a 12-hour notice of report time if the assigned flight begins before, and operates into, a flight crewmember's window of circadian low.[113] The incident captain was assigned to the flight to SFO at 0849 (1149 EDT) and reported for the flight at 1640 (1940 EDT), resulting in a notice period of 7 hours 51 minutes. Thus, the notice period would not have complied with US regulations for long-call reserve. Canadian regulations do not include a limitation on minimum notice of report time.

For pilots on short-call reserve, 14 *CFR* 117.21(c)(3) indicated that the total number of hours that a flight crewmember spends on reserve and on duty cannot exceed 16 hours (from the beginning of the reserve availability period). The incident captain went on reserve call at 0813 (1113 EDT) on July 7. If the captain had been subject to the flight and duty limitations of Part 117 (and considered to be on short-call reserve), he could operate a flight as long as his duty period ended before 0013 (0313 EDT) on July 8. Because of the 49-minute takeoff delay, the flight was projected to arrive at the gate at SFO at 0002 (0302 EDT) with an estimated duty end time of 0017 (0317 EDT), which would have exceeded Part 117 requirements by 4 minutes. To comply with

[110] Specifically, 14 *CFR* 117, Table B, "Flight Duty Period: Unaugmented Operations," provided the maximum flight duty period limits (in hours) for line pilots. According to the table, the first officer would have been limited to 12 hours of duty. He worked from 1640 to 0032 (1940 to 0332 EDT), which was a total of 7 hours 52 minutes.

[111] According to 14 *CFR* 117.3, *long-call reserve* meant that, before beginning the rest period required by section 117.25, a pilot is notified to report for a flight duty period after the completion of the rest period, whereas *short-call reserve* meant a period of time in which a pilot is assigned to a reserve availability period. Generally, pilots on long-call reserve can be on call for a 24-hour period but, when scheduled, are released from duty and put on rest for a particular assignment. Pilots on short-call reserve are typically on reserve for a set amount of time each day and can be required to report to work with short notice.

[112] Transport Canada's "Guidance Material Concerning Flight Time and Flight Duty Time Limitations and Rest Periods," S740.21, "Flight Crew Members on Reserve," indicated the following: "When a flight crew member is on reserve, an air operator must provide the flight crew member with the opportunity to obtain at least 8 consecutive hours [of] sleep in any 24 hours by one of the 3 methods indicated in the standard. When that flight crew member is contacted and required to report for duty during the period of reserve duty, the flight crew member is no longer considered to be on reserve but on duty…. This means that at anytime during the reserve period, a flight crew member can be required to start a 14 hour duty period (or longer depending on the applicability of those sections of 700.16 and 720.16 which permit extended flight duty times). A flight crew member therefore must remain rested while on reserve such that they are able to cope with a full duty day if called."

[113] This section previously described the human circadian low period as between 0300 and 0500 body clock time, which was consistent with Air Canada's fatigue guidance and academic research. According to 14 *CFR* 117.3, the window of circadian low occurs between 0200 and 0559 body clock time.

regulations, the flight would have had to take off by 1854 (2154 EDT); however, the airplane took off at 1858 (2158 EDT).[114]

Transport Canada indicated that its current flight and duty time regulations have been in effect since 1996. In 2010, the Canadian Aviation Regulatory Advisory Council Working Group began to update Canada's regulations relating to fatigue. In 2014, Transport Canada released a draft of proposed new regulations and, in 2017, revised the draft proposed regulations.[115] According to Transport Canada, the proposed regulations would better address the challenge of fatigue mitigation for pilots on reserve duty who are called to operate evening flights extending into their window of circadian low.

The NTSB is aware that the Air Canada Pilots Association and Safer Skies, which comprises five unions in Canada, have been advocating for stricter rest requirements and flight time limitations to address pilot fatigue. However, Transport Canada has not yet finalized its rulemaking in this area. The NTSB concludes that current Canadian regulations do not, in some circumstances, allow for sufficient rest for reserve pilots, which can result in these pilots flying in a fatigued state during their window of circadian low. Therefore, the NTSB recommends that Transport Canada revise current regulations to address the potential for fatigue for pilots on reserve duty who are called to operate evening flights that would extend into the pilots' window of circadian low.

2.3.4 Mitigations to Overcome Expectation Bias

Expectation bias occurs automatically and can be difficult to overcome once established because of its inherent strength. One way to overcome expectation bias is through training that stresses active questioning of observations and recognizing the presence of conflicting cues. About 3 months before this incident, Air Canada implemented training on plan continuation and expectation bias. The training, which was provided to company pilots during annual recurrent training, comprised a video titled "Understanding Gut Feel," which explained that a gut feeling was a sense of knowing things before a person could consciously know, communicate, or explain them. The video also explained that a gut feeling indicated a potential threat resulting from a situation that was different or strange or had changed. The NTSB reviewed the video and the planned PowerPoint presentation (to be introduced during the 2018/2019 training cycle) and found that they provided a good overview of the hazards of expectation bias and stressed monitoring and active questioning to mitigate the hazards.

The incident captain and first officer did not receive this training before the incident flight and were scheduled to receive the training during their next annual recurrent training. Such training might have provided the captain and first officer with techniques to actively question their expectations, recognize their error, and act sooner. For example, during postincident interviews, the first officer stated that, when he looked up after the captain asked him to contact the controller to verify that the runway was clear, he thought that something was not right but could not resolve

[114] If the flight had taken off at 1854 (2154 EDT), the captain would have been in compliance with Part 117 because the delay in his actual duty end time (0032/0332 EDT) occurred due to events after takeoff.

[115] Information about the proposed regulations is available at http://www.gazette.gc.ca/rp-pr/p1/2017/2017-07-01/html/reg2-eng.html (accessed September 14, 2018).

what he was seeing. The training video provided pilots with a process for assessing such a feeling. Specifically, the video presented a basic strategy for listening to gut feelings when evaluating a situation, as expressed by the acronym “LIVE”: listen (to signals), investigate (what has changed or is different), validate (test and confirm a theory about what is different), and express (communicate the concern to others). Although the flight crewmembers eventually recognized (just before initiating the go-around) that the situation was not what they expected, they missed opportunities earlier in the approach (as indicated in sections 2.3.1 and 2.3.2) to reassess their expectations.

In addition to active questioning to overcome expectation bias, which may be prone to human limitations such as fatigue impairment, cockpit systems to improve crew positional awareness could provide a conspicuous cue of a misalignment with an intended landing surface. For example, an EGPWS option developed by Honeywell (known as RAAS) provides supplemental information to a flight crew about an airplane’s position relative to a runway during final approach. Studies showed that RAAS was effective in improving pilot performance and recognition of potential conflicts related to positional awareness (Khatwa 2004).

