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

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A23F0062

RUNWAY EXCURSION ON TAKEOFF

WestJet Airlines Ltd.
Boeing 737-7CT, C-GWCN
Harry Reid International Airport, Nevada, United States
16 February 2023

Canada

ABOUT THIS INVESTIGATION REPORT

This report is the result of an investigation into a class 3 occurrence. For more information, see the Policy on Occurrence Classification at www.tsb.gc.ca

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

Citation

Transportation Safety Board of Canada, *Air Transportation Safety Investigation Report* A23F0062 (released 23 April 2024).

Transportation Safety Board of Canada
200 Promenade du Portage, 4th floor
Gatineau QC K1A 1K8
819-994-3741; 1-800-387-3557
www.tsb.gc.ca
communications@tsb.gc.ca

Air transportation safety investigation report A23F0062

Cat. No. TU3-10/23-0008E-PDF
ISBN: 978-0-660-70544-6

This report is available on the website of the Transportation Safety Board of Canada at www.tsb.gc.ca

Le présent rapport est également disponible en français.

Table of contents

1.0 Factual information ... 6

1.1 History of the flight ... 6

1.2 Injuries to persons ... 10

1.3 Damage to aircraft ... 10

1.4 Other damage ... 10

1.5 Personnel information ... 11

1.6 Aircraft information ... 11

1.7 Meteorological information ... 12

1.8 Aids to navigation ... 12

1.9 Communications ... 12

1.10 Aerodrome information ... 12

1.10.1 Visual environments of runway thresholds and displaced thresholds ... 13

1.10.2 Taxiway centreline marking ... 14

1.10.3 Runway edge markings ... 15

1.10.4 Runway and taxiway shoulder markings ... 17

1.10.5 Runway lighting ... 19

1.11 Flight recorders ... 20

1.12 Wreckage and impact information ... 21

1.13 Medical and pathological information ... 21

1.14 Survival aspects ... 21

1.15 Fire ... 21

1.16 Tests and research ... 21

1.16.1 TSB laboratory reports ... 21

1.17 Organizational and management information ... 21

1.17.1 *Route & Aerodrome Qualification* document ... 22

1.18 Additional information ... 22

1.18.1 Other occurrences and investigations of misaligned takeoffs ... 22

1.18.2 Human factors issues ... 24

2.0 Analysis ... 28

2.1 Flight crew attention ... 28

2.2 Visual cues ... 29

2.2.1 Lighting ... 29

2.2.2 Markings ... 30

2.3 Flight crew expectations ... 31

2.3.1 Captain's experience and expectation ... 31

2.3.2 First officer's expectation ... 32

2.4 Harry Reid International Airport ... 33

2.4.1 Detection equipment ... 33

2.4.2 Reporting procedures for misaligned aircraft ... 34

3.0 Findings ... 35

3.1 Findings as to causes and contributing factors ... 35

3.2 Findings as to risk 35
3.3 Other findings 36

4.0 Safety action 37

4.1 Safety action taken 37
4.1.1 WestJet Airlines Ltd. 37
4.1.2 Harry Reid International Airport 37

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A23F0062

RUNWAY EXCURSION ON TAKEOFF

WestJet Airlines Ltd.
Boeing 737-7CT, C-GWCN
Harry Reid International Airport, Nevada, United States
16 February 2023

Summary

On 16 February 2023, the WestJet Airlines Ltd. Boeing 737-7CT aircraft (registration C-GWCN, serial number 34157) was conducting flight WJA1447 from Harry Reid International Airport (KLAS), Nevada, United States, to Edmonton International Airport (CYEG), Alberta, with 5 crew members and 109 passengers on board. At approximately 1825 Pacific Standard Time, the aircraft took off while aligned with the right edge of Runway 01R, and its right nosewheel contacted 8 runway edge lights. The flight crew were unaware of the misaligned takeoff and subsequent contact with the edge lights, and the aircraft continued to CYEG, where it landed uneventfully. None of the passengers or crew members were injured. The next day, WestJet Airlines Ltd. maintenance noted minor damage to the right tire on the nose landing gear and replaced both nosewheel tires before releasing the aircraft back to service. The airport operator at KLAS discovered the damage to the runway edge lights 32 hours after the occurrence; it notified the airline operator of the damage to the runway edge lights 8 days after the occurrence.

1.0 FACTUAL INFORMATION

The National Transportation Safety Board of the United States (U.S.) elected not to investigate the occurrence. Per International Civil Aviation Organization (ICAO) Annex 13,[1] the TSB conducted the investigation.

1.1 History of the flight

On 16 February 2023, the occurrence flight crew were scheduled to fly from Winnipeg/James Armstrong Richardson International Airport (CYWG), Manitoba, to Harry Reid International Airport (KLAS), Nevada, U.S., then from KLAS to Edmonton International Airport (CYEG), Alberta, on the Boeing 737-7CT aircraft,[2] which was being operated by WestJet Airlines Ltd. (WestJet). At 1709,[3] the aircraft landed at KLAS as instrument flight rules flight WJA1352 and, at 1715, it arrived at the gate. After this inbound flight, the crew, which consisted of 2 flight crew members and 3 cabin crew members, began to prepare for the flight to CYEG (flight WJA1447) on the same aircraft.

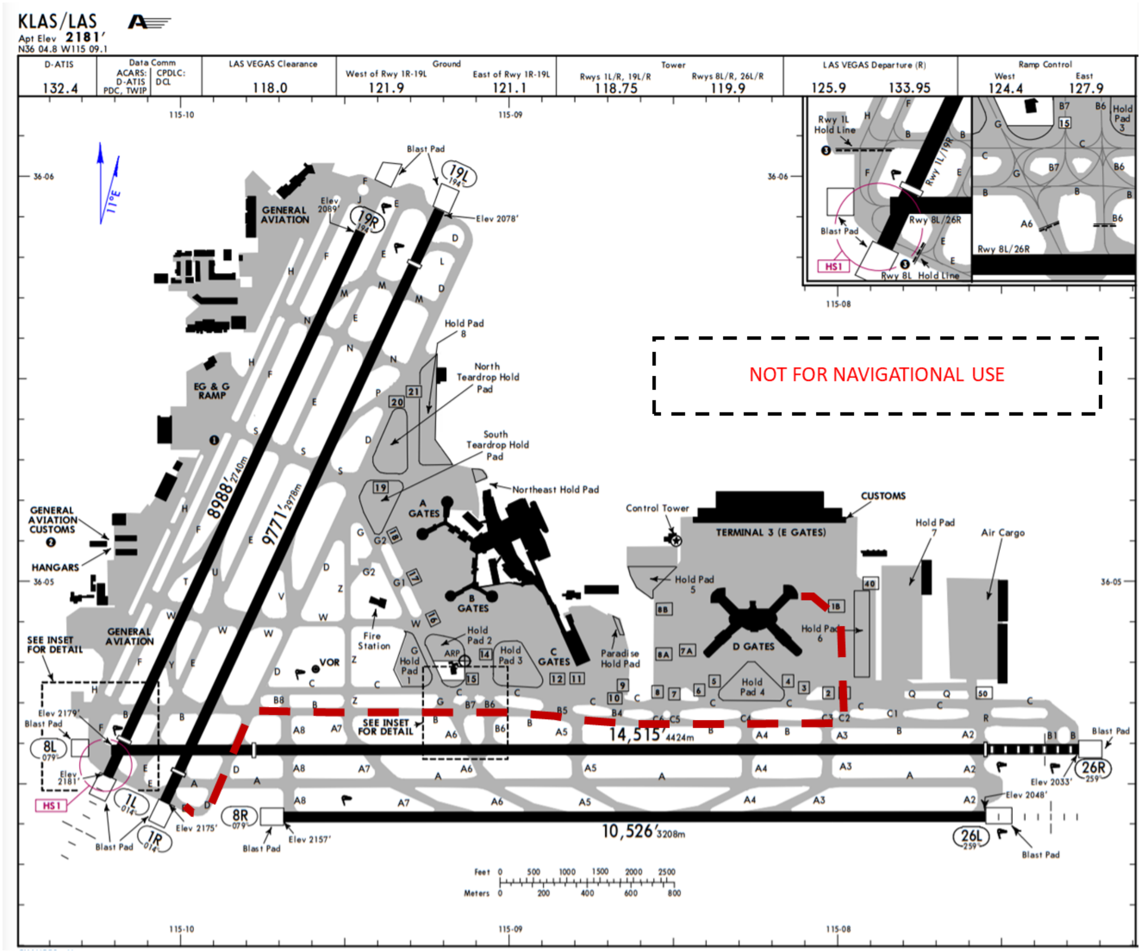
Before passengers boarded, the flight crew conducted a departure briefing and discussed known threats and challenges associated with the procedure to be flown. The captain had been the pilot flying (PF) from CYWG to KLAS, and it was planned that the first officer (FO) would be the PF for the occurrence flight. The FO was seated in the right seat. After 109 passengers had boarded and the aircraft had been loaded with fuel, the aircraft pushed back from the gate at 1814 and, at 1817, the captain taxied the aircraft onto Taxiway B with a clearance to turn onto Taxiway D from B and cross Runway 08L/26R to hold short of Runway 01R, the active runway (Figure 1).

1 International Civil Aviation Organization (ICAO), Annex 13 to the *Convention on International Civil Aviation, Aircraft Accident and Incident Investigation*, 12th Edition (July 2020).

