Final Report

TWO MISALIGNED TAKE-OFFS AT SELETAR AIRPORT

17 JULY and 6 OCTOBER 2024

TIB/AAI/CAS.233

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

27 August 2025

The Transport Safety Investigation Bureau of Singapore

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Table of Contents

ABBREVIATIONS

ATC	Air Traffic Control
ANSP	Air Navigation Service Provider
CVR	Cockpit Voice Recorder
FDR	Flight Data Recorder
FO	First Officer
FOD	Foreign Object Debris
HUD	Head-Up Display
LT	Local Time
MLG	Main Landing Gear
NLG	Nose Landing Gear
NOTAM	Notice to Airmen
OTSB	Oman Transport Safety Bureau
PIC	Pilot-in-Command
RWC	Runway Controller
WoW	Weight-on-Wheels

SYNOPSIS

On 17 July 2024, after a Dassault Falcon 900EX aircraft took off from Runway 03 at Seletar Airport, a runway edge light was found damaged. During the rotation, the pilots heard a loud noise and reported the noise to the Runway Controller after the take-off. The flight crew were subsequently informed of the damaged runway edge light. The aircraft continued to its destination in Muscat, Oman. After landing there, the aircraft was found with damage to a nose landing gear tyre and to the nose landing gear auxiliary shield door.

On 6 October 2024, after a Bombardier Global 6000 aircraft took off from Runway 03 at Seletar Airport, seven runway edge lights and one taxiway edge light were found damaged. The flight crew were subsequently informed of the damaged edge lights and the aircraft continued to its designation in Bangalore, India. After landing there, the aircraft was found with damage to its right main landing gear wheel assemblies and hydraulic fluid leaking from its right brake system.

For both incidents, the investigations revealed that the two aircraft had likely misaligned on the runway side stripe marking (runway edge line) on the right side of Runway 03 for the take-off.

The Transport Safety Investigation Bureau of Singapore classified these occurrences as serious incidents.

AIRCRAFT DETAILS

	Aircraft A	Aircraft B
Aircraft Type	Dassault Falcon 900EX	Bombardier Global 6000
Operator	Allianz Se	Luxaviation
Aircraft Registration	M-ILTA	T7-RIC
Date and time of Occurrence	17 July 2024, 2122 hours	6 October 2024, 2042 hours
Location of occurrence	Seletar Airport Runway 03	Seletar Airport Runway 03
Type of flight	Non-scheduled	Non-scheduled
Persons on board	Four	Four

1 FACTUAL INFORMATION

All times used in this report are Singapore Local Time (LT) unless otherwise stated. Singapore Local Time is eight hours ahead of Coordinated Universal Time (UTC).

1.1 History of the flight – Aircraft A

1.1.1 On 17 July 2024, a Dassault Falcon 900EX (Aircraft A) was planned to operate from Seletar Airport, Singapore to Muscat, Oman. The flight crew arrived at the aircraft at about 1830 hours. The flight crew comprised two Captains, one as Pilot-in-Command (PIC) on the left seat and the other as Co-pilot on the right seat.

1.1.2 The walkaround check on Aircraft A before the flight did not reveal any damage to the aircraft. After completing the pre-flight checks, the flight crew contacted the Air Traffic Control (ATC) for engine start-up and taxi clearance.

1.1.3 For the flight, the PIC was the Pilot Flying (PF) and the Co-pilot the Pilot Monitoring (PM). At about 2117 hours, Aircraft A commenced taxiing from its parking bay to the runway-holding position on Taxiway E4 (holding point E4) for Runway 03. When the aircraft was nearing the holding point E4, the Runway Controller (RWC A) instructed the aircraft to line up on Runway 03. At about 2119 hours, the aircraft turned onto the runway as instructed. According to the flight crew, as the aircraft was lining up, they checked the approach path, reviewed the aircraft configuration and performed the line-up checklist. The flight crew stated that there was no time pressure for the departure.

1.1.4 According to the data from the aircraft's flight data recorder (FDR), after turning onto the runway, the aircraft remained stationary on the runway for about 17 seconds before starting its take-off roll.

1.1.5 The aircraft lifted off at about 2122 hours. According to the flight crew, they had lined up their aircraft on the centre line of the runway and in the middle of the threshold markings[1]. They recalled that the aircraft maintained its take-off roll on the centre line before lifting off. However, data from the aircraft's FDR

[1] The runway threshold markings (dubbed "piano keys") demarcates the beginning of the runway. These markings are longitudinal stripes of uniform dimensions on either side of the runway centre line.

and from Flightradar24[2] as well as the aerodrome's CCTV recordings[3], showed that the aircraft started and maintained its take-off roll on the right edge of the runway. **Figure 1** shows the path of the aircraft's take-off roll. Aircraft A was the last departure that night and, as evidenced by the aerodrome CCTV, the edge light at Taxiway E2 was still lit before Aircraft A's departure (see paragraph 1.8.5.1).

(Source: Flightradar24) (Annotation: TSIB)

Figure 1: Aircraft A's path

1.1.6 During the rotation, the flight crew heard a loud noise and reported the noise to RWC A after the take-off. RWC A immediately initiated a runway inspection by the aerodrome operator. After the aircraft had been transferred to Singapore Approach, the flight crew contacted RWC A to inquire if there was any foreign object debris (FOD) found on the runway. As the runway inspection was still in progress at that time, RWC A replied that the inspection outcome would be relayed to them.

1.1.7 The runway inspection found one damaged runway edge light near Taxiway E2. The flight crew were informed via radio of the damage to the runway edge light. The flight crew acknowledged the information and elected to continue their flight to Muscat.

[2] Flightradar24 is an online platform that gathers flight data (e.g. aircraft location, speed, trajectory and altitude).
[3] The aerodrome's CCTV recordings also showed that the runway edge light went off at this moment.

1.1.8 Aircraft A landed at Muscat International Airport at about 0404 hours (0004 hours Oman local time). When the nose gear touched down on the runway, the flight crew heard an unusual noise. They were able to vacate the runway and taxied to the parking stand normally.

1.1.9 While taxiing, the flight crew informed the airport authority about their suspicion of a flat tyre and recommended the airport authority to inspect the runway. The airport authority's subsequent inspection found the auxiliary shield door of Aircraft A's nose landing gear (NLG) on the runway (see Paragraph 1.4.1).

1.2 History of the flight – Aircraft B

1.2.1 On 6 October 2024, a Bombardier Global 6000 (Aircraft B) was planned to operate from Seletar Airport, Singapore to Bangalore, India. The flight crew arrived at the aircraft at about 1745 hours. The flight crew comprised two Captains, one as PIC on the left seat and the other as Co-pilot on the right seat.