As a result of its investigation of the August 27, 2006, wrong runway takeoff at Blue Grass Airport, Lexington, Kentucky, the NTSB recommended (A-07-45) that the FAA “require that all 14 *Code of Federal Regulations* Part 91K, 121, and 135 operators install on their aircraft cockpit moving map displays or an automatic system that alerts pilots when a takeoff is attempted on a taxiway or a runway other than the one intended” (NTSB 2007). In a July 13, 2010, letter regarding Safety Recommendation A-07-45, the FAA provided details about a program to determine the effectiveness of cockpit moving map displays and described RAAS as “a product intended to improve situational awareness by providing pilots with aural advisories.” On April 9, 2014, the FAA stated that it drafted policy changes based on the lessons learned from the program but that it had no plans to require the technology requested in the NTSB’s recommendation. As a result, the NTSB classified Safety Recommendation A-07-45 “Closed—Unacceptable Action” on July 23, 2014.

Although the FAA has not mandated a system that provides supplemental information to a flight crew about an airplane’s position relative to a runway during final approach, the investigation of this incident found a safety benefit of such a system. Specifically, the NTSB asked Honeywell to conduct a simulation of the incident circumstances with an EGPWS that had the SmartLanding option, which had some features not provided by RAAS, including an alert for a potential taxiway landing. The simulation showed that the flight crew would have received the aural alert “Caution Taxiway, Caution Taxiway” when the airplane was at a radio altitude of 235 ft. At that point, the airplane would have been 2,600 ft (0.43 nm) from the airport seawall, and the flight crew would have been required to conduct a go-around because landing could not have been accomplished within the touchdown zone. Thus, such technology, if it had been installed on the incident airplane, could have helped the flight crew identify the surface misalignment and could have resulted in a go-around that was performed at a safer altitude (before the airplane was dangerously close to other airplanes), thereby improving safety margins.

FAA data (as of August 3, 2018) indicated that 85% of wrong surface landings involved general aviation airplanes.[116] Thus, additional information about an airplane's position relative to a runway on final approach would benefit all pilots of airplanes landing at primary airports within Class B and Class C airspace.[117] The NTSB concludes that flight safety would be enhanced if airplanes landing at primary airports within Class B and Class C airspace were equipped with a cockpit system that provided flight crews with positional awareness information that is independent of, and dissimilar from, the current ILS backup capability for navigating to a runway.

Although Honeywell's SmartLanding system provides an alert if a potential taxiway landing is predicted, the NTSB understands (from conversations with the FAA) that there are current limitations on the widespread implementation of taxiway mapping.[118] However, for a system that provides an alert when an airplane is not aligned with a runway surface, only the airplane position and the runway location are required, which are currently available in many transport-category airplanes. As a result, the NTSB believes that developing a system that provides an alert for non-runway surface alignment would be feasible in the near term with existing technology.[119] Therefore, the NTSB recommends that the FAA establish a requirement for airplanes landing at primary airports within Class B and Class C airspace to be equipped with a system that alerts pilots when an airplane is not aligned with a runway surface.

The system described in Safety Recommendation A-18-25 would alert if an airplane was predicted to land on a non-runway surface, such as a taxiway. The NTSB recognizes that the technology for a system that provides an alert to pilots when an airplane is not aligned with the intended runway surface may not currently be available. Such a system would also need to define and compare information about the intended runway (from ATC clearance instructions and/or the airplane's navigation system) with the airplane's runway alignment on final approach.

[116] The FAA's data also showed that 85% of wrong surface landings involved ATCT facilities that were considered to be between levels 4 and 9, indicating operations at small- or medium-sized ATCT facilities. These facilities might not have as many controllers and some of the equipment that level 10 through 12 ATCT facilities have. Thus, it is important for pilots operating at airports with level 4 through 9 ATCT facilities to have cockpit technology to aid in determining an airplane's position relative to a runway on final approach.

[117] According to the FAA, primary airports have more than 10,000 passenger boardings (enplanements) each year. Per the FAA's *Aeronautical Information Publication*, Class B airspace is generally "surrounding the nation's busiest airports in terms of IFR operations or passenger enplanements." Class C airspace is generally "surrounding those airports that have an operational control tower, are serviced by a radar approach control, and that have a certain [minimum] number of IFR operations or passenger enplanements."

[118] The FAA indicated that one limitation is getting teams from (or contracted by) the FAA to every airport in the FAA's database to survey taxiways, which would be a significant undertaking for a benefit that could be gained by installing a cockpit system that provides flight crews with positional awareness information by notifying them when an airplane is not aligned with a runway surface.

[119] The NTSB is investigating the August 10, 2018, incident involving a Gulfstream IV airplane operated by Pegasus Elite Aviation as PEGJET flight 19 at Philadelphia International Airport, Philadelphia, Pennsylvania. The airplane, which was operating under 14 *CFR* Part 135 as a charter flight, was cleared to land on runway 35 about 2050 EDT. During the visual approach, the airplane aligned with taxiway E. About 0.1 mile from the end of taxiway E, the pilot initiated a go-around, and the airplane overflew four air carrier airplanes on taxiway E during the climb. The incident airplane came within about 200 ft of the first airplane on the taxiway. At the time of the approach, the runway 35 runway end identifier lights and the precision approach path indicator lights were out of service. The seven airplane occupants were not injured, and the airplane was not damaged. For more information, see NTSB incident number DCA18IA265. The circumstances of this incident demonstrate the importance of equipping airplanes with additional positional awareness technology when landing at primary airports in Class B and Class C airspace because of the risk to passengers in airplanes on a taxiway.

Honeywell's systems are examples of existing technology that can accurately identify a runway surface when a pilot is on final approach.[120] However, the NTSB is not aware of an automated system that has reliably demonstrated the ability to indicate whether an airplane is aligned with the specific runway for which it has been cleared. Such a system would further improve safety, especially at airports with parallel runways (which, according to the FAA's wrong surface landing video, account for 75% of wrong surface landings), and provide a longer term and more robust solution to wrong surface landings. Therefore, the NTSB recommends that the FAA (1) collaborate with aircraft and avionics manufacturers and software developers to develop the technology for a cockpit system that provides an alert to pilots when an airplane is not aligned with the intended runway surface and (2) once such technology is available, establish a requirement for the technology to be installed on airplanes landing at primary airports within Class B and Class C airspace.

2.4 Reporting of the Incident Flight

Air Canada's *Flight Operations Manual* stated that pilots were to report any accident, incident, emergency, or other safety-related event (which might require investigating, monitoring, or tracking) to company flight dispatch as soon as possible. Examples of reportable events included a significant navigation error, an unstable approach, a go-around, and any hazard that poses a direct threat to flight safety. Because all of these events occurred during the incident flight, the flight crew was required to report the incident, but Air Canada's procedures at the time of the incident did not indicate what "as soon as possible" meant regarding the specific timeframe for reporting events.