2 The 737-7CT model designation describes a Boeing 737 Next Generation airliner.

3 All times are Pacific Standard Time (Coordinated Universal Time minus 8 hours), unless otherwise indicated.

Figure 1. Diagram of Harry Reid International Airport showing occurrence aircraft's taxi route onto Runway 01R (dashed line) (Source: Jeppesen, with TSB annotations)



From 1800 to 1845,[4] departures at KLAS were predominantly on Runway 01R, with arrivals on runways 01L and 26L. All departures from Runway 01R took place from the beginning of the runway pavement in front of the displaced threshold at Taxiway D. Behind the occurrence flight, there were 2 other aircraft scheduled for departure on this runway. There was one arrival for Runway 01R, which occurred 4 minutes after the occurrence aircraft's departure.

Just before obtaining clearance for takeoff, the captain requested that the FO retrieve the departure frequency and enter it into the radio tuning panel. With the departure imminent and his checks not yet complete, the FO suggested that they obtain the departure frequency after takeoff given that they would be staying on the tower frequency for 5 minutes after takeoff. At approximately 1823, during this discussion about the departure frequency and while the aircraft was approaching the runway holding position marking for Runway 01R, the air traffic control (ATC) tower controller cleared the aircraft for takeoff. The flight crew missed this call, and after a subsequent call from the tower, which was acknowledged by both flight crew members, the FO responded with a readback. The FO then asked the tower

4 This was the timeframe examined by the TSB as part of the investigation.

for the departure frequency. The controller responded that the departure frequency was 133.95 MHz, which the FO read back.

At approximately 1824, the captain taxied the aircraft along the taxiway centreline until reaching the right runway edge marking[5] (a white line), turned to the right, entered Runway 01R approximately 330 feet before the displaced threshold, and lined up with what was believed to be the runway's centre. During the turn, the captain looked over at the FO to confirm that the take-off checks were being completed. While the aircraft was moving onto the runway, the FO was tuning the departure frequency, telling the cabin crew to prepare for takeoff, and completing his geographic flow[6] and the Before Takeoff Checklist. Given that the FO was taking longer than the captain had expected to complete the checklist, the captain advanced the thrust levers to about 40% N_1[7] to commence the takeoff.

After the thrust had stabilized at 40% N_1, the captain advanced the thrust levers toward the desired take-off setting. The captain noted that the target N_1 thrust had not been attained and the takeoff/go-around (TOGA) button had not been activated. He then pressed the TOGA button (Table 1). At this time, the FO had completed the checklist and as the aircraft accelerated through 50 knots, the captain gave control to the FO. The FO assumed the role of PF, and the captain became the pilot monitoring.

Both flight crew members heard sounds and felt vibrations during the take-off roll, but they thought they were going over embedded runway centreline lights. Although the captain told the FO to move to the left to avoid the vibrations, the aircraft maintained its alignment on the runway.

Following the takeoff, the tower instructed the aircraft to transfer to the departure frequency. The aircraft climbed normally and continued uneventfully to CYEG.

On 17 February 2023, WestJet maintenance noted foreign object damage to the right tire on the nosewheel and replaced both nosewheel tires before releasing the aircraft back to service. The following day, at 0226 on 18 February, the KLAS airport operator discovered the damage to the runway edge lights on Runway 01R and notified WestJet of the damage 6 days later. WestJet then notified the TSB.

The airport operator determined that 8 runway edge lights on the right side of Runway 01R had been struck: 7 lights were damaged and the 8th light had its lens knocked off. The distance from the 1st damaged light to the 8th damaged light was approximately 2680 feet (Figure 2).

---

5 Runway edge markings are known as runway side stripe markings in Canada.

6 A geographic flow is a check of switches, controls, and gauges prescribed in the checklist but conducted without a checklist and completed in a consistent order each time.

7 N_1 is the rotational speed of the low-pressure turbine and compressor spool, expressed as a percentage of the maximum normal operating rpm of the spool. On the Boeing 737 Next Generation, the N_1 rotor consists of a fan, a low-pressure compressor, and a low-pressure turbine.

Figure 2. Occurrence aircraft's take-off path, based on quick access recorder data and automatic dependent surveillance - broadcast data. Runway edge light positions are indicated, along with the locations (labelled A to F and listed in Table 1) at which the flight crew performed significant actions during the take-off sequence (Source: Google Earth, with TSB annotations)

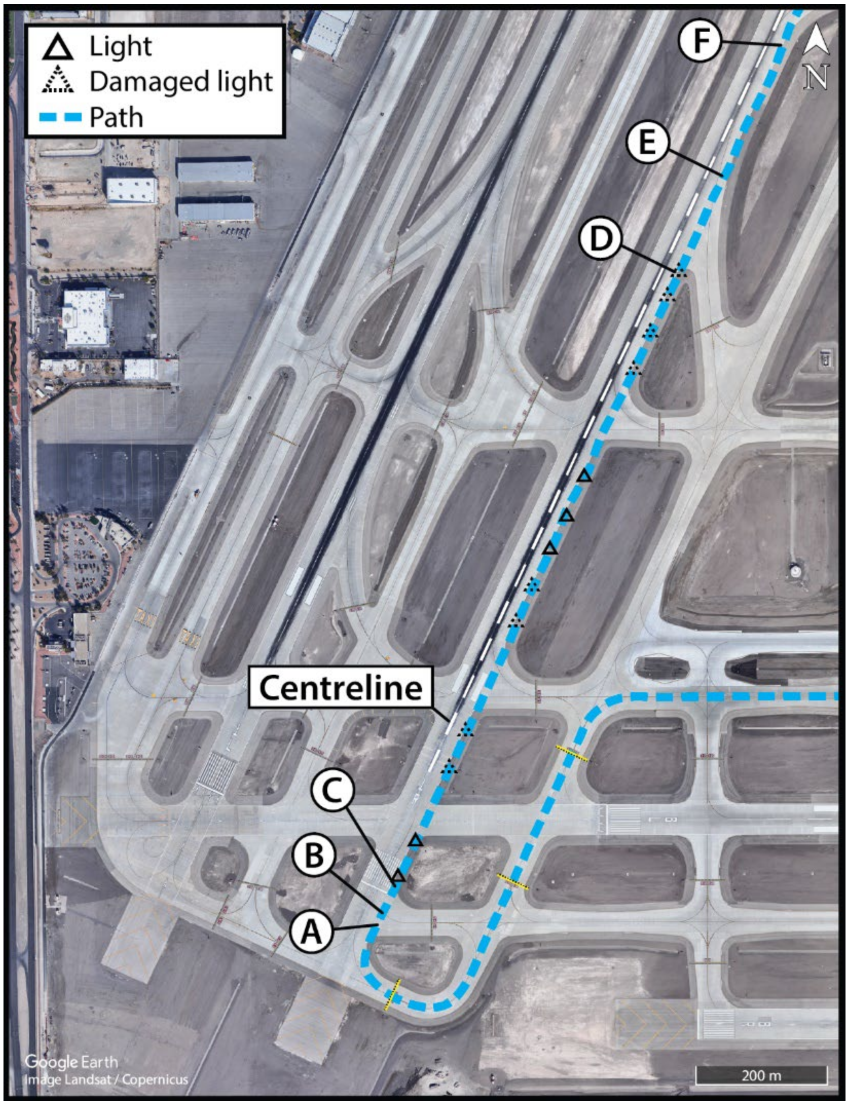


Table 1. Occurrence aircraft's take-off sequence

Event	Time (hhmm:ss.ss)	Event description	Knots ground speed (GS) or knots calibrated airspeed (CAS)	Engine power setting (N_1) for left engine/right engine
A	1824:56.94	On runway heading	14.6 GS	26.4/26.0
B	1824:59.86	Throttle levers advanced	16.5 GS	43.6/41.8
C	1825:04.59	TOGA pressed	27 GS	78.5/74.8
D	1825:28.98	Passed and damaged 8th runway edge light	132 CAS	88/87.7
E	1825:32.07	Rotate (nosewheel weight on wheels [WOW] sensor indicated air mode)	141 CAS	87.8/87.5
F	1825:35.87	Main landing gear WOW sensor indicated air mode	152 CAS	87.5/87.4

1.2 Injuries to persons

There were no injuries to passengers or crew members.

1.3 Damage to aircraft

There was minor damage to the right (No. 2) nosewheel tire.

1.4 Other damage

At the time of the occurrence, since the flight crew were unaware of the aircraft's contact with the runway edge lights, they did not communicate with ATC to report possible damage.

The debris was contained and located just outside of the runway edge markings. Airport electricians replaced the 7 damaged lights and repaired the 8th light. There was no indication of any impact on airport operations from the damaged lights.

1.5 Personnel information

Table 22. Personnel information

	Captain	First officer
Pilot licence	Airline transport pilot licence (ATPL)	Airline transport pilot licence (ATPL)
Medical expiry date	01 August 2023	01 July 2023
Total flying hours	26 000	3794
Flight hours on type	14 712	159.2
Flight hours in the 24 hours before the occurrence	5.7	5.7
Flight hours in the 7 days before the occurrence	13.4	5.8
Flight hours in the 30 days before the occurrence	72.4	38.5
Flight hours in the 90 days before the occurrence	164.65	145.7
Flight hours on type in the 90 days before the occurrence	164.65	145.7
Hours on duty before the occurrence	5.0	5.5
Hours off duty before the work period	19.0	13.5

The flight crew held the appropriate licences and ratings for the flight in accordance with existing regulations. The captain had been employed by WestJet for 22 years, and the FO had been employed by WestJet for approximately 5 months. The previous flight and the occurrence flight marked the first time that they had been paired together and flown together as a crew. The captain had flown to KLAS frequently, but the FO had flown there only once before.

Based on a review of the flight crew's work and rest schedule, there was no indication that their performance was degraded by fatigue.