1.2.2 The walkaround check on Aircraft B before the flight did not reveal any damage to the aircraft. After completing the pre-flight checks, the flight crew contacted the ATC for engine start-up and taxi clearance.

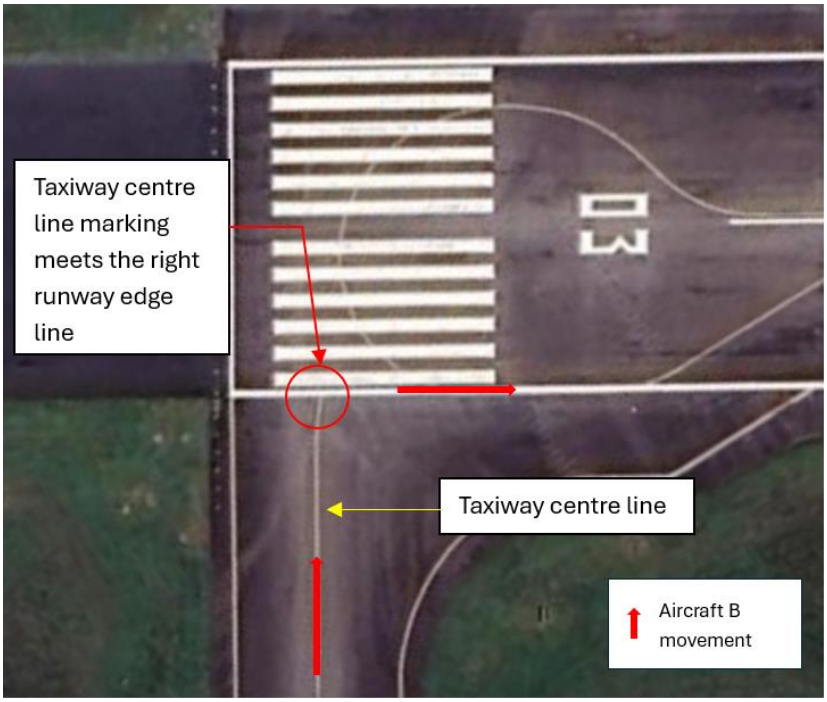
1.2.3 The PIC was the Pilot Flying (PF) and the Co-pilot the Pilot Monitoring (PM). At about 2033 hours, Aircraft B commenced taxiing from its parking bay to the holding point on Taxiway E4 for Runway 03. According to the flight crew, the PF taxied slowly to allow the PM ample time to perform the take-off checklist with no rush, and the aircraft was maintained on taxiway centre line during the taxi. The Runway Controller (RWC B) instructed the aircraft to line up on Runway 03 via Taxiway E4. When the aircraft crossed the holding point E4, RWC B cleared the aircraft for take-off.

1.2.4 After that, the PF positioned his head-up display (HUD)[4] as he normally wound and turned the aircraft onto the runway centre line to position the aircraft for take-off. During the turn, the PF checked the glareshield selector panel to ensure that the runway heading bug and the climbing altitude were set correctly. The PM performed the take-off checklist items and communicated

[4] HUD is a means for presenting information to the pilot. HUD projects key flight instruments onto a small 'see-through' screen positioned in front of the pilot in his forward line of sight to outside the aircraft.

with RWC B. The flight crew of Aircraft B could not recall seeing any runway threshold markings and runway designation marking.

1.2.5 **Figure 2** shows the path of Aircraft B's turning from Taxiway E4 onto the runway. According to the PF, he followed the taxiway centre line marking closely when he was turning the aircraft onto the runway.



(Source: Google Map) (Annotation: TSIB)

Figure 2: Aircraft B's path from Taxiway E4 to Runway 03

1.2.6 According to data from Aircraft B's FDR, after turning onto the runway, the aircraft remained stationary on the runway for about 11 seconds before starting its take-off roll.

1.2.7 Data from the aircraft's FDR and from Flightradar24, as well as the aerodrome's CCTV recordings showed that the aircraft started and maintained its take-off roll on the right edge of the runway. **Figure 3** shows the path of Aircraft B's take-off roll. The aircraft lifted off at about 2042 hours. According to the flight crew, there were no abnormal vibrations and sounds during the take-off roll.

(Source: Flightradar24) (Annotation: TSIB)

Figure 3: Aircraft B's path

1.2.8 Two aircraft landed on Runway 21 (reciprocal to Runway 03) at about 2106 hours (24 minutes after Aircraft B's departure) and 2114 hours (32 minutes after Aircraft B's departure) respectively. The flight crew of the second aircraft reported to RWC B that they saw debris on the runway between Taxiways E3 and E4. RWC B initiated a runway inspection, which found seven consecutive runway edge lights on the right side of Runway 03 and one taxiway edge light on right side of Taxiway E4 damaged.

1.2.9 The Singapore Air Navigation Service Provider (ANSP), through an adjacent ANSP, informed the flight crew of Aircraft B about the damage to the edge lights. The flight crew acknowledged the information and, observing that there was no anomaly with the aircraft systems, elected to continue their flight to Bangalore, India.

1.2.10 Aircraft B landed at Kempegowda International Airport in Bangalore at about 0032 hours (2202 hours India time). While taxiing to the parking bay, the PIC noticed that the brake for the outer wheel of the right main landing gear (MLG) was not working properly. After arrival at the parking bay and upon applying the parking brake, the aircraft displayed an EICAS message "R OUTBD BRAKE FAIL".

1.2.11 After the aircraft was parked, the PM conducted a walkaround check and found damage to the aircraft's right tyres (see paragraph 1.4.2).

1.2.12 During the interview by the investigation team, the flight crew of Aircraft B said that they were aware that Seletar Airport did not have runway centre line lights. It was only after the post-flight inspection that they realised they had a slip of their mind, and they had most likely mistaken the runway edge lights[5] as the runway centre line lights for the take-off.

1.3 Injuries to persons

1.3.1 There was no injury to any person in both incidents.

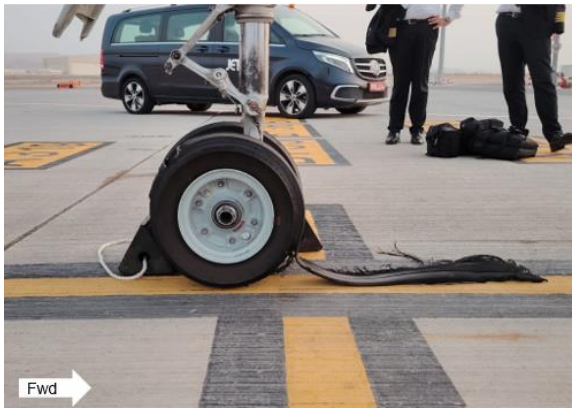
1.4 Damage to aircraft

1.4.1 For Aircraft A, the NLG sustained the following damage (see **Figure 4** to **Figure 6**):

(a) The right tyre of the NLG was found with a rectangular hole[6]. Its tyre tread was also separated from the tyre.