The captain stated that he did not report the incident to company dispatch shortly after it occurred because he was "very tired" and it was "very late."[121] No available evidence indicated that the flight crew was aware at that point that ACA759 had overflown four air carrier airplanes positioned along taxiway C; specifically, the crewmembers reported (during postincident interviews) that they did not see any airplanes on the taxiway, and the controller's transmission to the crew about the misalignment did not mention any airplanes positioned on the taxiway. At 0747 on the morning after the incident (July 8), the incident airplane (flown by another flight crew) departed SFO for Montreal, Canada. The incident captain and first officer met at 1100 on the morning after the incident to discuss the facts surrounding the event for the ASR. Air Canada records showed that the captain reported the event to dispatch at 1608. (At that time, the captain and the first officer would have been preparing for the flight from SFO to YYZ, which departed at 1649.)

According to the dispatcher who received the initial notification about the event, the captain reported that the airplane was lined up with the wrong runway and that a go-around was performed. The dispatcher also stated that the captain's report sounded "innocuous" given the amount of time (16 hours) that had elapsed since the event. However, Air Canada senior personnel first learned about the severity of the event—the proximity of the incident airplane to the airplanes

[120] As stated in section 1.5.2, Garmin also has such a system available, and Rockwell Collins has a system in development.

[121] The flight crew could have sent an ACARS message to report the event in a timely manner.

on the taxiway—when the TSB sent an e-mail about 2200 EDT on July 9 that advised company personnel about the incident circumstances.[122] The Air Canada A320 assistant chief pilot stated that, during a meeting on July 10, the flight crewmembers were told that ACA759 had overflown airplanes on a taxiway and that the crewmembers' responses were "shock" and "surprise." (The NTSB could not determine if the flight crew was aware, before this meeting, that ACA759 had flown over airplanes on taxiway C.)

Air Canada's director of corporate safety, investigation, and research stated that the incident airplane had flown about 40 hours before Air Canada senior officials became aware of the severity of the incident and realized that data from the airplane needed to be retrieved. However, by that point, the CVR information from the incident flight had been overwritten; the CVR installed in the incident airplane was designed to record 2 hours of operational data.[123]

CVR data for this incident would have provided additional information about the circumstances leading to the overflight, including the flight crew's verbalized approach preparations (during approach set up and approach review) and the timing of pertinent conversations, such as when the captain asked the first officer to verify that the runway was clear and when the first officer called for the go-around (compared with when the captain initiated the go-around). In addition, CVR information would have allowed the NTSB to (1) determine the timing and content of the flight crew's conversations during final approach and for any conversations during and after the go-around and (2) assess the flight crew's CRM, workload, and fatigue according to verbalized information and cockpit sounds. The NTSB concludes that, although the investigation into this incident identified significant safety issues, CVR information, had it been available, could have provided direct evidence regarding the flight crew's approach preparation, cockpit coordination, perception of the airport environment, and decision-making.

2.5 Air Traffic Control Services

2.5.1 Air Traffic Control Tower Midnight Shift Staffing

On the night of the incident, the SFO ATCT was staffed with two controllers for the midnight shift, which began at 2230 and ended at 0630 the next day. Before the incident occurred, the controllers evaluated the traffic complexity and determined that the traffic volume would allow ATCT staffing to be reduced to a single-person operation (which was authorized for midnight shift staffing), with one controller working all positions in the tower cab and the other controller taking a recuperative break in the ATCT building. All control positions and frequencies were combined and operated from the local control position starting about 2349, which was 7 minutes before the incident occurred.

The controller provided no indications, during a postincident interview, that the single-person operation affected his workload at the time of the incident. The controller stated that

[122] As previously stated, the NTSB learned about this incident from the FAA at 1630 EDT on July 9 and notified the TSB at 1840 EDT the same day.

[123] In 2016, the International Civil Aviation Organization adopted a new standard calling for the installation of CVRs capable of recording the last 25 hours of aircraft operation on all aircraft manufactured after January 1, 2021, with a maximum certificated takeoff mass over 27,000 kg engaged in commercial transport.

he would not combine positions unless he was comfortable and had some predictability about the tasks that he would need to perform. He also stated that the traffic volume on the night of the incident was normal and that he was not overly busy, even with the various frequencies that he was monitoring. The controller further stated that, if the traffic had become too busy or complex, he would have asked the other on-duty controller to return to the tower cab to assist. (The other on-duty controller returned to the tower cab at the end of his recuperative break at 0300 on July 8.) In addition, analysis of the ATC voice recording indicated that the controller was calm and engaged during transmissions while ACA759 was on approach through the time that the UAL1 captain asked where the arriving airplane was going. Thus, the controller's confusion that resulted from that transmission was most likely due to the situation and not his workload.

During postincident interviews, pilots of airplanes positioned along taxiway C suggested that ATCT staffing at the time of the incident was not adequate. Specifically, the UAL1118 captain stated that the tower controller "was performing way too many functions," and a UAL863 pilot stated that the tower controller "should not have been the only controller working the entire airport." Although no evidence indicated that ATC workload was a factor in this incident, the decision to combine local and non-local positions led to congestion on the tower frequency. Specifically, postincident interviews with the ACA759 flight crew indicated that the first officer waited to contact the controller (to confirm that the runway was clear) because the tower frequency was busy. The ATC voice recording showed that, during the 61 seconds before the flight crew's query to the controller (from 2354:44 to 2355:45), there were ongoing communications between the tower and airplanes on the ground.

Given the congestion on the tower frequency, it is possible that the ACA759 flight crew was waiting for a pause in the conversations between the controller and pilots of airplanes on the ground but then decided to break into a conversation to relay the crew's concern about the perceived lights on the runway. The ATC recording showed that, when the ACA759 flight crew began its transmission to query whether runway 28R was clear, another pilot was talking to the controller. However, the controller clearly heard the transmission from ACA759 given that he checked the status of runway 28R and responded to ACA759's query 1 second after the flight crew completed its transmission.

According to postincident interviews, the captain's request for the first officer to verify with the controller that runway 28R was clear occurred between the time that the airplane passed F101D (at an altitude of about 1,100 ft) and the time that the airplane reached an altitude of 600 ft. The airplane descended below 600 ft at 2355:07, so the flight crew did not break into the conversation until 38 seconds later. The airplane performance study for this incident found that, when the flight crew acknowledged the controller's transmission that the runway was clear, the airplane was about 500 ft (0.08 nm) from the airport seawall. If the local (tower) and ground control positions had not been combined, the flight crewmembers would likely have had the opportunity to communicate their concern earlier. The NTSB concludes that, once the flight crewmembers perceived lights on the runway, they decided to contact the controller to ask about the lights; however, their query was delayed because of congestion on the tower frequency, which reduced the time available for the crewmembers to reconcile their confusion about the lights with the controller's confirmation that the runway was clear.