1.6 Aircraft information

Table 33. Aircraft information

Manufacturer	Boeing
Type, model, and registration	737-7CT, C-GWCN
Year of manufacture	2005
Serial number	34157
Certificate of airworthiness	23 November 2005
Total airframe time	56 352 hours
Engine type (number of engines)	CFM56-7B24 (2)
Maximum allowable take-off weight	154 500 lb (70 080 kg)
Recommended fuel type(s)	Jet A, Jet A1
Fuel type used	Jet A

There were no outstanding recorded defects at the time of the occurrence that would have affected the flight, nor was there any indication that a component or system malfunction played a role in this occurrence.

1.7 Meteorological information

Sunset at KLAS occurred at 1723, and civil twilight occurred at 1749. At about 1814, during the hours of darkness, the aircraft pushed back from the terminal gate to begin the taxi for takeoff on the occurrence flight.

The aerodrome routine meteorological report (METAR) for KLAS issued at 1856 indicated visual meteorological conditions:

- Winds from 020° true at 7 knots
- Visibility of 10 statute miles
- Few clouds at 25 000 feet above ground level
- Temperature 7 °C
- Dew point −17 °C

Neither weather nor visibility conditions were considered to be factors in this occurrence.

1.8 Aids to navigation

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome information

KLAS is an international airport located in Paradise, Nevada, U.S., approximately 5 statute miles south of the city of Las Vegas. Managed and operated by the Clark County Department of Aviation, it is the main airport for the Las Vegas Valley. In 2022, KLAS ranked 5th in the U.S. for the total number of aircraft movements.[8] The airport is described as having a high tempo of operations to ensure a timely movement of a large number of aircraft.

The airport has 4 runways. Runway 01R/19L is 150 feet wide and 9771 feet long. Runway 01R has a permanently displaced threshold distance of 491 feet. The runway's edge lights have variable brightness settings with a maximum setting of medium intensity. During the occurrence, they were set to setting 1 of 3. Although runway end identifier lights are installed, Runway 01R is not equipped with centreline lighting, nor is it installed on any of the other runways.

KLAS uses an Airport Surface Detection Equipment—Model X (ASDE-X) surveillance system with data distribution. This equipment provides cues to controllers in the ATC tower, located 1.4 nautical miles from the threshold of Runway 01R, and allows for an accurate

---

8 Federal Aviation Administration (FAA), *Air Traffic by the Numbers* (April 2023), p. 9, at faa.gov/air_traffic/by_the_numbers/media/Air_Traffic_by_the_Numbers_2023.pdf (last accessed on 11 March 2024).

identification of all aircraft and vehicles on the airport movement area. The system is not designed to automatically alert controllers to the hazardous situations leading to misaligned takeoffs.

For the detection of foreign objects, KLAS relies on runway inspections conducted by ground crews in vehicles. Up to the time of the occurrence, inspections consisted of 2 passes conducted after dark, and there were no formal procedures on where the passes would be conducted. For the most part, inspection passes were conducted on the centre portion of the runway.

1.10.1 Visual environments of runway thresholds and displaced thresholds

Canadian and U.S. standards for runway threshold markings are very similar. Runway threshold markings help identify the beginning of the runway that is available for landing. These markings are longitudinal stripes that are painted white and extend laterally across the approximate width of the runway. The specifications of the stripes are determined by the certification of the runway, by its width, as well as by the approach category servicing the runway.

In addition, the runway designation marking (known as the runway landing designator marking in the U.S.) is the painted runway number centred on the runway centreline and located 12 m from the top edge of the runway threshold marking.

In some instances, the landing threshold may be relocated or displaced; for example, when natural or fabricated obstacles interfere with runway approach paths and require limitations to their use. In the U. S.,

> [a] displaced threshold is a threshold located at a point on the runway other than the designated beginning of the runway. Displacement of a threshold reduces the length of runway available for landings. The portion of runway behind a displaced threshold is available for takeoffs in either direction and landings from the opposite direction. A ten feet wide white threshold bar is located across the width of the runway at the displaced threshold. White arrows are located along the centerline in the area between the beginning of the runway and displaced threshold.[9]

Standards in Canada indicate that the arrowhead must be 10 m long and the shaft at least 20 m.[10] Standards in the U.S. are similar, with required lengths of 13.5 m and 24 m, respectively (figures 3 and 4). The displaced portion of a runway can be used for taxiing and takeoff. It can also be used for rollouts after landing on the opposite end.

---

9 Federal Aviation Administration (FAA), *Aeronautical Information Manual*, Chapter 2, section 2-3-3: Runway Markings.

10 Transport Canada, TP 312E, *Aerodromes Standards and Recommended Practices*, 5th Edition, Amendment 1 (effective 15 January 2020), Figure 5-6(a): Arrow markings, p. 100.

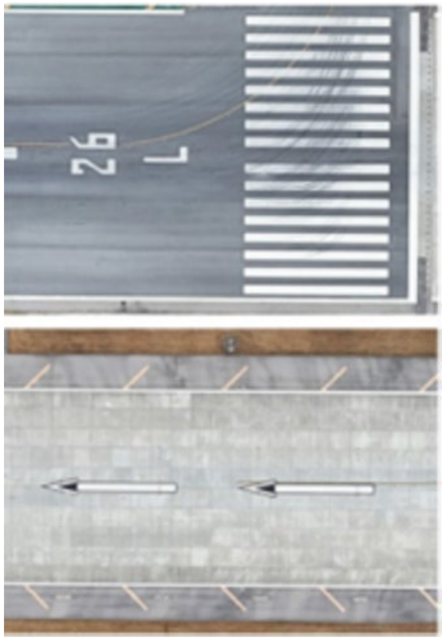


Figure 3. Runway threshold (top) and displaced threshold area (bottom) at Vancouver International Airport (Source: Google Earth)

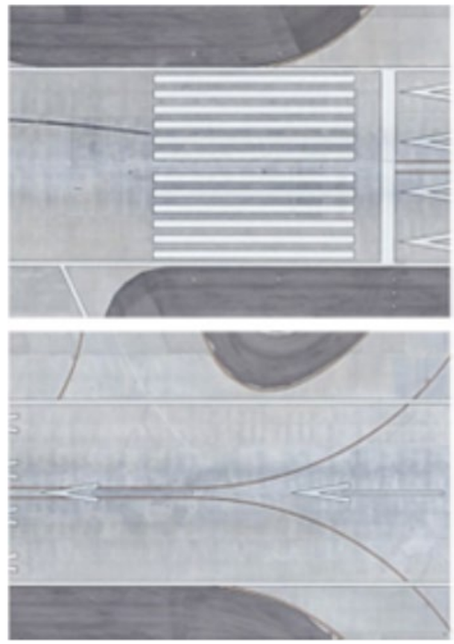


Figure 4. Runway threshold (top) and displaced threshold area (bottom) at Harry Reid International Airport (Source: Google Earth)

1.10.2 Taxiway centreline marking

Taxiway centreline markings and lighting provide flight crews with continuous visual guidance along a designated path. According to the U.S. Federal Aviation Administration (FAA) standard for airport markings, the centreline markings on a lead-on taxiway can terminate at the runway edge, but for taxiways that enter onto the runway in a displaced threshold area, the taxiway centreline markings continue onto the runway and extend parallel to the arrows that lead to the displaced threshold for at least 200 feet beyond the point of tangency or to the displaced threshold bar, whichever is less.[11] The taxiway centreline markings at KLAS are yellow with a black border.

Taxiway centreline lights are embedded parallel to the centreline of the taxiway and coloured green and amber. In the U.S., per the FAA standard for airport lighting, taxiway centreline lead-on lighting cannot be installed within the confines of the runway where operations are not conducted below 1200 feet (365 m) runway visual range[12] (low-visibility operations) (Figure 5). The purpose of this standard is to avoid excessive lighting in the runway area.

---

11 Federal Aviation Administration (FAA), Advisory Circular (AC) 150/5340-1M: Standards for Airport Markings, Change 1 (23 December 2020), Section 4.2: Taxiway Centerline Markings, p. 4-2.

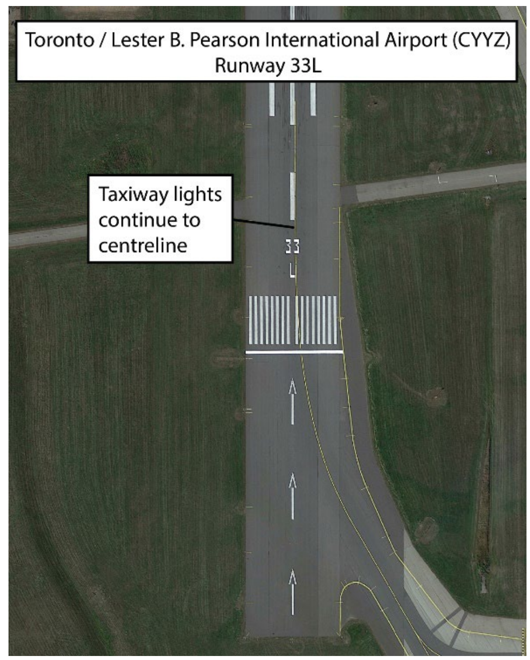
12 Federal Aviation Administration (FAA), Advisory Circular (AC) 150/5340-30J: Design and Installation Details for Airport Visual Aids (12 February 2018), Section 4.3.5.3: Taxiway/Runway Intersections Other Than Acute-Angled Exits, p. 4-6.

Canadian airports, on the other hand, do allow taxiway centreline lighting to continue onto runways not certified for low-visibility operations, even though it is not required (Figure 6). This is to ensure that the visual signal provided to pilots is consistent and standardized. However, if taxiway centreline lighting is provided, the lighting must comply with the standard; the airport operator cannot implement only part of a standard.[13]

In this occurrence, the aircraft entered Runway 01R from Taxiway D, on which taxiway centreline markings extended to the centre of the runway; however, the lighting stopped at the runway edge markings, as required by the standard.