(b) The auxiliary shield door was sheared off from the NLG. The main shield door of the NLG was also damaged.

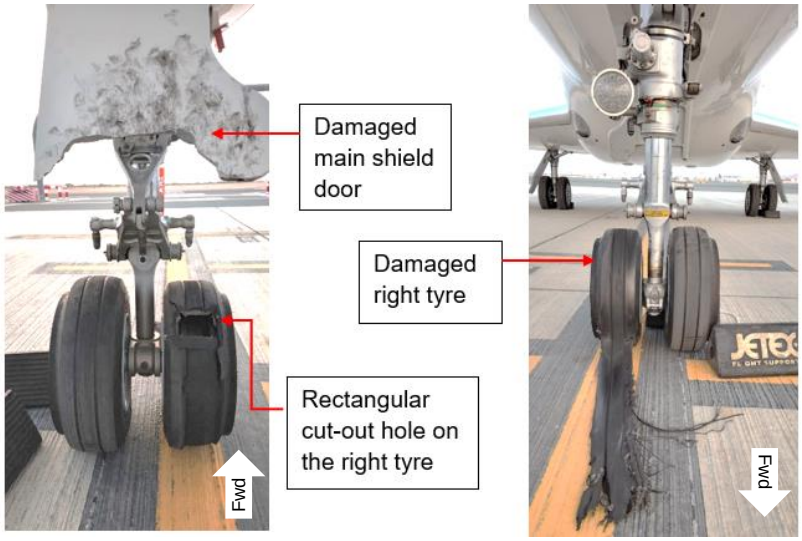
(c) An NLG electrical harness was also damaged.



(Source: Oman Transport Safety Bureau (OTSB))(Annotation: TSIB)

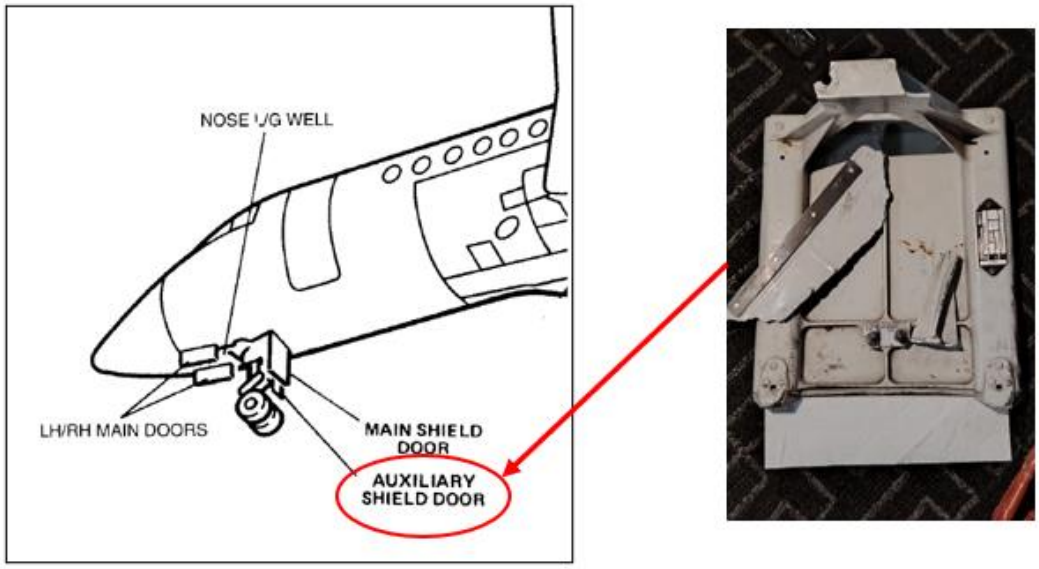
Figure 4: Damaged right tyre of NLG

[5] Based on ICAO Annex 14 Volume I and CAAS Aviation Specifications 5, runway edge lights and runway centre line lights, where provided, shall be white.
[6] The rectangular hole was about the size of the runway edge light body. More on runway edge light body in paragraph 1.5.1.



(Source: OTSB) (Annotation: TSIB)

Figure 5: Damage to the right tyre and main shield door of the NLG



(Source: (left) Aircraft Manufacturer (right): OTSB) (Annotation: TSIB)

Figure 6. Damage to the sheared NLG auxiliary shield door

1.4.2 For Aircraft B, the right MLG sustained the following damage:

(a) The inboard and outboard tyres had deep cuts (see **Figure 7**).

(b) There was hydraulic fluid leaking from the sheared bleeder plugs on the outboard brake assembly (see **Figure 8**).

(c) There was damage on the aft equipment bay skin. The damage was located just below the right aft equipment bay vent and right pylon lower skin precooler exhaust panel.

(Source: Aircraft B Operator) (Annotation: TSIB)

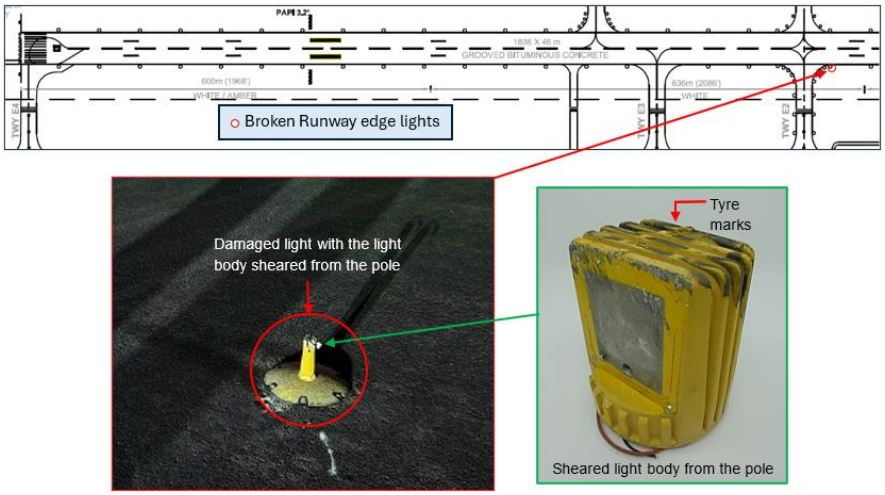
Figure 7: Damages to the right MLG tyres (viewed from the front)