At the time of the incident, the SFO ATCT's standard operating procedures described staffing requirements between 0630 and 2200 but did not provide such requirements between 2200 and 0630 the next day. After the incident, the SFO ATCT acting air traffic manager issued guidance that stated that the local and ground control positions could not be combined before 0015. In response to the NTSB's June 2018 query about the significance of the 0015 time (which is 26 minutes after the reported time that all positions were combined on the night of the incident), the SFO ATCT operations manager indicated that 0015 was determined to be the earliest time that the positions could be combined based on normal traffic patterns, runway closures, administrative duties, and fatigue guidance.

The SFO ATCT's standard operating procedures also did not describe the procedures to be used (and not to be used) during the midnight shift, including those for single-person operations with combined positions. While working single-person operations on the night of the incident, the controller applied LUAW procedures. However, FAA Order JO 7210.3Z stated that, when conducting LUAW operations, the local control position should not be combined with any non-local control position. Thus, LUAW procedures should not have been used at that point.

The controller was aware that LUAW operations should not be conducted when the local and ground control positions were combined. However, during a postincident interview, the controller stated, "when aircraft were on a 5-mile final and compressing, it was hard to fit in a departure from runway 1, without using LUAW." The SFO acting air traffic manager stated that, if LUAW procedures were needed to efficiently move traffic, then traffic was "too busy to combine positions" into a single-person operation. Thus, the NTSB concludes that, although the use of LUAW procedures during single-person ATC operations was not a factor in this incident, the tower controllers should have delayed consolidating local and non-local control positions until LUAW procedures were no longer needed. The SFO acting air traffic manager stated that, after the incident, ATCT management had been reemphasizing the correct application of LUAW procedures.

2.5.2 Airport Surface Surveillance Capability System

The ASSC system was designed to detect aircraft, vehicles, and other objects on the surface of an airport and present those images on a tower display. If the ASSC system detected a situation involving two tracks on a runway (aircraft/aircraft, aircraft/vehicle, or aircraft/other tangible object) and predicted an imminent collision, the system would produce a visual and an aural alarm. However, the ASSC system was not designed to predict an imminent collision involving an arriving airplane lined up with a taxiway, so the system functioned as designed and did not produce an alarm as ACA759 approached taxiway C. The system also functioned as designed during the 12-second period when the ACA759 data block was not shown on the ASSC display (while the airplane was on short final) because the airplane was not in the system's depiction area (coverage cone) during that time.

The controller stated that he noticed that the ACA759 data block had disappeared from the ASSC display, but he was not concerned about that because he could see the airplane out of the tower cab windows.[124] The ACA759 data block reappeared on the ASSC display just before the flight crew initiated a go-around. Although the disappearance of the ACA759 data block from the ASSC display did not contribute to the incident, the current design of the ASSC system does not assist a tower controller in detecting potential taxiway landings. Such capability would be especially critical during nighttime and poor visibility conditions when a controller might not be able to visually observe an airplane lining up with a taxiway.

The ASSC system was one of three ASDE systems in the national airspace system; the other two were ASDE-3 and ASDE-X. As a result of an October 2009 taxiway landing involving a Boeing 767 at Hartsfield Jackson Atlanta International Airport, Atlanta, Georgia, the NTSB recommended in March 2011 that the FAA expand ASDE-X capabilities to detect taxiway landings by taking the following actions:[125]

> Perform a technical review of Airport Surface Detection Equipment—Model X to determine if the capability exists systemwide to detect improper operations such as landings on taxiways. (A-11-12)
>
> At those installation sites where the technical review recommended in Safety Recommendation A-11-12 determines it is feasible, implement modifications to Airport Surface Detection Equipment—Model X to detect improper operations, such as landings on taxiways, and provide alerts to air traffic controllers that these potential collision risks exist. (A-11-13)

On May 13, 2011, the FAA stated that "the ability to accurately predict that an aircraft is arriving to a taxiway is not possible without significant degradation in performance, timeliness, and accuracy of safety logic alerts for the more likely event of an aircraft arriving to a closed or occupied runway." The FAA also stated that those performance tradeoffs existed at some airports with close parallel and offset threshold runways. The FAA further stated that implementing the recommended actions could (1) degrade the ASDE-X's ability to provide correct and timely predictions to the associated parallel runway, (2) result in additional false alerts due to incorrectly predicting an aircraft landing on a taxiway, and (3) cause an actual alert to be missed if a runway is occupied at the time of an incorrect taxiway landing prediction. The FAA planned no further action regarding the recommendations.

On September 14, 2011, the NTSB noted the FAA's intent not to implement the recommended actions and recognized that the recommended review would need to consider performance tradeoffs, including those that the FAA discussed in its letter. However, the NTSB stated that the FAA determined, without performing the recommended review, that the performance tradeoffs would outweigh the safety benefits of providing the recommended

[124] The primary responsibility of the local controller was to observe traffic outside of the tower cab window. The local controller could use the ASSC display and the radar display in the ATCT to augment visual observations of departing and arriving aircraft as well as aircraft and vehicle movements on runways, taxiways, and other parts of the movement area.

[125] (a) For more information about this incident, see NTSB incident number OPS10IA001. (b) When these recommendations were issued, the ASSC system had not yet been developed.

capabilities, which was not an acceptable response to the recommendations. Accordingly, the NTSB classified Safety Recommendations A-11-12 and -13 “Closed—Unacceptable Action.”

Since that time, technology has advanced considerably. The FAA’s February 2018 tests at SEA provided promising results regarding the potential of the ASDE-X system to detect and predict taxiway landings with only a negligible number of nuisance or false alarms. As previously stated, the ASDE-X system at SEA was configured to apply the same parameters that are used to predict a landing on a closed runway, and the tests showed that the system predicted the potential taxiway landings and provided an ASDE-X alarm when the airplane was within 20 seconds or 3,000 ft of landing. The tests also showed that the alarm occurred with enough time for ATC personnel to respond, and no false alarms occurred during any of the approaches and taxiway landing scenarios. Thus, the results of the tests at SEA demonstrated that the concerns that the FAA expressed in its response to Safety Recommendations A-11-12 and -13 appear to have been resolved. According to the FAA, a software enhancement, the taxiway arrival prediction capability, was implemented at SEA in May 2018, and the FAA has a schedule to evaluate the remaining ASDE-X-equipped airports and implement the software enhancement, where feasible, by the end of fiscal year 2020.

The NTSB concludes that, if an airplane were to align with a taxiway, an automated ASDE alert would assist controllers in identifying and preventing a potential taxiway landing as well as a potential collision with aircraft, vehicles, or objects that are positioned along taxiways. The taxiway arrival prediction capability that was implemented at SEA (and was scheduled to be evaluated and implemented at other feasible ASDE-X locations) could be expanded to other ASDE system models (ASDE-3 and ASSC). Therefore, the NTSB recommends that the FAA modify ASDE systems (ASDE-3, ASDE-X, and ASSC) at those locations where the system could detect potential taxiway landings and provide alerts to air traffic controllers about potential collision risks.