Figure 5. Taxiway lighting at intersection with Runway 01R at Harry Reid International Airport (Source: Google Earth, with TSB annotations)

Figure 6. Taxiway lighting at intersection with Runway 33L at Toronto/Lester B. Pearson International Airport (Source: Google Earth, with TSB annotations)



1.10.3 Runway edge markings

Runway edge markings (known as runway side stripe markings in Canada) provide enhanced visual contrast between the runway edges and the surrounding terrain or runway shoulders and define the runway width. The side stripe markings consist of 1 parallel stripe on each edge of the runway. The Canadian aerodrome standard for runway markings states that side stripes are interrupted at intersections between 2 runways or at intersections

13 Transport Canada, TP 312E, *Aerodromes Standards and Recommended Practices*, 5th Edition, Amendment 1 (effective 15 January 2020), Preamble, p. 19.

between a runway and a taxiway.[14][15] By contrast, the U.S. standard[16] for runway edge markings specifies that runways shall have uninterrupted edge markings (figures 7 and 8).

Figure 7. Runway side stripe markings at Vancouver International Airport (Source: Google Earth, with TSB annotations)

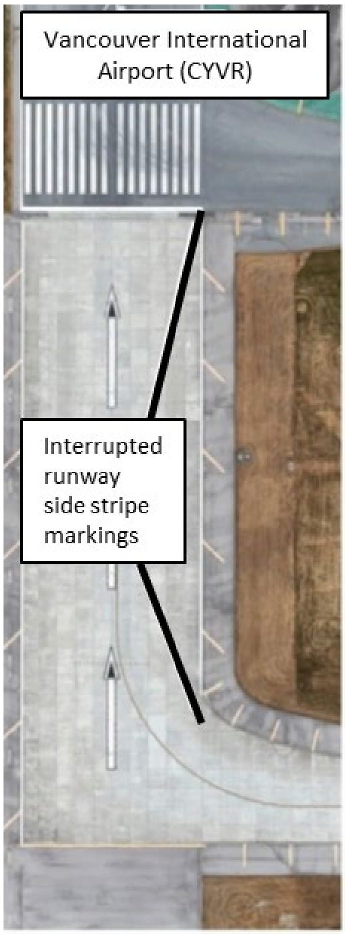
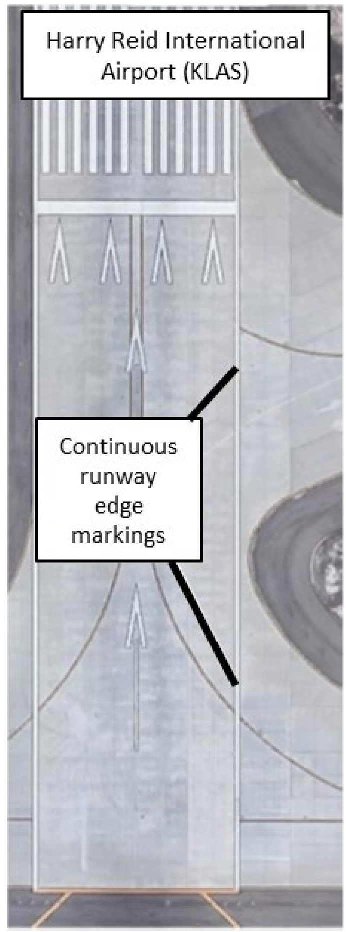


Figure 8. Runway edge markings at Harry Reid International Airport (Source: Google Earth, with TSB annotations)



In this occurrence, the aircraft entered Runway 01R from Taxiway D, crossing over a continuous runway edge marking.

---

14 Ibid., Section 5.2.11: Runway Side Stripe Marking, subsection 5.2.11.4, p. 105.

15 The investigation is aware of 1 runway in Canada that does not adhere to this standard: Runway 06L/24R at Toronto/Lester B. Pearson International Airport (CYYZ), Ontario. This runway had runway side stripe markings painted onto it before the publication of the most recent edition of TP 312 *Aerodrome Standards and Recommended Practices*, which established the current standard. Transport Canada Advisory Circular (AC) 302-018 (Grandfathering at Airports Pursuant to *Canadian Aviation Regulation* [CAR] 302.07) provides guidance to clarify that when airport parts and facilities are being maintained, they can be grandfathered to the same edition of TP 312 applicable at the time of initial certification (and with which they currently comply), but if replaced or improved, they must comply with the latest edition of TP 312.

16 Federal Aviation Administration (FAA), Advisory Circular (AC) 150/5340-1M: Standards for Airport Markings, Change 1 (23 December 2020), Section 2.8: Runway Edge Markings, pp. 2-16 - 2-17.

1.10.4 Runway and taxiway shoulder markings

Runway shoulders are the areas adjacent to the defined runway edges that provide resistance to blast erosion and accommodate the passage of maintenance and emergency equipment. Paved shoulders assist in reducing the amount of dirt and debris that enters the runway, providing a smoother runoff area for runway side excursions and allowing for the passage of airport operations vehicles without the use of the runway surface.

While the U.S. standards[17] for runway geometry indicate that stabilized surfaces, such as turf or low-cost paving, are suitable for the shoulder, paved shoulder surfaces are required for runways that accommodate aircraft with a wingspan of 36 m or longer and a tail height of 13.7 m or higher (the approximate measurements of a Boeing 767 aircraft, which is larger than the occurrence aircraft, the Boeing 737). Taxiway shoulders serve a function similar to that of runway shoulders and are not intended for use by aircraft.

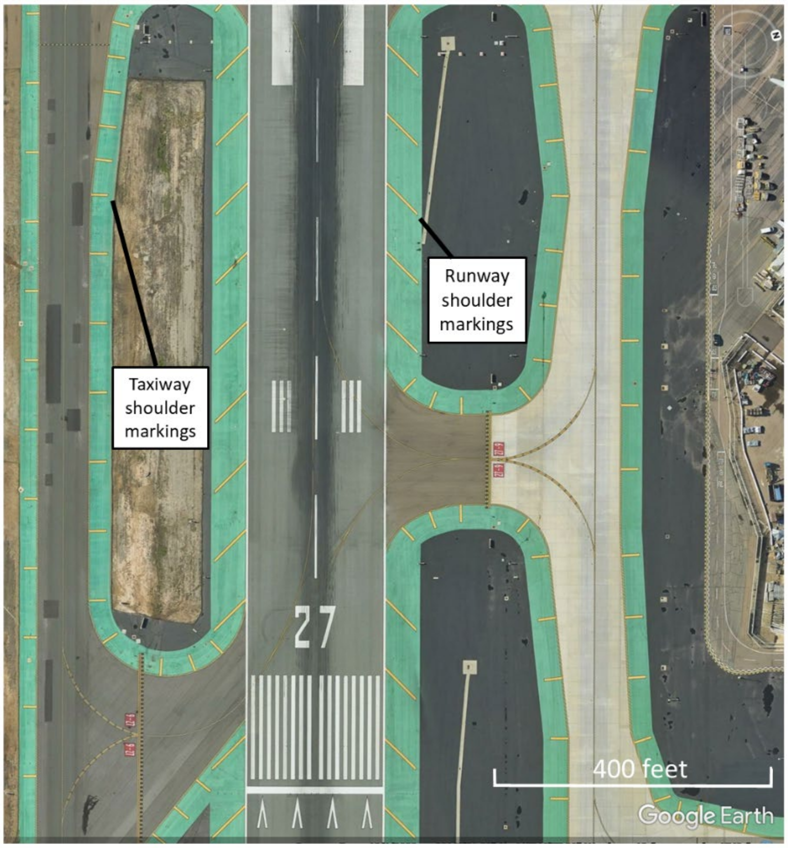
In the U.S., runway shoulders can have markings to further delineate the shoulder from the runway. If used, they consist of stripes oriented 45° from the runway centreline and painted yellow (Figure 9).[18]

---

17 Federal Aviation Administration (FAA), Advisory Circular (AC) 150/5300-13A: Airport Design, Change 1 (26 February 2014), Section 304: Runway geometry, p. 54.

18 Federal Aviation Administration (FAA), Advisory Circular (AC) 150/5340-1M: Standards for Airport Markings, Change 1 (23 December 2020), Figure A-12: Runway Shoulder Markings, p. A-12.

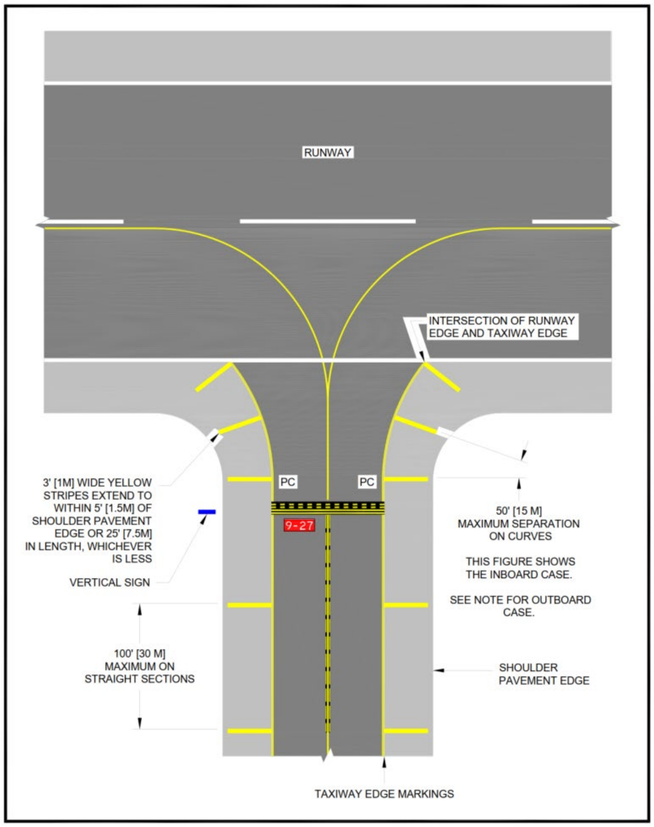
Figure 9. Runway and taxiway shoulder markings at San Diego International Airport (Source: Google Earth, with TSB annotations)



Taxiway shoulders can also feature markings that make it clear that those areas are not part of the taxiway surface. Such markings, which are also painted yellow, consist of stripes oriented perpendicular to the taxiway centreline (Figure 10).[19]

[19] Ibid., Section 4.10: Taxiway Shoulder Markings, pp. 4-23 to 4-24.