(Source: Aircraft B Operator) (Annotation: TSIB)

Figure 8: Sheared bleeder plugs of the right MLG outboard brake assembly

1.5 Other damage

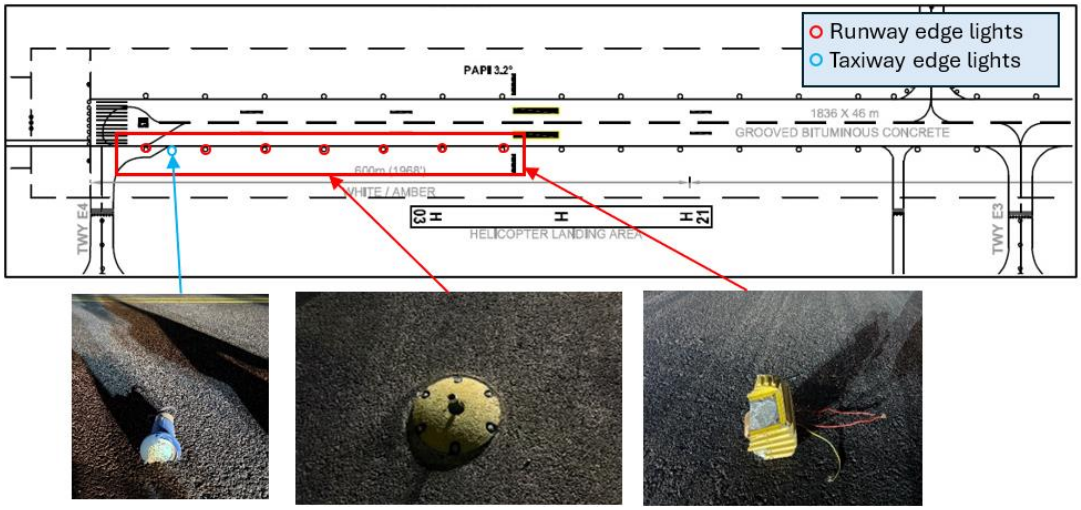
1.5.1 For the incident involving Aircraft A and as mentioned in paragraph 1.1.7, a runway edge light near Taxiway E2 was damaged (see **Figure 9**)**.** The light body was sheared off from the supporting pole. There were tyre marks on the top part of the edge light body. Debris pieces of the edge light were found on the grass patch about 50m away in the direction of the departure.



(Source: Singapore Aeronautical Publication) (Annotation: TSIB)

Figure 9: Damaged runway edge light near Taxiway E2

1.5.2 For the occurrence involving Aircraft B, seven consecutive runway edge lights on the right side of Runway 03, between Taxiways E4 and E3 and the first taxiway edge light on Taxiway E4 were damaged (see **Figure 10**).



(Source: Aerodrome operator) (Annotation: TSIB)

Figure 10: Damage runway edge lights and taxiway edge light between Taxiways E4 and E3

1.6 Personnel information

1.6.1 Flight crew of Aircraft A

1.6.1.1 PIC

Age	58 years old
Licence type	Airline Transport Pilot Licence
Issuing authority	The U.S. Federal Aviation Administration
Licence validity	Valid till 6 March 2025
Medical certificate	First Class
Medical certificate validity	Valid till 18 November 2025
Medical operational proviso	NIL
Last Base Check date	25 August 2023
Last Line Check date	N.A.
Total flying hours	10,458 hours
Aircraft types flown	Falcon 900 EX EASY and variants, Falcon 2000 EX EASY and variants, Falcon 50, Learjet 45
Total hours on type	1,297 hours
Flying in last 90 days	95 hours 44 minutes
Flying in last 7 days	21 hours 26 minutes
Flying in last 24 hours	0 hour

Duty time in last 48 hours	5 hours 48 minutes
Rest period in last 48 hours	42 hours 12 minutes

1.6.1.2 Co-pilot

Age	41 years old
Licence type	Airline Transport Pilot Licence
Issuing authority	Austro Control GmBH
Licence validity	Valid till 8 May 2026
Medical certificate	Class 1
Medical certificate validity	Valid till 9 December 2024
Medical operational proviso	NIL
Last Base Check date	26 August 2023
Last Line Check date	N.A.
Total flying hours	3,170 hours
Aircraft types flown	Falcon 900 EX EASY and variants
Total hours on type	1,278 hours
Flying in last 90 days	99 hours 19 minutes
Flying in last 7 days	24 hours 31 minutes
Flying in last 24 hours	0 hour
Duty time in last 48 hours	8 hours 56 minutes
Rest period in last 48 hours	39 hours 04 minutes

1.6.2 Flight crew of Aircraft B

1.6.2.1 PIC

Age	56 years old
Licence type	Airline Transport Pilot Licence
Issuing authority	The U.S. Federal Aviation Administration
Licence validity	Valid till 30 June 2025
Medical certificate	First Class
Medical certificate validity	Valid till 21 November 2024
Medical operational proviso	Need reading glasses
Last Base Check date	7 June 2024
Last Line Check date	8 August 2024
Total flying hours	13,348 hours
Aircraft types flown	Bombardier BD-700 Global Express
Total hours on type	3,396 hours (482 vision)
Flying in last 90 days	122 hours 24 minutes
Flying in last 7 days	8 hours

Flying in last 24 hours	0 hour
Duty time in last 48 hours	3 hours
Rest period in last 48 hours	45 hours

1.6.2.2 Co-pilot

Age	53 years old
Licence type	Airline Transport Pilot Licence
Issuing authority	The U.S. Federal Aviation Administration
Licence validity	Valid till 23 October 2025
Medical certificate	Class 1
Medical certificate validity	Valid till 4 March 2025
Medical operational proviso	NIL
Last Base Check date	30 September 2024
Last Line Check date	30 May 2024
Total flying hours	15,950 hours
Aircraft types flown	Bombardier BD-700 Global Express
Total hours on type	310 hours
Flying in last 90 days	94 hours
Flying in last 7 days	4 hours 22 minutes
Flying in last 24 hours	0 hour
Duty time in last 48 hours	3 hours
Rest period in last 48 hours	45 hours

1.7 Meteorological information

1.7.1 The flights of Aircraft A[7] and B[8] were conducted at night.

1.7.2 According to weather reports issued by the Meteorological Service Singapore[9] around the time of the incidents, visibility was 10 kilometres in both incidents and there was no precipitation at the time of both incidents.

[7] The sunset time on 17 July 2024 was 1916 hours.
[8] The sunset time on 6 October 2024 was 1855 hours.
[9] The weather report on 17 July 2024 was between 2030 hours and 2200 hours. The weather report on 6 October 2024 was issued between 2000 hours and 2100 hours.