2.6 Runway Closure Markers

A runway closure marker with a lighted flashing white “X” appeared at the approach and departure ends of runway 28L when it was closed, including on the night of the incident. The lighted “X” was consistent with the specifications in FAA AC 150/5345-55A, “Specification for L-893, Lighted Visual Aid to Indicate Temporary Runway Closure.” Although the runway closure marker might have been effective at preventing a takeoff from or a landing on runway 28L when it was closed (the specific risks that the lighted “X” was designed to address), the runway closure marker did not capture the attention of the incident flight crew as the airplane approached the airport while aligned with taxiway C.

The lighted “X” runway closure marker was not designed to address the possibility that a flight crew could misidentify a runway surface due to ineffective signaling of a runway closure. Although air traffic controllers can provide instructions to pilots about the closure of a runway, NOTAMs and ATIS broadcasts/messages are the primary means to inform pilots about runway closures. However, the information about runway closures provided in NOTAMs and ATIS broadcasts/messages is not necessarily a reliable means for ensuring that pilots are aware of the closure information.[126] As previously stated, although the runway 28L closure on the night of the incident was indicated in NOTAM and ATIS information that the incident flight crew received, that information was not effective in preventing the flight crew from misaligning the airplane during the approach to runway 28R.[127]

The incident flight crew and the flight crew of DAL521 (which landed on runway 28R about 4 minutes before the incident occurred) stated that they did not see a lighted “X” on runway 28L to indicate that it was closed. Given the current specifications for the runway closure marker, these flight crews likely did not see the “X” because their airplanes were not aligned with runway 28L. This situation highlights the need for a surface-based system with conspicuous and unambiguous visual cues that clearly indicate when a runway is closed, even if an approaching airplane is not aligned with the closed runway. Such a system would provide redundancy in case a flight crew does not review or retain runway closure information presented in NOTAMs or ATIS broadcasts/messages. Such a system would also be especially critical in situations involving the closure of a runway at an airport with parallel landing and taxiway surfaces (such as SFO).

As previously discussed, cockpit mitigations (such as the use of navigational aids to back up a visual approach to the intended landing runway, as used by the DAL521 flight crew, and a system to provide additional positional awareness information) and ATC systems to alert controllers about a potential runway misalignment or taxiway alignment can provide multiple layers of protection to prevent a flight crew surface alignment error. In addition, when closed runways are marked conspicuously, the view outside the cockpit (during VMC) of an airport environment can assure flight crews that an airplane is correctly aligned with a parallel landing runway.

If the incident flight crewmembers had observed the runway 28L closure marker early in the approach, their mistaken perception of the airport environment and alignment with taxiway C might not have occurred. Further, if the runway 28L closure marker had captured the incident flight crew’s attention later in the approach, that information might have been sufficient for the crewmembers to detect their mistaken perception and respond to the situation before the airplane reached the seawall.

The NTSB is not aware of any operational or human factors research to improve the conspicuity of L-893 runway closure markers during the 31 years since the FAA issued a technical report about its research on runway closure markers (other than subsequent research on the use of light-emitting diode bulbs). During that time, widespread advances in lighting and control

[126] The NTSB investigated a September 25, 2001, incident in which a Boeing 757 took off from a closed runway at Denver International Airport, Denver, Colorado. A system failure affected the availability of a NOTAM about the runway closure, and a controller cleared the airplane to take off from the closed runway. After that incident, the flight crewmembers stated that they were unaware that the runway was closed, and the captain did not recall if the runway closure information was included in the ATIS broadcast. As a result of the incident, the NTSB recommended that the FAA “require the use of physical devices or other means to clearly indicate to flight crews of arriving and departing aircraft that a runway is closed” (A-03-5). In response, the FAA issued AC 150/5370-2F, “Operational Safety on Airports During Construction,” which indicated that airports should use physical devices or other means to indicate to flight crews that a runway is closed. The NTSB classified Safety Recommendation A-03-5 “Closed—Acceptable Action” on January 30, 2012.

[127] The NTSB has investigated other events in which pertinent NOTAM information was missed; for example, see NTSB accident numbers DFW07CA092, CEN12LA229, and CEN14FA505.

technology have occurred. These advances could allow more conspicuous attentional capture features to be incorporated into a runway closure marker's design. Such features, which include varying the flash pattern, incorporating strobe lights, and/or creating apparent movement, might direct a pilot's attention to a closed runway better than the current design of the lighted "X."

The NTSB concludes that increased conspicuity of runway closure markers, especially those used in parallel runway configurations, could help prevent runway misidentification by flight crews while on approach to an airport. Therefore, the NTSB recommends that the FAA (1) conduct human factors research to determine how to make a closed runway more conspicuous to pilots when at least one parallel runway remains in use and (2) implement a method to more effectively signal a runway closure to pilots during ground and flight operations at night.

3. Conclusions

3.1 Findings

1. None of the following were factors in this incident: (1) flight crew qualifications, which were in accordance with Canadian and US regulations; (2) flight crew medical conditions; (3) airplane mechanical conditions; and (4) airport lighting, which met US regulations.

2. The first officer did not comply with Air Canada's procedures to tune the instrument landing system (ILS) frequency for the visual approach, and the captain did not comply with company procedures to verify the ILS frequency and identifier for the approach, so the crewmembers could not take advantage of the ILS's lateral guidance capability to help ensure proper surface alignment.

3. The flight crew's failure to manually tune the instrument landing system (ILS) frequency for the approach occurred because (1) the Flight Management System Bridge visual approach was the only approach in Air Canada's Airbus A320 database that required manual tuning of a navigation frequency, so the manual tuning of the ILS frequency was not a usual procedure for the crew, and (2) the instruction on the approach chart to manually tune the ILS frequency was not conspicuous during the crew's review of the chart.

4. The first officer's focus on tasks inside the cockpit after the airplane passed the final waypoint reduced his opportunity to effectively monitor the approach and recognize that the airplane was not aligned with the intended landing runway.

5. The flight crew-initiated, low-altitude go-around over the taxiway prevented a collision between the Air Canada airplane and one or more airplanes on the taxiway.

6. The controller responded appropriately once he became aware of the potential conflict.

7. Errors that the flight crewmembers made, including their false assumption that runway 28L was open, inadequate preparations for the approach, and delayed recognition that the airplane was not lined up with runway 28R, reflected breakdowns in crew resource management and led to minimal safety margins as the airplane overflew taxiway C.

8. The flight crewmembers' lack of awareness about the runway 28L closure and the crewmembers' previous experience seeing two parallel runways at San Francisco International Airport led to their expectation to identify two runway surfaces during the approach and resulted in their incorrect identification of taxiway C instead of runway 28R as the intended landing runway.