Figure 10. Taxiway shoulder markings (Source: Federal Aviation Administration, Advisory Circular [AC] 150/5340-1M: Standards for Airport Markings, Change 1 [23 December 2020], Figure A-23: Taxiway Shoulder Markings, p. A-23)



At the time of the occurrence, Runway 01R at KLAS did not have runway shoulder markings, nor did Taxiway D have taxiway shoulder markings where it approaches and intersects with Runway 01R.

KLAS has several safety initiatives that collect data regarding airport operations, and the analysis of that data has resulted in changes at the airport. Runway and taxiway safety area markings are not a universal requirement, and therefore, KLAS has no plans to add any around the taxiway-runway intersection where the occurrence aircraft entered Runway 01R. However, in the past when construction occurred at KLAS, these taxiway safety area markings were added when the data supported additional safety measures (which include the addition of taxiway and runway shoulder markings) in certain areas.

1.10.5 Runway lighting

In both Canada and the U.S., the standard for runway edge lighting is to emit white light. As an aircraft nears the end of the runway lighting, the colour changes from white to yellow, signifying the final 600 m (or 610 m in the U.S.) of the runway, which can include a displaced threshold. When a runway threshold is displaced, the runway edge lighting located in the area before the displaced threshold emits red light toward the aircraft on approach[20][21] and yellow in the opposite direction. For the displaced threshold area for Runway 01R at KLAS, there were 2 embedded red edge lights on the right side in front of the displaced threshold.

All runway edge lights are placed in 2 parallel rows, each equidistant from the runway centreline, and with uniform spacing of not more than 60 m (or 61 m in the U.S.).

If a runway is equipped with runway centreline lighting, these lights emit a white light in the direction of the approaching aircraft. To warn flight crews of the impending end of a runway, the colouring changes to alternating red and white for the final 900 m, then to red for the final 300 m.[22][23] At KLAS, none of the runways are equipped with runway centreline lighting owing to the fact that visual flight rules weather conditions are predominant at the airport all year round.

Canada and the U.S. have similar standards for the operation of airport lighting. Between sunset and sunrise, or when other specific environmental conditions persist, runway edge and centreline lights (if installed) must be on for departing aircraft. Approach lighting is required to be on only for the landing runway served by the lights. However, controllers can activate lights otherwise, as they deem necessary, and pilots can also request that approach lighting be activated.

During the occurrence aircraft's takeoff, the runway edge lights were on.

1.11 Flight recorders

The occurrence aircraft flew about 80 hours flight time before WestJet officials became aware of the occurrence at KLAS and recognized that data from the aircraft would need to be retrieved for investigative purposes. However, by that time, flight data recorder and cockpit voice recorder data from the occurrence flight had been overwritten.

Data from the quick access recorder (QAR) were still available. The QAR data were downloaded and contained information from the occurrence flight.

Finding: Other

The elapsed time between the misaligned takeoff and the discovery, by airport personnel, of the broken runway edge lights, as well as the time taken to report the occurrence to

---

20 Transport Canada, TP 312E, *Aerodromes Standards and Recommended Practices*, 5th edition, Amendment 1 (effective 15 January 2020), Section 5.3.12.5: Characteristics, p. 172.

21 Federal Aviation Administration (FAA), Advisory Circular (AC) 150/5340-30J: Design and Installation Details for Airport Visual Aids (12 February 2018), Section 2.3.2.1.2: Displaced Runway Thresholds, p. 2-4.

22 Transport Canada, TP 312E, *Aerodromes Standards and Recommended Practices*, 5th edition, Amendment 1 (effective 15 January 2020), Figure 5-37: Runway edge, centreline and touchdown zone lighting, p. 173.

23 Federal Aviation Administration (FAA), Advisory Circular (AC) 150/5340-30J: Design and Installation Details for Airport Visual Aids (12 February 2018), Section 3.3.1.2: Color Coding, p. 3-2.

WestJet, resulted in data from both the cockpit voice recorder and the flight data recorder being overwritten.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

According to information gathered during the investigation, there was no indication that the flight crew's performance was affected by medical factors.

1.14 Survival aspects

Not applicable.

1.15 Fire

Not applicable.

1.16 Tests and research

1.16.1 TSB laboratory reports

The TSB completed the following laboratory report in support of this investigation:

- LP034/2023 - QAR and ADS-B Data Recovery and Analysis

1.17 Organizational and management information

WestJet is a Canadian air operator certified for airline operations under *Canadian Aviation Regulations* Subpart 705 and an approved maintenance organization under *Canadian Aviation Regulations* Subpart 573. The air operator is also a Transport Canada–approved flight training organization.

At the time of the occurrence, the WestJet mainline fleet consisted of 41 Boeing 737-700, 37 Boeing 737-800, and 24 Boeing 737 Max series aircraft, as well as 7 Boeing 787 aircraft. WestJet also has 3 B737-700 pilot training simulators, located in Calgary, Alberta. Both initial and recurrent classroom training take place at the company's headquarters in Calgary.

WestJet's training includes the crew resource management and threat and error management content required under *Commercial Air Service Standards* subsection 725.124(39).[24]

---

[24] Transport Canada, *Commercial Air Service Standards*, Standard 725: Airline Operations - Aeroplanes, subsection 725.124(39) (amended 09 December 2020).

The company monitors and addresses operational risk using a Transport Canada–approved safety management system with tools, such as flight data monitoring, a flight operations quality assurance program, and standard operating procedures, that generate a feedback loop to assist with identifying and mitigating safety risks.

As well, WestJet routinely issues safety letters with timely information. For example, the company's Flight Operations team published a memo immediately after this occurrence to keep crews informed of possible issues with displaced thresholds on takeoff.[25]

1.17.1 *Route & Aerodrome Qualification* document

WestJet also produces a document known as a *Route & Aerodrome Qualification* for each aerodrome at which it operates. This manual provides crews with aerodrome-specific guidance that includes cautions and procedures pertaining to departure, en route flight, and approach and landing. For example, the document for KLAS notes that the airport does not use runway centreline lighting.

1.18 Additional information

1.18.1 Other occurrences and investigations of misaligned takeoffs

The TSB has previously reported on runway side excursions resulting from misaligned takeoffs. TSB records indicate 9 other occurrences[26] in which flight crews lined up with and commenced a take-off roll on a runway edge rather than the runway centreline. Common to all occurrences were operations conducted in nighttime conditions.

One of these occurrences, the 2006 misaligned takeoff of a Canadian registered Airbus A319-114 from KLAS to Montréal/Pierre Elliott Trudeau International Airport (CYUL), Quebec, resulted in a TSB investigation.[27] This investigation found that the runway markings, combined with the PF's primary focus on the preceding aircraft's departure and his use of peripheral vision when orienting the aircraft onto the runway, contributed to the aircraft being aligned on the runway's asphalt shoulder rather than on the centreline. Subsequently, runway edge lights were damaged during the take-off roll. Of note is the fact that this misalignment was not known to ATC or to the airport until 2 hours after the event, and during that time, potential debris from broken lights could have been a hazard to departing aircraft.

In 2009, the Australian Transport Safety Bureau (ATSB) researched the factors influencing occurrences of misaligned takeoffs. The study identified 7 prevalent safety factors

---

25 Refer to section 4.1 *Safety action taken* in this report.

26 TSB occurrences A21F0210 (ongoing), A18O0009, A11F0107, A09F0158, A09F0019, A09F0010, A07F0186, A06F0014, and A97A0185.

27 TSB Aviation Investigation Report A06F0014.

contributing to misaligned takeoffs, with the presence of each factor increasing the risk of an occurrence. The 7 factors were:

- night time operations
- the runway and taxiway environment, including confusing runway entry markings or lighting, areas of additional pavement on the runway, the absence of runway centreline lighting, and recessed runway edge lighting
- flight crew distraction (from within the cockpit) or inattention
- bad weather or poor/reduced visibility
- conducting a displaced threshold or intersection departure
- provision of air traffic control clearance when aircraft are entering the runway or still taxiing
- flight crew fatigue[28]

These factors can be summarized as human factors, environmental factors, and operational factors. A key human factor identified in the research was distraction resulting in divided attention. Distraction causes the flight crew's attention to be divided, with a focus on completing tasks inside the cockpit at the expense of accurately assessing the external environment. This often occurs during the taxi, when flight crew members must have their eyes inside the cockpit for significant periods of time. As the ATSB report explains,

> instead of maintaining a visual look out from when they enter the runway, their attention is drawn inside for some reason such as checking instruments, confirming aircraft configuration or performing checklist items. While multi-crew operations partially mitigate this risk by articulating and dividing aircraft handling and monitoring roles between the pilots, there are still times when both crew members may not be processing the external environmental cues accurately. This divided attention is often a necessary part of lining up or beginning the take-off roll [...].[29]

One of the environmental factors mentioned by the ATSB report is runway threshold markings. A runway's threshold markings, colloquially known as "piano keys," assist flight crews by defining the width of the runway. The report explains that

> [a]ircraft using a displaced threshold will not be able to see the normal threshold markings, such as the runway number or 'piano keys', which provide important cues during the line up phase of flight.[30]

The report also highlights operational factors, one of which is the necessity to follow any available lead-on taxiway centreline markings and centreline lights to maximize the flight crew's opportunity to correctly align the aircraft on the runway for takeoff, especially at times when ATC clearances are transmitted while the aircraft is lining up or when it is

---

[28] Australian Transport Safety Bureau, ATSB Transport Safety Report, Aviation Research and Analysis Report AR-2009-033, Final, *Factors influencing misaligned take-off occurrences at night* (June 2010), p. 19.