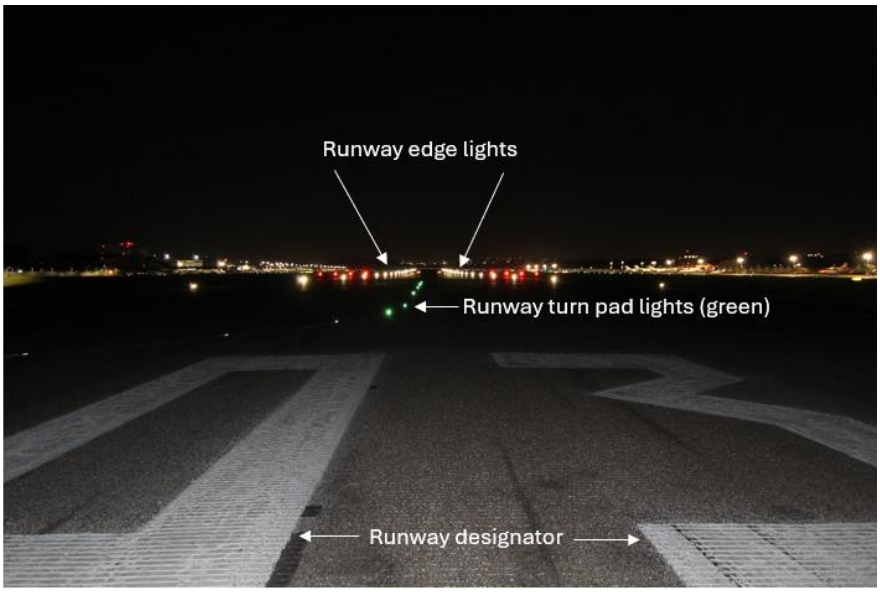
1.8 Aerodrome information

1.8.1 Runway length

1.8.1.1 Runway 03/21 in Seletar Airport is 1,836m long and 46m wide. There is a 7m wide shoulder beyond the runway edge on both sides of the runway.

1.8.2 Runway and taxiway lights and markings

1.8.2.1 Runway 03/21 has a runway centre line marking but does not have runway centre line lights[10]. This is reflected in Section WSSL 2.14 of the Singapore Aeronautical Information Publication. The runway has elevated edge lights (see **Figure 11**) which are bi-directional. The runway edge lights are white, except for the last 600m on either end of the runway where the edge lights are yellow (not visible in Figure 11). The runway edge lights have five brilliancy intensities[11].

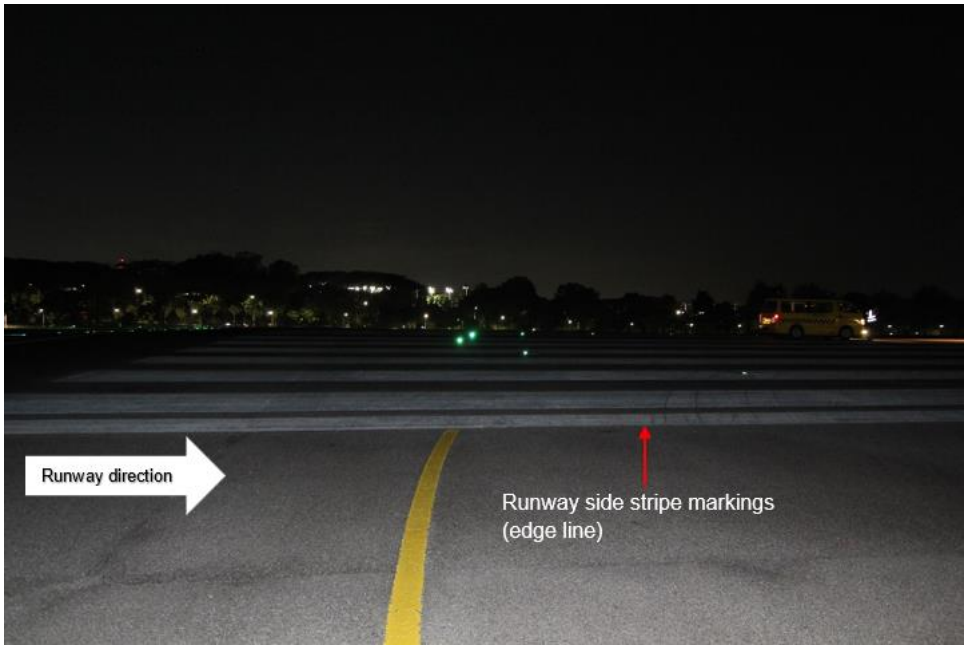


(Source and annotation: TSIB)
(The green lights on the runway are to help pilots perform a 180-degree turn on the runway turn pad (see paragraph 1.8.3.))

Figure 11: Night view of Runway 03 from the runway designator (Note: The light in the foreground was from a vehicle.)

[10] International standards require runway centre line lights, where installed, to be white.
[11] The brilliancy settings can be adjusted by air traffic controllers at Seletar Tower to 1%, 3%, 10%, 30% and 100%.

1.8.2.2 The runway threshold markings (see **Figure 12**) and runway designation markings[12] (see Figure 11**)** for Runway 03 were repainted on 16 March 2024 and 18 May 2024 respectively[13].



(Source and annotation: TSIB)

Figure 12: View of runway threshold markings from Taxiway E4

1.8.2.3 Taxiway E4 has green centre line lightings which stop at the red stop bar light at holding point E4. Beyond this holding point, Taxiway E4 has a yellow centre line marking which stops at the runway side stripe marking (hereinafter referred to as runway edge line).