9. Although the notice to airmen about the runway 28L closure appeared in the flight release and the aircraft communication addressing and reporting system message that were provided to the flight crew, the presentation of the information did not effectively convey the importance of the runway closure information and promote flight crew review and retention.

10. The cues available to the flight crewmembers to indicate that the airplane was aligned with a taxiway were not sufficient to overcome their belief, as a result of expectation bias, that the taxiway was the intended landing runway.

11. Multiple salient cues of the surface misalignment were present as the airplane approached the airport seawall, and one or more of these cues likely triggered the captain's initiation of a go-around, which reportedly occurred simultaneously with the first officer's call for a go-around.

12. The captain and the first officer were fatigued during the incident flight due to the number of hours that they had been continuously awake and circadian disruption, which likely contributed to the crewmembers' misidentification of the intended landing surface, their ongoing expectation bias, and their delayed decision to go around.

13. Current Canadian regulations do not, in some circumstances, allow for sufficient rest for reserve pilots, which can result in these pilots flying in a fatigued state during their window of circadian low.

14. Flight safety would be enhanced if airplanes landing at primary airports within Class B and Class C airspace were equipped with a cockpit system that provided flight crews with positional awareness information that is independent of, and dissimilar from, the current instrument landing system backup capability for navigating to a runway.

15. Although the investigation into this incident identified significant safety issues, cockpit voice recorder information, had it been available, could have provided direct evidence regarding the flight crew's approach preparation, cockpit coordination, perception of the airport environment, and decision-making.

16. Once the flight crewmembers perceived lights on the runway, they decided to contact the controller to ask about the lights; however, their query was delayed because of congestion on the tower frequency, which reduced the time available for the crewmembers to reconcile their confusion about the lights with the controller's confirmation that the runway was clear.

17. Although the use of line up and wait (LUAW) procedures during single-person air traffic control operations was not a factor in this incident, the tower controllers should have delayed consolidating local and non-local control positions until LUAW procedures were no longer needed.

18. If an airplane were to align with a taxiway, an automated airport surface detection equipment alert would assist controllers in identifying and preventing a potential taxiway landing as well as a potential collision with aircraft, vehicles, or objects that are positioned along taxiways.

19. Increased conspicuity of runway closure markers, especially those used in parallel runway configurations, could help prevent runway misidentification by flight crews while on approach to an airport.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this incident was the flight crew's misidentification of taxiway C as the intended landing runway, which resulted from the crewmembers' lack of awareness of the parallel runway closure due to their ineffective review of notice to airmen (NOTAM) information before the flight and during the approach briefing. Contributing to the incident were (1) the flight crew's failure to tune the instrument landing system frequency for backup lateral guidance, expectation bias, fatigue due to circadian disruption and length of continued wakefulness, and breakdowns in crew resource management and (2) Air Canada's ineffective presentation of approach procedure and NOTAM information.

4. Recommendations

As a result of this investigation, the National Transportation Safety Board recommends the following:

To the Federal Aviation Administration:

> Work with air carriers conducting operations under Title 14 *Code of Federal Regulations* Part 121 to (1) assess all charted visual approaches with a required backup frequency to determine the flight management system autotuning capability within an air carrier's fleet, (2) identify those approaches that require an unusual or abnormal manual frequency input, and (3) either develop an autotune solution or ensure that the manual tune entry has sufficient salience on approach charts. (A-18-23)
>
> Establish a group of human factors experts to review existing methods for presenting flight operations information to pilots, including flight releases and general aviation flight planning services (preflight) and aircraft communication addressing and reporting system messages and other in-flight information; create and publish guidance on best practices to organize, prioritize, and present this information in a manner that optimizes pilot review and retention of relevant information; and work with air carriers and service providers to implement solutions that are aligned with the guidance. (A-18-24)
>
> Establish a requirement for airplanes landing at primary airports within Class B and Class C airspace to be equipped with a system that alerts pilots when an airplane is not aligned with a runway surface. (A-18-25)
>
> Collaborate with aircraft and avionics manufacturers and software developers to develop the technology for a cockpit system that provides an alert to pilots when an airplane is not aligned with the intended runway surface, and, once such technology is available, establish a requirement for the technology to be installed on airplanes landing at primary airports within Class B and Class C airspace. (A-18-26)
>
> Modify airport surface detection equipment (ASDE) systems (ASDE-3, ASDE-X, and airport surface surveillance capability) at those locations where the system could detect potential taxiway landings and provide alerts to air traffic controllers about potential collision risks. (A-18-27)

> Conduct human factors research to determine how to make a closed runway more conspicuous to pilots when at least one parallel runway remains in use, and implement a method to more effectively signal a runway closure to pilots during ground and flight operations at night. (A-18-28)

To Transport Canada:

> Revise current regulations to address the potential for fatigue for pilots on reserve duty who are called to operate evening flights that would extend into the pilots' window of circadian low. (A-18-29)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

ROBERT L. SUMWALT, III
Chairman

EARL F. WEENER
Member

BRUCE LANDSBERG
Vice Chairman

T. BELLA DINH-ZARR
Member

JENNIFER HOMENDY
Member

Adopted: September 25, 2018

Board Member Statements

Vice Chairman Landsberg filed the following concurring statement on October 4, 2018:

Vice Chairman Bruce Landsberg
Concurring Statement – Air Canada Taxiway Overflight Investigation

Concurring statements for SFO

This incident report should be required reading for all pilots. Only a few feet of separation prevented this from possibly becoming the worst aviation accident in history. I have some reservations about some of our recommendations where we may have gone farther than necessary in some cases and not far enough in others. Time will tell if we got it right.

Recommendation A-18-24 to the FAA on Preflight Information:

From a human factors perspective, the preflight briefing system is archaic and poorly designed. This Air Canada crew missed two warnings about the closed runway in SFO, first in pre-departure and secondly, via ACARS before landing. Concerns about legal liability rather than operational necessity, drive the current system to list every possible Notice to Airmen (Notam) that could, even under the most unlikely circumstance, affect a flight.

The current system prioritizes protecting the regulatory authorities and airports. It lays an impossibly heavy burden on individual pilots, crews and dispatchers to sort through literally dozens of irrelevant items to find the critical or merely important ones. When one is invariably missed, and a violation or incident occurs, the pilot is blamed for not finding the needle in the haystack!

GPS and TFR notices often fall into the same category of overly complex and geographically irrelevant. The legalistic descriptions of TFRs and poorly-descriptive GPS outage areas are worthless to pilots and dispatchers without tremendous and time-consuming effort. A graphic presentation of where a flight might be restricted or impacted should be easily found on FAA's website and suffice as an official brief. It should also be disseminated to other preflight or electronic Flight bag providers and be both accurate and timely. FAA should not be allowed to hide behind FSS using this disclaimer which currently appears on the *official FAA TFR website*. "**Depicted TFR data may not be a complete listing. Pilots should not use the information on this website for flight planning purposes. For the latest information, call your local Flight Service Station at 1-800-WX-BRIEF."**

The problem of hard-to-read codes and irrelevant information has been pointed out to the FAA for more than 15 years. In 2012 it was even put into Public Law 112-153 (Pilot's Bill of Rights) and FAA was given one year to address. This incident makes it clear that there is much more work to be done. This is a safety issue that calls for urgent action.