[29] Ibid., p. 15.

[30] Ibid., p. 17.

departing from an area other than a runway's threshold, with fewer cues for lateral runway alignment.

1.18.2 Human factors issues

1.18.2.1 Multitasking

When considering an individual's ability to manage multiple competing tasks, also known as multitasking, the most common theory for evaluating this type of performance is multiple resource theory. There are 3 key elements in multiple resource theory: resource demand, multiplicity of resources, and executive allocation of resources.[31] Resource demand describes how much effort (i.e., attentional resources) it takes to complete the tasks. The greater the attentional resources required, the greater the mental workload. Resource multiplicity, the 2nd element of the theory, refers to the variety of resources available to complete a particular task. When 2 tasks demand the same resource (for example, visual attention), there will be a larger decrement in performance than if they were using separate resources—for example, both visual and aural attention. The final element, the executive allocation of resources, is the conscious prioritization of which task receives more of an individual's resources and attention.[32] Using these 3 elements, the possible degradation of an individual's performance while he or she tries to manage multiple tasks can be better understood, based on the nature of the tasks and the context in which they were performed.

1.18.2.2 Information processing in dynamic environments

Information processing is critical to human performance. It is described in stages, which are perceiving information, transforming information into different forms, acting on information, processing feedback information, and assessing the effects on the environment.[33]

1.18.2.2.1 Perception

Perception is the process by which humans acquire, process, and interpret information from the external world. The identification of an object in an environment is related not only to an individual's physical sensitivity to sensing properties such as light, sound, and temperature, but also to the individual's goals, knowledge, and expectations.[34] Objects are recognized more quickly when they are viewed in context, rather than when presented in

---

31 C.D. Wickens, "Multiple resources and mental workload." *Human Factors*, Volume 50, Issue 3 (June 2008), p. 452.

32 C.D. Wickens, W.S. Helton, J.G. Hollands, and S. Banbury, *Engineering Psychology and Human Performance,* 5th edition (Routledge, 2022), Chapter 11: Multitasking, pp. 433-434.

33 C.D. Wickens and C.M. Carswell, "Information Processing," in G. Salvendy, *Handbook of Human Factors and Ergonomics,* 4th Edition (John Wiley & Sons, 2012), p. 117.

34 Ibid., p. 122.

isolation or in incoherent contexts.[35] In addition, objects and attributes that look similar to the target object can be perceived and understood as the object they resemble.

The way in which an individual can perceive information through a mixture of sensing cues from the external environment and through their own goals, knowledge, and expectations can be described in the context of a runway departure. Each side of a runway, starting from the centreline, has an expanse of asphalt approximately 75 feet wide with an additional paved shoulder. The sight of the width of the asphalt and shoulder are cues from the environment that the aircraft is positioned on the centreline. Some runways in the U.S. have very large expanses of asphalt extending beyond the runway edge line on either side of the runway. In contrast, at airports in Canada, the paved shoulder beside a runway's edge is up to only 25 feet wide, and beyond the shoulder lies grass or some other textured surface. When a pilot sees a wide area of asphalt beside the aircraft, this cue can be interpreted as an indicator that the aircraft is positioned at the centreline when in fact, the aircraft may be positioned on the runway's edge. A collection of external cues is combined with a pilot's goals, knowledge, and expectations to form an understanding of position in space.

An individual's expectancies can be used to prevent misinterpretations when working in degraded conditions.[36] For example, expectancies created through training and experience contribute to how an individual perceives and interprets information in an environment and what information is perceived. Thus, knowledge of the fact that the environment in the area of a displaced threshold has different and fewer cues for identifying the runway centreline is important for flight crews operating in these areas. Furthermore, knowing how and why vision and perception can be negatively impacted in degraded or dark visual conditions is also useful for supporting operations under these conditions.

Sensory cues and information can be ambiguous depending on the environment in which they are sensed. A core aspect of processing sensory cues and information is resolving ambiguity. The brain resolves ambiguity in 2 ways: bottom-up processes and top-down processes, or a combination of both.[37] Bottom-up processing is when information flows up from lower levels to higher levels of analysis; simple characteristics of cues and information are integrated into larger images or forms on the basis of rules or knowledge held by the observer.[38] Top-down processing is when information flows down from higher levels to lower levels of analysis; prior knowledge and experience are used to direct lower level perceiving.[39]

When this concept is applied to a pilot perceiving a visual runway environment, a pilot sees the visual cues and information in the environment and uses bottom-up processing (i.e.

---

[35] C.D. Wickens and C.M. Carswell, "Information Processing," in G. Salvendy and W. Karwowski, *Handbook of Human Factors and Ergonomics,* 5th Edition (John Wiley & Sons, 2021), p. 120.

[36] Ibid., p. 121.

[37] G. Mather, *Essentials of Sensation and Perception* (Routledge, 2011), p. 127.

[38] Ibid., p. 111.

[39] Ibid.

perceptual sensors of the eye knowing where to look and what to look at) and top-down processing (i.e. knowledge from training and past experiences about the organization of the environment) to interpret the cues and information to understand the aircraft's position on the runway. Ambiguous cues and information in the external environment become more difficult to resolve and are more susceptible to misinterpretations when there is interference or degradation in the environmental cues and information (for example, in degraded visibility or dark conditions).

1.18.2.2.2 Transforming information and taking actions

Human information processing can be grouped into 3 levels: skill-based, rule-based, and knowledge-based.[40] Despite the distinction, many of the meaningful tasks that individuals perform represent combinations of skill-, rule-, and knowledge-based levels of performance.

Rule-based performance involves the conscious perception of environmental cues, which trigger the application of rules learned on the basis of experience. These rules link environmental cues and goals of the task with actions to be performed.[41] Activities performed at the rule-based level use rules that have been committed to memory based on experiences and training. Problems in rule-based performance can occur when the information gathered, or the cues perceived in the environment, are inappropriately matched and either an action is missed or the wrong action for the situation is applied. A cue can go undetected or be misidentified when an individual is in a hurry or has a strong expectation of something occurring as a result of an action. Cues can also be missed when a problem is not expected in a particular location, when the cue is ambiguous or degraded, and when cues are similar.[42]

Rule-based performance is closely related to recognition-primed decision making.[43] As explained in *Sources of Power: How People Make Decisions*,

> [t]he recognition-primed decision (RPD) model fuses two processes: the way decision makers size up the situation to recognize which course of action makes sense, and the way they evaluate that course of action by imagining it.[44]

In these types of situations, people make decisions by recognizing situations as typical and familiar, and proceed to take action. They understand which types of goals make sense,

---

40 J. Rasmussen, "Skills, Rules, and Knowledge; Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-13, No. 3 (May/June 1983), p. 257.

41 C.D. Wickens and C.M. Carswell, "Information Processing," in G. Salvendy, *Handbook of Human Factors and Ergonomics,* 4th Edition (John Wiley & Sons, 2012), p. 143.

42 J. Reason, *The Human Contribution: Unsafe Acts, Accidents and Heroic Recoveries* (CRC Press, 2008), pp. 38-39.

43 M.R. Lehto, F.F. Nah, and J.S. Yi, "Decision-making models, decision support, and problem solving", in: G. Salvendy, *Handbook of Human Factors and Ergonomics*, 4th edition (John Wiley & Sons, 2012), p. 211.

44 G. Klein, *Sources of Power: How People Make Decisions* (MIT Press, 1998), p. 24.

which priorities to set, which cues are important, and what can be anticipated next, as well as typical ways to respond in given situations.[45] When they recognize a situation as typical, they also determine a course of action likely to succeed and conduct rapid mental simulation to assess its fit for the situation. This decision-making model has come from research on how decisions are made in time-sensitive, dynamic, real-world settings.[46] Situation assessment is an important aspect of decision making in these real-world environments.[47]

When people make decisions and take actions based on this model, errors and poor outcomes can result from insufficient experience (e.g. when they do not have experience with the situation) or inadequate information (e.g. if the information or cues needed to make a good assessment of the situation are unavailable or degraded), or due to errors in mental simulation (e.g. when they connect cues or signs of a problem to a different situation).[48]

---

45 Ibid.

46 M.R. Lehto, F.F. Nah, and J.S. Yi, "Decision-making models, decision support, and problem solving", in: G. Salvendy, *Handbook of Human Factors and Ergonomics*, 4th edition (John Wiley & Sons, 2012), p. 211.

47 Ibid., p. 212.

48 G. Klein, *Sources of Power: How People Make Decisions* (MIT Press, 1998), p. 274-275.

2.0 ANALYSIS

During the occurrence aircraft's nighttime departure from the displaced threshold of Runway 01R at Harry Reid International Airport (KLAS), Nevada, United States (U.S.), the aircraft, unbeknownst to the flight crew, was aligned with the runway's right edge marking and made contact with 8 runway edge lights as it performed the take-off roll. The investigation determined that the pilots held the proper qualifications to conduct the flight, and there were no indications of a malfunction in the aircraft's systems.