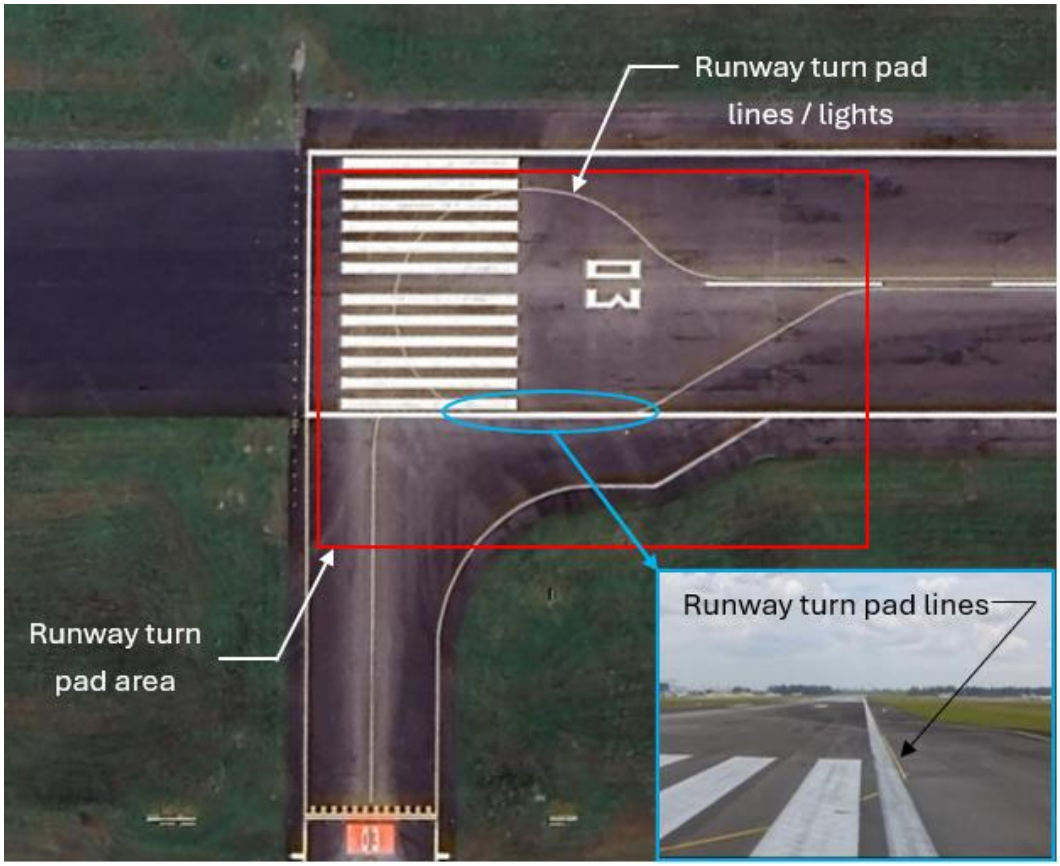
1.8.2.4 According to ICAO Annex 14 "Aerodrome, Volume 1 - Aerodrome Design and Operations", *taxiway centre line can be interrupted at the runway side stripe markings*. Runway 03 complies with this standard.

1.8.3 Runway turn pad

1.8.3.1 There is a runway turn pad[14] at the threshold of Runway 03 (see **Figure 13**). The yellow turn pad marking is fitted with uni-directional green lights for night

[12] The runway designator marking is the painted runway number centred on the runway. It is used to identify the runway for landing and take-off, and it is painted on the runway a short distance behind the threshold marking.
[13] These markings are repainted every six months.
[14] A turn pad is a defined area adjacent to a runway for aircraft to safely complete a 180-degree turn on the runway.

operations (see **Figure 11**). Associated with the turn pad, there is an additional paved area of about 56m by 19.50m on the right side of Runway 03 to allow for the aircraft to turn around. The extra paved area and turn pad lights are in line with ICAO's requirements.



(Source: Google Map) (Annotation: TSIB)

Figure 13: Runway turn pad on Runway 03

1.8.4 FOD management

1.8.4.1 There is no automatic FOD detection system for Runway 03/21. The distance between Runway 03/21 and Seletar Tower is such that the ATC in the tower will have difficulty spotting debris on the runway at night. The aerodrome operator and the ATC rely on visual reports from pilots, scheduled runway inspections and ad hoc wildlife dispersal inspections to be informed of any FOD on the runway.

1.8.4.2 Runway inspections are scheduled four times a day[15]. This frequency of inspection exceeds[16] international standards. The last runway inspection before the incident involving Aircraft A on 17 July 2024 was conducted at 1921 hours. The last runway inspection before the incident involving Aircraft B on 6 October 2024 was conducted at 1940 hours. There was no unserviceable light or FOD reported during these two runway inspections.

1.8.5 Runway edge light conditions

1.8.5.1 The brilliancy of the runway edge lights was set at 10% on the night of 17 July 2024. The aerodrome's CCTV recordings[17] revealed that the runway edge lights on the night of 17 July 2024 were functioning properly before Aircraft A took-off. The runway edge light went off when Aircraft A passed the position of runway edge light (that was later found damaged) near Taxiway E2 (see **Figure 14**).

[15] Runway inspections are scheduled between the following timings: 0000 – 0130, 0700 – 0830, 1300 – 1430 and 1800 – 2000 hours. Each inspection typically takes about 15 minutes.
[16] The international standards require runway inspections to be conducted at least twice a day.
[17] The investigation found that the CCTV recording time was not synchronised to local time. The difference in recorded time was three minutes. The CCTV recording was confirmed to be of Aircraft A by corroborating the aircraft departures with CCTV footage, i.e. the previous flight was 31 minutes prior to Aircraft A's departure and Aircraft A was the last departure on 17 July 2024.

A) Lighted runway edge light near E2

B) Aircraft A approaching the runway edge light. The light was still lighted at this point.

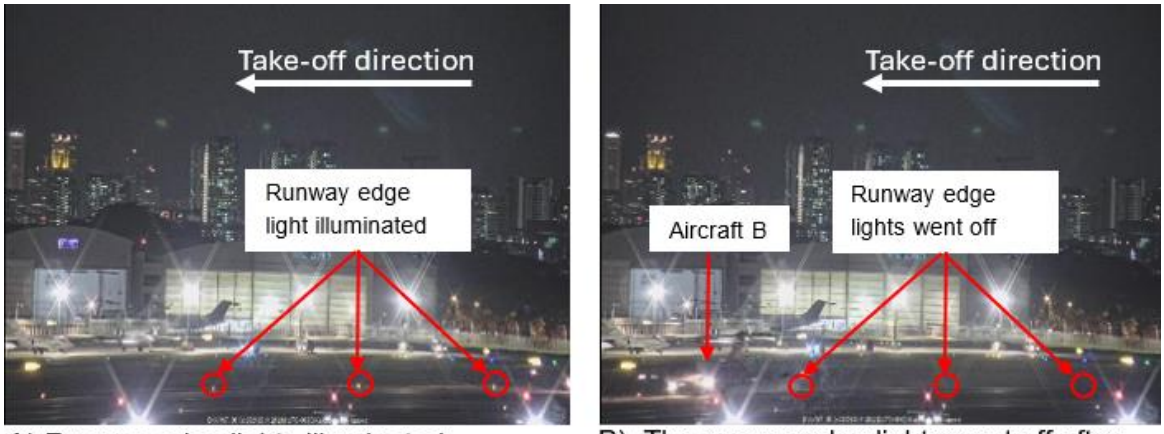
C) Runway edge light went off after Aircraft A went past it

(Source: Aerodrome Operator) (Annotation: TSIB)

Figure 14: CCTV recordings[18] showing the runway edge light went off after Aircraft A had passed its location

[18] The time stamped in the CCTV recordings of the aerodrome was not synchronised to local time and there was a three-minute time difference.