Finding 15 - Cockpit Voice Recorder: The Cockpit Voice Recorder (CVR), which would have provided much more information on what happened, unfortunately, was overwritten during normal operations. We are unable to say that the delay in reporting was deliberate and may never understand all the reasons behind the several other procedural failures that allowed this incident to get so close to catastrophe. The CVR would have provided a much better picture.

As of this writing, the Board is considering a recommendation to extend CVR recording time to 25 hours so that valuable data are not lost. However, cockpit image recording investigators provide another source of critical information, which will help to ensure that NTSB's findings are comprehensive, and recommendations are well targeted. An image recorder recommendation was originally issued in 2000 (A-00-031).

Non-punitive response - Image recording technology currently exists in *every* other mode of public transportation except commercial aviation. Some pilot groups are concerned about the right to privacy and that the information gathered will be used punitively. Workplace right-to-privacy has been extensively litigated but in safety-critical positions, it must take a backseat to human life. Most importantly, the data, gathered routinely *before an accident,* will be invaluable in preventing the next tragedy. This approach has been highly effective in FOQA. There may be some technical challenges to address but the payoff in increased safety and accountability will be significant.

One of the strongest attributes of aviation is the concept of just culture or non-punitive corrective action. When a mistake is made, most people put their best foot forward and attempt to minimize a critical error, which is perfectly understandable. Some supervisors want to mete out sanctions to "teach a lesson" or to make an example of the crew. Unless someone is habitually error prone and they shouldn't be in a safety-critical position, punitive response is completely ill-suited to critical performance environments.

It's almost a certainty this crew will never make such a mistake again and my hope is that they will continue to fly to the normal end of their careers.

Everyone will gain much more from being introspective rather than judgmental on this incident. We should reward all aviation personnel and celebrate when someone self-confesses a mistake and learns from it. More importantly, the system learns from it and can take steps to eliminate event precursors. This is a key factor in the decades-long decline in commercial aviation's accident rate. Fortunately, we'll get another chance to put some fixes in place to make a highly improbable event even less likely to reoccur.

Recommendation A-18-25 – Automatic Warning of Wrong surface landing: The recommendation to require an automatic warning system for runway alignment for all aircraft is redundant. All commercial aircraft and nearly all GA aircraft flying into Class B and C airports are already equipped with runway alignment equipment – ILS, RNAV or FMS. Although Air Canada requires their crews to use systems that would have prevented the misalignment, the crew on the incident flight failed to program the system for unknown reasons. If the command bars and raw data do not align by 500 feet above ground level – something is clearly wrong, and a go-around is in order. This is basic checklist discipline – especially for night visual approaches.

In modern air carrier aircraft, the FMS autotunes the final approach aids so the pilots don't have to. In this incident, the Bridge Visual Approach *was the only one* in Air Canada's FMS system that did not have the autotune function. That certainly could have been misleading to a crew that was used to always having the approach tuned for them. It was an unusual procedure; charts for such procedures should highlight the need for verifying that electronic guidance is tuned. It might also be mentioned in the dispatch package.

Recommendation A-18-26 – New Equipment or Software: The recommendation to require a separate warning system in addition to the primary navigation system and be applicable to ALL aircraft flying into Class B and C airspace (especially light, non-turbine Part 91) is far too broad and fails to put the focus on the heavier airplanes that are most likely to cause loss of life in a ground surface collision.

I concur because safety takes preference but there should be reasonable risk management behind recommendations. There was not enough data to fully support a dissenting view at the Board meeting. An FAA risk assessment study was cited as the justification for this recommendation by noting that 85% of taxiway or wrong runway landings occurred during Part 91 operations. However, this study discussed before the Board meeting, noted in passing that GA incidents almost always occurred in daylight visual conditions when collision was highly unlikely. FAA's assessment was that risk of a collision was "extremely improbable."

My hope is that forthcoming software design will allow this recommendation to be implemented without much added complexity of additional hardware added to cockpits. Perhaps it can be a part of the Electronic Flight Bag (EFB).

Recommendation A-18-29 to Transport Canada on Fatigue Rules: Fatigue continues to be a recurring factor in accidents and incidents. This captain had been awake for 19 hours. It's estimated that he awoke around 0800 Eastern time; the incident occurred at 0300 ET the following day. While not technically on duty all that time, under Canadian regulations for reserve crew members, he could have been available for duty for another nine hours. Adjusting circadian rhythm, even with naps, is not a precise activity.

The captain's statement as to why he did not make a timely incident report to dispatch after landing was that "It was very late" and he "was tired." The captain was too tired to make a phone call to report the incident, but the rules required him to be able to fly a challenging night approach with 139 passengers and crew behind him. If we expect solid human performance where lives are at stake, fatigue rules need to be based on human factors science and not on economic considerations.

Member Weener joined this statement.

Member Weener filed the following concurring statement on October 4, 2018:

Member Earl F. Weener, Ph.D.
Concurring

As a longtime pilot and flight instructor, I understand that mistakes are inevitable for even the best aviators. Thus, it is critical that safety systems are instilled with redundancy and multiple layers which work effectively to mitigate, correct, or prevent these errors. I agree with findings and conclusions but wonder if they go far enough. We have focused on what can be done in the future to preserve the cockpit voice recorder. An opportunity to review a voice recording of events leading to an incident is invaluable but does not serve the same function as an immediate evaluation of a flight crew's fitness for duty.

In this event a commercial aircraft filled with passengers came within feet of striking another aircraft and causing a collision with several others on the ground. Over 1000 people were at imminent risk of serious injury or death. The commercial operator had policies in place that required the reporting of serious incidents and that would have removed the flight crew from service immediately and until they could be evaluated for flight readiness. However, the subjective observations of the crew as they flew over the aircraft on the ground and executed a go-around did not prompt them to report anything to their operational control until the next day. Moreover, they reportedly did not perceive the gravity of the situation, stating to NTSB investigator they did not descend below 400ft prior to initiating a go-around. According to the crew, they did not realize just how near they were to striking another aircraft.