The analysis will therefore focus on the flight crew's attention while aligning the aircraft on Runway 01R, the visual cues available to the flight crew to determine their location, the flight crew's expectations regarding those cues, and the airport operator's runway inspection process.

2.1 Flight crew attention

Both the first officer (FO) and the captain were each experiencing a relatively high workload at the time of the departure. The FO was managing several tasks as the aircraft approached the runway holding position marking, until the point at which he assumed control during takeoff. These tasks included, but were not necessarily limited to, finding and tuning the departure frequency, receiving and reading back the take-off clearance, talking to the cabin crew, and completing the geographic flow and the Before Takeoff Checklist. These tasks would have consumed most of the FO's attentional resources, to the extent that he missed the announcement of the initial take-off clearance from the air traffic control (ATC) tower controller while he was discussing the departure frequency with the captain.

This "head-down" time and focus on activities inside the cockpit would have limited his ability to perform outside scans during the taxi, making it unlikely that he was paying attention to any of the environmental cues outside of the cockpit window to aid in ensuring that the aircraft was properly aligned for takeoff. The FO directed his attention outside the window only once control of the aircraft was transferred to him. At that time, the aircraft was already aligned with the right edge of the runway, which the flight crew mistook for the centreline, and beginning its take-off roll on Runway 01R.

Finding as to causes and contributing factors

The FO's high workload contributed to his attention being focused primarily on managing tasks within the cockpit as the aircraft was taking position on Runway 01R. As a result, he was unable to provide additional support in visually aligning the aircraft on Runway 01R in the proper position.

The captain's pre-takeoff workload was divided between 2 main tasks: taxiing the aircraft into position and monitoring the FO's progress. In this case, the task of taxiing the aircraft likely required fewer information-processing resources, given that he was familiar with the airport layout and had flown to KLAS regularly; the aircraft was 1st in line to depart on Runway 01R, and there was thus no preceding aircraft to monitor; the flight crew had taxiway centreline lighting to follow; and the weather conditions were optimal, aside from the darkness.

Therefore, more of the captain's attentional resources were likely devoted to monitoring and supporting the FO. For example, the captain acknowledged, simultaneously with the FO, ATC's 2nd call granting them take-off clearance after they had both missed the 1st call. At one point, while taxiing the aircraft into position on Runway 01R, the captain looked over at the FO because the captain perceived that the FO was taking slightly longer than he expected it to take to complete certain tasks, such as the Before Takeoff Checklist.

This focus on the FO was likely being driven by a sense of time pressure to ensure an expeditious departure. Having flown to KLAS regularly over the course of his employment with WestJet Airlines Ltd. (WestJet), the captain was aware of the tendency of KLAS ATC to be direct and purposeful to ensure timely movements of air traffic. He had also noted that 2 aircraft were moving into position behind them as they made their way past the terminal. Later on, once the tower controller had issued the take-off clearance without receiving an immediate response, the controller waited only 3 to 4 seconds before contacting the crew again. These factors contributed to the captain's sense of pressure to depart as soon as possible and, when combined with being paired with an FO with whom he had flown only once before (on the previous leg), they led the captain to devote a significant portion of his attention to the FO's tasks within the cockpit.

Once the aircraft was on Runway 01R and in anticipation of the take-off roll, the captain began setting the thrust levers and monitoring the engine gauges. In addition to monitoring the FO, these tasks diverted his attention from looking outside and required additional attentional resources. This limited his ability to thoroughly perceive the environmental cues outside the aircraft, such as the runway threshold markings, that could have indicated that the aircraft was misaligned laterally. Aware of the speed at which KLAS operations tended to operate and the potential for delay, the captain was trying to ensure a timely departure.

Finding as to causes and contributing factors

Influenced by his perceived time pressure to depart, the captain's attention was focused primarily on the FO and setting take-off thrust. This diverted his attention away from laterally aligning the aircraft on the runway.

2.2 Visual cues

2.2.1 Lighting

KLAS is equipped with taxiway centreline lighting to assist aircraft in navigating the aerodrome. However, the taxiway centreline lighting on Taxiway D, on which the occurrence aircraft taxied to arrive at Runway 01R, terminates at the runway edge markings, whereas the taxiway centreline markings continue to the centre of the runway. This complies with the U.S. Federal Aviation Administration (FAA) standard stipulating that taxiway centreline lead-on lighting cannot be installed within the confines of the runway where operations are not conducted below 1200 feet (365 m) runway visual range, which applies to KLAS operations.

The standard differs from that which applies to Canadian airports, where taxiway centreline lighting can continue onto runways even if they are not certified for low-visibility operations. Although the intention of the U.S. standard is to reduce excessive lighting in the runway area, in this occurrence, it created a potential hazard by stopping a key visual indicator partway to the aircraft's intended destination, ending it instead at the runway edge markings. The termination of these lights at the runway edge markings reduces their salience during nighttime operations and made it more likely that the occurrence crew would have had to rely on other cues to align the aircraft properly.

In addition, in both Canada and the U.S., the centreline and runway edge lighting use white lights. At night, the runway centreline lights are a cue commonly used by Canadian crews to ensure that their aircraft are aligned for takeoff, given the difficulty in discerning runway markings in dark conditions. However, unlike most of the major airports that WestJet services in Canada, KLAS does not have runway centreline lights. This is because operations at KLAS normally take place in visual flight rules conditions—in which runway centreline lighting is not necessary—rather than in instrument flight rules conditions.

Information regarding the absence of runway centreline lighting was available in WestJet's *Route & Aerodrome Qualification* document, which is used as a reference in departure briefings. This item could potentially have been included as part of the departure briefing; however, given the experience of the captain with KLAS, the benign weather conditions, and the fact that WestJet's procedures do not require specific topics to be covered during the departure briefing, the absence of runway centreline lighting was likely not discussed.

2.2.2 Markings

At major airports, the visual cues provided by the runway dimensions and markings, including runway side stripe markings, are distinctively different in Canada from what they are in the U.S. In Canada, a runway's side stripe markings do not cross taxiways or other runways that intersect it. In the U.S., conversely, these markings—called runway edge markings—continue across such intersections. This difference in markings between Canadian and American aerodromes is not included in WestJet's *Route & Aerodrome Qualification* document as an item of which flight crews should be aware.

When the occurrence aircraft entered the runway, the first runway marking visible to the captain was the solid white right edge marking, which aligns with the runway's orientation.

A possible defence that can aid flight crews in determining whether they are on the edge of a runway or taxiway is shoulder markings. These yellow lines help to highlight paved areas that are not meant for use by aircraft but can be difficult to differentiate from active runway and taxiway surfaces. These are not required markings but they can provide additional visual cues to help flight crews determine their location when taxiing and lining up on runways at airports with a significant amount of paved surface. At the time of the occurrence at KLAS, Runway 01R did not have runway shoulder markings, nor did Taxiway D have taxiway shoulder markings where it intersects with Runway 01R.

In addition, runway thresholds typically provide distinctive visual environments, established by runway threshold markings and runway numbers, that allow flight crews to distinguish the runway's width and orientation. However, when flight crews commence takeoffs from the area before a displaced threshold (or from an intersection elsewhere on the runway), they have fewer visual cues to assist in defining the runway's width and, thus, the centreline. In this occurrence, the aircraft entered the runway approximately 330 feet before the displaced threshold of Runway 01R and, therefore, the crew did not have the typical runway threshold markings as an easily and readily accessible cue that could have helped them align the aircraft.

Finding as to risk

If airport operators incorporate only the minimum marking and lighting required by regulation and do not adopt optional enhanced visual aids where possible, there is an increased risk that pilots will not have a full awareness as to where they are on airport surfaces.

2.3 Flight crew expectations

2.3.1 Captain's experience and expectation

The captain's experience and expectation affected the way he perceived the visual environment at the time he was taxiing the aircraft into position on the runway.

One of the strongest visual cues available to the captain while he was taxiing the aircraft onto the runway was likely the runway edge marking, given that it is white and thicker than the taxiway centreline, which is a yellow line with a black border. A white line such as this was also what the captain was expecting to see, which would have indicated that they had reached the centre of the runway. In this case, however, the white line, compared to the markings used at Canadian airports, was located in an unexpected place. With good weather conditions present and having already received the take-off clearance, the captain did not want to delay the departure and so his attention was primarily focused within the cockpit to monitor the FO.

In his career, a significant portion of the captain's night flying experience took place at airports with runway centreline lighting, and it is likely that runway centreline lights represented another commonly used cue for alignment in night-flying conditions. It is therefore likely that the captain misinterpreted the runway edge lights in this environment to be the centreline lights, even though the first 2 lights ahead of the aircraft were red. The fact that KLAS had no runway centreline lights was not at the forefront of his mind during a period of higher workload, divided attention, and an increased sense of pressure for a timely departure.

While the captain was lining up the aircraft on Runway 01R, his divided attention would have caused his perception of cues outside of the cockpit to be guided more heavily by top-down information processing. This means his experience and knowledge would have been more active in shaping his understanding of his surroundings and, thus, creating an expectation of how the situation should have unfolded. This contrasts with a more bottom-up approach, where an individual is directing more attentional resources to actively seek out all the granular details available in the physical environment to inform an understanding of a particular situation. While the captain was still seeking out environmental cues during the taxi and line-up of the aircraft, his perception and processing of those cues were likely influenced by his expectations, given where the majority of his attentional resources were being focused.

Finding as to causes and contributing factors

When the aircraft was turning right to establish the runway heading in preparation for takeoff, the captain perceived the right runway edge marking as the runway centreline and the right runway edge lights as the centreline lights. The limited and ambiguous visual cues that were available likely met the captain's expectation that the aircraft was aligned on the runway. As a result, the aircraft was aligned laterally with the right edge of the runway, rather than with its centre.