1.8.5.2 The brilliancy of the runway edge lights was also set at 10% on the night of 6 October 2024. CCTV recordings also revealed that the runway edge lights on the night of 6 October 2024 were functioning properly before Aircraft B took-off. When Aircraft B passed the runway edge lights' locations, the lights went off (see **Figure 15**).



A) Runway edge lights illuminated

B) The runway edge lights went off after the aircraft went past them

(Source: Aerodrome Operator) (Annotation: TSIB)

Figure 15: CCTV recording showing runway edge lights went off after Aircraft B had passed their locations

1.9 Flight recorders

1.9.1 The FDR and CVR of Aircraft A were removed and the data was downloaded in Dubai, United Arab Emirates (UAE) with the assistance of the UAE General Civil Aviation Authority (GCAA). UAE GCAA made the FDR and CVR data available to the investigation team.

1.9.2 The FDR and CVR of Aircraft B were removed and the data was downloaded in Bangalore, India with the assistance of the aircraft operator. The latter made the FDR and CVR data available to the investigation team.

1.9.3 The CVR recordings for the period of interest for both incidents had been overwritten.

1.10 Medical and pathological information

1.10.1 The pilots involved in both incidents were not sent for medical toxicological tests.

1.11 Additional information

1.11.1 According to the ANSP, one of the runway controller's duties is to ensure that an aircraft taxies to the correct runway, and that both the runway and departure path are clear for take-off. From their control positions, runway controllers will not be able to determine whether an aircraft is positioned on the runway centre line[19], nor were runway controllers required to do so. The onus is on pilots to ensure that their aircraft is properly lined up on the runway centre line.

1.11.2 The Australian Transport Safety Bureau (ATSB) had published a Transport Safety Report (AR-2009-033) on *Factors Influencing Misaligned Take-off Occurrences at Night*. This study identified the following common safety factors which may contribute to misaligned take-offs:

- Night time operations *(environmental factor)*
- Confusing runway entry markings or lighting, unusual additional pavement on the runway, absence of runway centre line lighting, and recessed runway edge lightning *(environmental factor)*
- Flight crew distraction or inattention *(human factor)*
- Bad weather or poor/reduced visibility *(environmental factor)*
- Conducting a displaced threshold or intersection departure *(operational factor)*
- Provision of air traffic control clearance when aircraft was entering the runway or still taxiing *(operational factor)*
- Flight crew fatigue *(human factor)*

[19] The investigation team visited the control tower and observed that a person would not be able to see whether an aircraft is or is not lined up on the runway centre line.

2 ANALYSIS

The investigation looked into the following:

(a) Misaligned take-off on Runway 03

(b) Contributing factors that resulted in the misaligned take-offs

(c) FOD Management

2.1 Misaligned take-off on Runway 03

2.1.1 The investigation team opines that both Aircraft A and Aircraft B had likely misaligned their aircraft on the right runway edge line and damaged the runway and taxiway edge lights during their take-off. The team's considerations are as follows:

Aircraft A

(a) Data from Aircraft A's FDR and Flightradar 24 showed that Aircraft A was on the right edge of the runway during the take-off.

(b) Data from Aircraft A's FDR also showed that the NLG's Weight-on-Wheels (WoW) parameter changed from GND (ground) to AIR (airborne) when Aircraft A was at the location of the damaged runway edge light. The loud noise heard by the flight crew during the rotation was likely the sound generated when Aircraft A's NLG hit the runway edge light that was found damaged after the incident.

(c) CCTV recordings from the aerodrome showed that the runway edge light went off after Aircraft A went past the location of the light.

(d) The rectangular hole found on Aircraft A's NLG right tyre after the aircraft landed at Muscat International Airport matched the size of the runway edge light body.

Aircraft B

(a) Data from Aircraft B's FDR and Flightradar 24 showed that Aircraft B was on the right edge of the runway during the take-off.

(b) CCTV recordings from the aerodrome showed that the edge lights went off after Aircraft B went past them. Data from the Aircraft B's FDR showed that at this moment the aircraft was still rolling on ground as the NLG and MLGs' WoW parameters were still at GND.

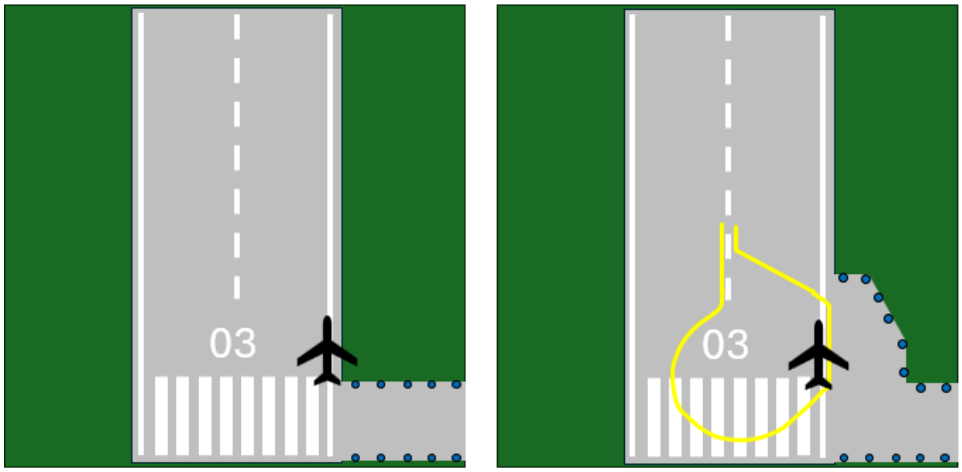
(c) The damages sustained by the right MLG were most likely the result of it hitting the runway and taxiway edge lights.

2.2 Contributing factors that resulted in the misaligned take-offs

2.2.1 Night operations always present challenges to flight crews as visual acuity is reduced due to the limited lights available. During daytime, flight crew will be able to identify the horizon, the grass areas and surrounding aerodrome markings in the vicinity of the aircraft. At night, it will be harder for the flight crew to identify such visual cues as the horizon, the grass areas and markings. The aerodrome lightings used coloured lightings to identify predefined areas such as taxiways and runways. Aircraft are equipped with taxi lights, however the throw of the lights only illuminates a narrow area ahead and slightly to the side of the aircraft.