In reality, the overflying crew may have been in a poor position to fully understand their proximity to disaster because of their perspective, looking down at night, and their workload, as they executed functions necessary to landing then undertook a go-around. And, although Air Canada procedures required incidents be reported as soon as possible, the crew was apparently unclear on the meaning of ASAP. They did not report the event to their Air Canada point of contact until the following day. The bottom line is that reliance on self-reporting in this instance resulted in a flight crew that only stopped flying that night because they had finished a shift. Had that not been the case, nothing would have stopped them from flying additional trips *immediately following this incident*. In this case, there turned out to be no medical issues or competency concerns with the crew. And, because they happened to be at the end of shift, any fatigue issues were resolved. However, I am not comforted because that despite a lack of immediate action, everyone made it home safely. I believe more robust measures should be in place to intervene when a dangerous situation become apparent.

There was only one controller in the tower that night and his work load was significant. Yet, while he was expected to continue his solo operation, he also had unique knowledge of the events that had just occurred. It was the controller who called for the go-around, knew the Air Canada flight almost landed on an active taxiway, reported the Air Canada crew was shaken, and stated that he himself was other than calm after the event. When a pilot on the ground contacted the controller to report the Air Canada flight had gone right over him, the controller replied that he had seen it happen. Yet, the controller did not report the event in the system until the end of his shift. When he did so, it was only as a go-around and he chose not to mark the event as significant when prompted by his reporting software.

The pilots on the taxiway that evening had perhaps the best perspective of what occurred, and one even went so far as to switch on extra lighting to warn the approaching Air Canada flight away. Yet, faced with the need to continue their own flights and without any requirement for immediate reporting, the pilots on the ground took no immediate action prompting an intervention and evaluation of the Air Canada crew.

I am left concerned that post-incident forensic analysis of a cockpit voice recorder, while vital, cannot replace immediate, safety-focused interventions designed to take crews involved in near miss situations out of service until they can be assessed as safe to continue. Whether it is industry, the FAA, or airports that stand up a more effective “if you see something, say something” style system regarding dangerous operational behavior, it is clear to me that the need exists.

Vice Chairman Landsberg and Member Dinh-Zarr joined this statement.

5. Appendixes

Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified of this incident at 1630 eastern daylight time on July 9, 2017, by the Federal Aviation Administration (FAA). Two NTSB investigators traveled to San Francisco International Airport (SFO) on July 15. Investigative groups were formed in the areas of air traffic control and operations/human performance. Specialists were assigned to perform the readout of the flight data recorder at the NTSB's laboratory in Washington, DC; conduct an aircraft performance study; and gather airport-related information.

Parties to the investigation were the FAA, the National Air Traffic Controllers Association, and Honeywell. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA), the NTSB's counterpart agency in France, participated in the investigation as the representative of the state of design and manufacture, and Airbus participated in the investigation as a technical advisor to the BEA. Also, the Transportation Safety Board of Canada (TSB), the NTSB's counterpart agency in Canada, participated in the investigation as the representative of the state of the operator and registry, and Air Canada, the Air Canada Pilots Association, and Transport Canada participated in the investigation as technical advisors to the TSB.

Appendix B: Air Canada Postincident Actions

Air Canada reported, in e-mails to the NTSB dated April 17 through 20, 2018, that it took the following actions after the incident:

- Developed a means for flight crews to use company tablets to highlight areas and make notes on digital flight releases.
- Modified its procedures for the Flight Management System (FMS) Bridge approach to runway 28R at SFO. The instruction to tune the instrument landing system frequency was replaced with the instruction to use lateral and vertical navigation guidance to align an airplane with the runway centerline on short final. Also, the FMS automatically sequences the missed approach procedure when the thrust levers are advanced to the takeoff/go-around detent.
- Began assessing the use of airplane systems to provide aural and visual alerts if an airplane is not aligned with a runway. This capability is currently installed in company simulators as part of an effort to determine the appropriate system settings to be used during normal operations.
- Upgraded the Airbus A320 simulator and increased its fidelity so that the simulator graphics could be set to replicate specific airports, including SFO.
- Implemented familiarization training for operations to and from SFO for all pilots during recurrent training.
- Implemented a learning management system module for all airports on the FAA’s Special Pilot-in-Command Qualification Airport list (including SFO), Air Canada restricted entry airports, and unique airports within Air Canada’s system.
- Reiterated the requirement to back up all approaches with electronic means when available.
- Explained the meaning of “as soon as possible” (in revision 33 of the *Flight Operations Manual*, which was issued in May 2018) for reporting aircraft accidents, incidents, emergencies, and other safety events.
- Amended the arrival and approach briefing procedures (in revision 33 of the *Flight Operations Manual*) to ensure that the approach and runway lighting and visual aids expected for a runway are briefed.

References

Bhattacherjee, Anol. 2001. "Understanding Information Systems Continuance: An Expectation-Confirmation Model." *MIS Quarterly* 25, no. 3 (September): 351-370.

Caldwell, John A. 1997. "Fatigue in the Aviation Environment: An Overview of the Causes and Effects as well as Recommended Countermeasures." *Aviation, Space, and Environmental Medicine* 68 (10): 932-938.

Colman, Andrew M. 2006. *Dictionary of Psychology*. New York: Oxford University Press, 688.

FAA (Federal Aviation Administration). 2008. *Aviation Instructor's Handbook*. FAA-H-8083-9A. Washington, DC: US Department of Transportation, FAA Flight Standards Service.

———. 2017. "Fact Sheet—Commercial Aviation Safety Team." Last modified December 27, 2017. https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22455.

———. 2018a. "ADS-B, Airport Surface Surveillance Capability (ASSC)." Last modified February 26, 2018. https://www.faa.gov/nextgen/programs/adsb/atc/assc/.

———. 2018b. "Wrong Surface Landing." Published July 25, 2018. Video, 3:57. https://www.youtube.com/watch?v=5II-s_j35cI&feature=youtu.be.

Harrison, Y. and J.A. Horne. 1999. "One Night of Sleep Loss Impairs Innovative Thinking and Flexible Decision Making." *Organizational Behavior and Human Decision Processes* 78 (2): 128-145.

Khatwa, Ratan. 2004. "Flight Simulator Evaluation of Pilot Performance with the Runway Awareness and Advisory System (RAAS)." *The 23rd Digital Avionics Systems Conference*, Salt Lake City (October).

Marinelli, Rick. 1987. *Development of a Visual Aid to Indicate Temporary Runway Closure*. FAA Technical Note DOT/FAA/CT-TN87/3, Atlantic City, New Jersey: FAA Technical Center (January).

Nickerson, Raymond. 1998. "Confirmation Bias: A Ubiquitous Phenomenon in Many Guises." *Review of General Psychology* 2 (2): 175-220.

NTSB (National Transportation Safety Board). 1994. *A Review of Flightcrew-Involved, Major Accidents of U.S. Air Carriers, 1978 Through 1990*. SS-94/01. Washington, DC: NTSB.

———. 2007. *Attempted Takeoff From Wrong Runway, Comair Flight 5191, Bombardier CL-600-2B19, Lexington, Kentucky, August 27, 2006*. AAR-07/05. Washington, DC: NTSB.