2.3.2 First officer's expectation

By the time control of the aircraft was transferred to the FO and the FO focused his attention outside the window, the captain had already aligned the aircraft on what he thought to be the centreline and begun the take-off roll. This left little time for the FO to perceive and process his environment and identify the relevant cues to determine their alignment. At this point, he relied on the strongest cue available to him, which was the lights with which the aircraft nose was aligned; he perceived these to be the centreline lights.

The FO, like the captain, was also likely expecting to see runway centreline lights given his flying experience at major Canadian airports, so the fact the aircraft was aligned with these lights did not appear out of the ordinary. In addition, the dark visual conditions suppressed additional cues that might have offered conflicting evidence regarding the perceived position of the aircraft. For example, the solid runway edge line would have been partially visible via the nose lights as a cue signaling the misalignment, given that it looks different from the runway centreline (which is dashed); however, this cue was not as salient as the runway edge lights given the darkness and the limited time available to the FO to process this cue.

In addition, considering that the captain, whom the FO knew to be very experienced, was the one who had aligned the aircraft to depart, the FO would have required an extremely strong and unambiguous cue for him to question the captain's positioning of the aircraft on the runway.

This misperception of the aircraft's location on the runway was shared by both flight crew members and is also why the flight crew did not further question the aircraft position when they contacted the runway edge lights. They believed so strongly that they were properly aligned on the runway that they perceived the sounds and vibrations of the aircraft striking the runway edge lights as those caused by embedded runway centreline lights. The cues that would have made their misalignment clear were either unavailable due to the darkness or were not perceived and processed given the additional factors at play during the initial taxiing and positioning of the aircraft on the runway.

Findings as to causes and contributing factors

Due to the reduced visual cues and the inadequate amount of time to fully process his environment from the moment he assumed control of the aircraft, the FO did not recognize that the aircraft was aligned with the right edge of the runway when he took control of the aircraft during the take-off roll.

The aircraft's contact with the 8 runway edge lights was not recognized by the flight crew because they perceived the sounds and vibrations to be normal contact with the embedded runway centreline lights and consequently continued with the departure.

2.4 Harry Reid International Airport

2.4.1 Detection equipment

KLAS is equipped with Airport Surface Detection Equipment. This equipment provides increased cues to controllers, allowing them to identify all aircraft and vehicles on the airport movement area. The system is not designed to automatically alert controllers to the hazardous situations leading to misaligned takeoffs. Furthermore, KLAS has no equipment, other than visual inspections, to detect for foreign objects on the runway surfaces.

The ATC tower is located 1.4 nautical miles from the threshold of Runway 01R, so it is unlikely that, during nighttime operations and with no alerts to a potential runway misalignment, the tower controller had sufficient cues to identify the occurrence aircraft's misalignment on the runway.

In this occurrence, damage to the aircraft was minor, though it necessitated the replacement of 2 nosewheel tires. While the flight crew were unaware of the damage to the nose tire, the airport operator and controllers were also unaware of the damage to the runway lighting and the debris that remained on the runway because, although KLAS has required runway inspections for foreign object damage, the debris was not discovered until nearly 32 hours later. The debris left by the broken lights on the right edge of the runway posed a hazard for other aircraft.

At the time of the occurrence, staff from the Clark County Department of Aviation, which manages and operates KLAS, typically made 2 passes with their vehicle during inspections after dark, and the passes covered only the centre of the runway and not necessarily the runway edges.

Finding as to risk

If runway inspections cover only the centre portion of a runway, there is a risk that debris on the edges of the runway will go undetected.

2.4.2 Reporting procedures for misaligned aircraft

As demonstrated in the Australian Transport Safety Bureau's research into factors influencing misaligned take-off occurrences at night, as well as in previous TSB occurrence reports, misaligned takeoffs may be infrequent, though they are not uncommon. Because the KLAS airport operator does not keep records of misaligned takeoffs, it is unknown exactly how many occur in the area before the Runway 01R displaced threshold. The true extent of the risk is therefore unknown.

Finding: Other

Until misaligned takeoffs at KLAS are identified and recorded, the full extent of the risk of misaligned takeoffs at KLAS will remain unknown.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

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

1. The first officer's high workload contributed to his attention being focused primarily on managing tasks within the cockpit as the aircraft was taking position on Runway 01R. As a result, he was unable to provide additional support in visually aligning the aircraft on Runway 01R in the proper position.

2. Influenced by his perceived time pressure to depart, the captain's attention was focused primarily on the first officer and setting take-off thrust. This diverted his attention away from laterally aligning the aircraft on the runway.

3. When the aircraft was turning right to establish the runway heading in preparation for takeoff, the captain perceived the right runway edge marking as the runway centreline and the right runway edge lights as the centreline lights. The limited and ambiguous visual cues that were available likely met the captain's expectation that the aircraft was aligned on the runway. As a result, the aircraft was aligned laterally with the right edge of the runway, rather than with its centre.

4. Due to the reduced visual cues and the inadequate amount of time to fully process his environment from the moment he assumed control of the aircraft, the first officer did not recognize that the aircraft was aligned with the right edge of the runway when he took control of the aircraft during the take-off roll.

5. The aircraft's contact with the 8 runway edge lights was not recognized by the flight crew because they perceived the sounds and vibrations to be normal contact with the embedded runway centreline lights and consequently continued with the departure.

3.2 Findings as to risk

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

1. If airport operators incorporate only the minimum marking and lighting required by regulation and do not adopt optional enhanced visual aids where possible, there is an increased risk that pilots will not have a full awareness as to where they are on airport surfaces.

2. If runway inspections cover only the centre portion of a runway, there is a risk that debris on the edges of the runway will go undetected.

3.3 Other findings

These items could enhance safety, resolve an issue of controversy, or provide a data point for future safety studies.

1. The elapsed time between the misaligned takeoff and the discovery, by airport personnel, of the broken runway edge lights, as well as the time taken to report the occurrence to WestJet, resulted in data from both the cockpit voice recorder and the flight data recorder being overwritten.

2. Until misaligned takeoffs at Harry Reid International Airport are identified and recorded, the full extent of the risk of misaligned takeoffs at Harry Reid International Airport will remain unknown.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 WestJet Airlines Ltd.

After this occurrence, WestJet Airlines Ltd. (WestJet) issued a company memo to all pilots concerning departures from the areas before the displaced threshold on a runway. This memo references the occurrence and informs flight crews of the potential for pilots to inadvertently line up with the runway edge during nighttime departures from runway areas other than the threshold when at airports with non-standard (according to the Canadian standards) runway and taxiway markings and/or lighting. The mitigations in place to minimize these threats are also outlined.

The memo warns flight crews of the following ground-based threats at Harry Reid International Airport (KLAS), Nevada, United States (U.S.):

- a visually uniform airport landscape,
- complex ground operating environment and possible unfamiliarity,
- airport and area lights blending,
- high intensity runway operations, and
- non-standard taxiway's *[sic]*, runway markings and lighting.[49]

In addition, WestJet's Flight Operations team has examined and updated its *Route & Aerodrome Qualification* for KLAS. Specifically, the pre-existing notes in the Departures—Taxi Outbound section were revised and placed in the Cautions section on the front page, and the risk associated with departures from the displaced area of Runway 01R has been highlighted. The Cautions section has also been updated with an increased focus on taxi and runway line-up threats to assist flight crews and raise their awareness of these threats.[50] The updated *Route & Aerodrome Qualification* was tagged with a "NEW" button to attract pilots' attention.

4.1.2 Harry Reid International Airport

The Safety Management System Coordinator at KLAS indicated that after this occurrence, additional training was offered and some procedural changes were made regarding runway inspections. Before the occurrence, the primary coordinator had been responsible for movement-area inspections, whereas the secondary coordinator had been responsible for only non-movement-area inspections. Following the occurrence, the secondary coordinator was made responsible for movement-area inspections. With this change in responsibility,

---

49 WestJet Airlines Ltd., FSF 23-01, Flight Safety Flash, Re: Las Vegas Runway Line Up (effective 17 March 2023).

50 WestJet Airlines Ltd., *Route & Aerodrome Qualification*, Harry Reid International, Las Vegas, Nevada, U.S.A., KLAS/LAS (02 March 2023), Cautions, pp. 1-2.

the secondary coordinator can prioritize the movement-area inspections with fewer distractions.

In addition, during inspections at KLAS, it is now a requirement to complete 3 passes (left side, right side, and centre) on each runway.

In the fall of 2023, KLAS implemented a 3-phase plan to address runway and taxiway conspicuity. Phase 1, which was completed in the fall of 2023, consisted of installing taxiway shoulder markings on the north side of taxiways A and D from the hold bar at each taxiway to the runway edge line of Runway 01R.

Phase 2, which is planned to be completed no later than 30 April 2024, will consist of the following:

- installing taxiway shoulder markings on the south side of taxiways E1, F1, and J from the hold bar at each taxiway to the runway edge line of Runway 19R;
- installing runway shoulder markings on Runway 19R from the approach end to approximately the precision approach path indicator (PAPI) lights;
- applying bituminous surface coating on the shoulders of runways 01L/19R and 01R/19L to increase contrast between runway and shoulder surfaces (full length); and
- continuing public outreach to inform airport users of local markings and light configurations.

After these items have been implemented, KLAS will monitor for incidents for 90 days.

Phase 3, which is estimated for the fall of 2025 and will take place in conjunction with the next Runway Incursion Mitigation (RIM) project, will consist of applying bituminous surface coating on the shoulders of runways 08L/26R and 08R/26L to increase contrast between runway and shoulder surfaces (full length).

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 10 April 2024. It was officially released on 23 April 2024.