2.2.2 When taxiing aircraft at night with taxiway centre line lights switched on, flight crew would use the centre line lights to maintain their aircraft on the centre of the taxiway. As described in paragraph 1.8.2.3, Taxiway E4 green centre line lights end at holding point E4. From holding point E4 to the runway, flight crew would follow the taxiway centre line marking (which has no lights) to enter the runway. As the aircraft entered the runway, the brightly lit runway edge lights would be attracting pilots' attention. Thus, there is a possibility that flight crew be misled and instinctively be attracted to align the aircraft to the right runway edge line. The flight crews of both Aircraft A and B knew that international standards required runway centre line lights, where installed, would be white and they had read form the Singapore Aeronautical Publication that Runway 03 did not have any centre line lights. However, it is likely that they had momentarily forgotten about the latter and, when they saw the white lights at the runway edge line, they instinctively treated them as the runway centre line lights.

2.2.3 The additional paved area to the right side of the runway edge at Runway 03 threshold may have led the flight crew to believe they were at the centre of the runway as they would have seen the taxiway edge lights demarcating the edge of the taxiway some distance away from the aircraft.



(Source: TSIB) (Annotation: TSIB)

Figure 16: Lateral positioning of an aircraft

2.2.4 From a human factors perspective, these visual limitations during night operations, along with visual cues that are less conspicuous (at night) relied upon by the flight crew to navigate to the runway may explain why both sets of flight crew misaligned their aircraft.

2.2.5 The two incidents highlight the importance for flight crew to be familiar with the aerodrome from which they are operating, such as knowing the layout of the aerodrome, so that they can improve situational awareness. In the case of Seletar Airport, information on the runway lighting equipage, taxiway marking and additional paved area required for the turn pad is published and available publicly.

2.2.6 It is worth noting that the environmental factor that had played a role in these two misaligned take-off incidents (i.e. confusing runway entry markings, unusual additional paved area on the runway, absence of runway centre line lighting) have already been identified in the ATSB Safety Report (AR-2009-033) on *Factors Influencing Misaligned Take-off Occurrences at Night*. Pilots should be mindful of possible hazards posed by confusing or unusual runway entry markings, unusual additional paved area on the runway, absence of runway centre line lighting.

2.3 FOD Management

2.3.1 For Aircraft A, after the take-off, the flight crew informed the ATC of the abnormal noise heard during take-off and the runway controller concerned had the presence of mind to immediately initiate a runway inspection by the aerodrome operator. The debris of the broken runway edge light was removed quickly.

2.3.2 For Aircraft B, the flight crew were not aware of any anomaly during the take-off. Subsequently, there were two other aircraft landing in Seletar Airport, with the FOD still on the runway. The ATC only became aware of an FOD situation after the flight crew of the second aircraft reported sighting of FOD to the ATC, whereupon a runway inspection was initiated and the FOD recovered. Although the FOD did not cause any incident to these two aircraft, the investigation team wishes to highlight the importance of early detection of FOD on the runway.

2.3.3 Unlike Changi Airport, the runway in Seletar Airport is not equipped with an automatic FOD detection system and the ATC relies on sighting and reporting of FOD by pilots and runway inspections to become aware of any FOD on the runway. Following the two misaligned take-off incidents, the Seletar aerodrome operator and ANSP reviewed their current FOD management regime and concluded that the regime is still robust and effective, despite the fact that the FOD in the case of Aircraft B was only discovered after two subsequent aircraft had landed. Although the aerodrome operator plans to carry out a daily inspection between 2100 and 2230 hours in lieu of the daily inspection between 0000 and 0130 hours in order to more effectively detect FOD on the runway during Seletar Airport's flight operational hours[20],[21]and that the aerodrome's four-times-a-day runway inspection frequency exceeds international standards, the investigation team opines that it would be desirable for the aerodrome operator to harness available technologies for early detection of FOD on the runway. Although delay in detecting the damaged lights was not a contributing factor, it remains relevant to highlight the importance of early detection of FOD on the runway.

[20] Seletar Airport observes curfew hours from 2200 hours to 0700 hours.
[21] The shift in the inspection timing is expected to be implemented in the fourth quarter of 2025.

3 CONCLUSIONS

From the information gathered, the following findings are made. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

3.1 The flight crews of Aircraft A and Aircraft B had likely misaligned their aircraft on the right edge line of Runway 03 at Seletar Airport for their take-offs at night, which resulted in the damage to the runway and taxiway edge lights.

3.2 The factors that could have contributed to both sets of flight crew misaligning the aircraft on the right edge of Runway 03 include the following:

(a) The reduced visibility of the visual cues during night conditions and a predominant dark surrounding may have reduced the pilots' visual acuity, making it difficult for them to identify aerodrome markings in the vicinity of the aircraft.

(b) The convergence of Taxiway E4 centre line marking with Runway 03 right edge line, in conjunction with the brighter runway edge lights relative to the surrounding, might have led the flight crews to believe that the taxiway centre line marking had guided them to the runway centre line.

(c) At the threshold of Runway 03, the additional paved area, which is intended to provide sufficient clearance for aircraft to execute the 180-degree turn on the turn pad, may have led the flight crews to believe that the aircraft was on (or at least near) the centre of the runway.

3.3 Runway 03/21 is not equipped with an automatic FOD detection system. In the event involving Aircraft B, the debris resulting from Aircraft B's hitting of the edge lights on the runway was discovered only after two aircraft had landed. The debris on the runway may present a safety risk to aircraft landing and taking off from the runway.

4 SAFETY ACTIONS

Arising from discussions with the investigation team, the organisations have taken the following safety action.

4.1 The aerodrome operator has taken the following actions:

(a) Published an Airside Safety Notice about the occurrence and to remind pilots to look out for the runway designator to ensure runway centre line alignment when lining up on Runway 03.

(b) Published a Notice to Airmen (NOTAM) to remind pilots to exercise caution when entering Runway 03 via Taxiway E4 for take-off and to not mistake runway edge lights as runway centre line lights.

(c) Extended Taxiway E4 centre line marking to the Runway 03 centre line on 20 December 2024.

(d) Shifting Taxiway E4 edge line and taxiway edge lights nearer to the runway edge line to reduce the extra paved area at Taxiway E4, by the fourth quarter of 2025, to reduce the likelihood of pilots perceiving that the aircraft was on or near the centre of the runway.

(e) Enhancing the current airfield lighting system detection capabilities for runway lighting failures by the first quarter of 2027. This would allow the ANSP and aerodrome's runway inspection team to be promptly alert of lighting fault and any resulting debris.

5 SAFETY RECOMMENDATIONS

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

5.1 It is recommended that the aerodrome operator improve the early detection of FOD on the runway by using available technologies. [TSIB Recommendation RA-2025-002]