Air Accident Investigation Unit Ireland

SYNOPTIC REPORT

SERIOUS INCIDENT
Boeing 767-33A, N378AX
Shannon Airport, Co. Clare

15 August 2019

An Roinn Iompair
Department of Transport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

Extracts from this Report may be published providing that the source is acknowledged, the material is accurately reproduced and that it is not used in a derogatory or misleading context.

[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.
[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.
[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

AAIU Report No: 2021 - 010
State File No: IRL00919042
Report Format: Synoptic Report
Published: 22 November 2021

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI No. 460 of 2009, the Chief Inspector of Air Accidents on 15 August 2019, appointed Howard Hughes as the Investigator-in-Charge, assisted by Kate Fitzgerald, to carry out an Investigation into this Serious Incident and prepare a Report. On 14 June 2021, the Chief Inspector re-assigned the function of Investigator-in-Charge to Kate Fitzgerald.

Aircraft Type and Registration:	Boeing 767-33A (ER), N378AX	
No. and Type of Engines:	2 x GE CF6-80C2B6F	
Aircraft Serial Number:	28147	
Year of Manufacture:	1996	
Date and Time (UTC)[4]:	15 August 2019 @ 05.13 hrs	
Location:	Shannon Airport (EINN), Co. Clare	
Type of Operation:	Commercial Air Transport	
Persons on Board:	Crew – 10	Passengers – 145
Injuries:	Crew – Nil	Passengers – 1 (Minor)
Nature of Damage:	Left main landing gear fire damage	
Commander's Licence:	Airline Transport Pilot Licence (ATPL), issued by the US Federal Aviation Administration (FAA)	
Commander's Age:	50 years	
Commander's Flying Experience:	6,623 hours, of which 1,231 were on type	
Notification Source:	Shannon Air Traffic Control (ATC)	
Information Source:	AAIU Field Investigation, AAIU Report Form submitted by the Pilot	

[4] **UTC**: Co-ordinated Universal Time. All times in this report are quoted in UTC; to obtain local time, add one hour.

SYNOPSIS

During the take-off roll on Runway (RWY) 24 at Shannon Airport (EINN), Ireland, the Commander heard an unusual noise and elected to reject the take-off. Following the rejected take-off, the aircraft was taxied to a holding area for brake cooling. It was subsequently decided to return to the parking stand. During the taxi back to stand, Shannon ATC observed smoke and then a fire in the area of the left main landing gear. Airport Fire and Rescue Service (AFRS) vehicles were deployed and the fire was extinguished. The passengers and crew evacuated the aircraft via emergency slides. One passenger sustained a minor injury during the evacuation.

NOTIFICATION

The AAIU was notified of the occurrence by Shannon ATC. Two Inspectors of Air Accidents deployed to the scene and commenced an Investigation.

1. FACTUAL INFORMATION

1.1 History of the Occurrence

At 04.46 hrs, the ATC Air Movements Controller (AMC) cleared the Boeing 767-33A (ER) aircraft for departure from RWY 24 at EINN. During the take-off roll, the Commander heard an unusual noise, which was increasing in volume and elected to abort the take-off. Following the aborted take-off, the Flight Crew taxied to Taxiway A (**Appendix A**) to carry out checks and discuss the holding time that would be required to cool the brakes before a take-off could be attempted again. They advised the AMC that they would require 35 - 40 minutes and the AMC directed them to hold on Taxiway C. Whilst on Taxiway C the Flight Crew contacted the Aircraft Operator's Maintenance Department, who advised that the aircraft should return to stand so that inspections could be carried out. Following discussions with the AMC, the Flight Crew were given permission to taxi the aircraft back to stand. At 05.13 hrs, during the taxi, and whilst the aircraft was on RWY 24, the AMC advised the Flight Crew that smoke was observed to be emanating from the aircraft's left main landing gear. The Flight Crew requested a service vehicle to assist. At 05.15 hrs, the airport Duty Office informed the AMC that the left main landing gear was on fire. The AMC informed the Flight Crew of the fire and requested that they initiate an immediate evacuation from the right side of the aircraft. The AFRS immediately dispatched to the aircraft. By 05.19 hrs all passengers and Cabin Crew had been evacuated using the aircraft emergency slides and the fire had been extinguished. Subsequently, the Commander informed ATC that the Flight Crew was about to leave the aircraft. One passenger sustained a minor injury during the evacuation.

1.2 Crew Interviews

The aircraft Flight Crew consisted of a Commander, a Co-Pilot and an International Relief Officer (IRO)[5]. All three Flight Crew members were interviewed by the Investigation. There were seven Cabin Crew members on board, of whom the Investigation interviewed the Chief Purser[6].

1.2.1 Commander

The Commander informed the Investigation that at the time of the occurrence he was the Pilot Monitoring (PM) and the Co-Pilot was the Pilot Flying (PF). The Commander stated that prior to the flight, the Flight Crew carried out the required check of the cockpit sliding windows. He said that the normal procedure was to confirm that the window lock lever was in the forward (locked) position, that a '*window not closed*' decal positioned below the window was not visible and that the window '*open/closed*' indicator above the window showed '*closed*'. The Commander was confident that the check had been carried out, on the day of the occurrence, according to the procedure.

He informed the Investigation that there were no abnormal system indications during the take-off roll. However, there was a loud noise coming from the left side of the cockpit which was increasing. He considered it was unsafe to continue, took control of the aircraft, called '*reject*' and brought the aircraft to a stop on the runway.

The Commander said that they notified ATC that they had rejected the take-off and did not require assistance. He informed the Investigation that he estimated the take-off had been rejected at approximately 100 kts and he calculated the cooling time for the brakes using 120 kts, which he believed was a conservative figure for the speed of the rejected take-off. He estimated that a cooling time of 44 minutes was required before another take-off could be attempted.

The Commander informed the Investigation that they then taxied the aircraft to hold on Taxiway C, during which time they had contacted the Operator to inform them of the situation. The Operator requested the Commander to return to the stand for an aircraft inspection and ATC cleared the aircraft to taxi to stand via RWY 24 and Taxiway A. As the aircraft was taxiing on RWY 24 the AMC reported to the Flight Crew that there was smoke visible from the left main gear. The Commander asked for a service vehicle to be sent out, but shortly after this, the AMC informed the Commander that there was a fire in the left main gear and that they should evacuate the aircraft. The Commander informed the Investigation that they immediately stopped the aircraft, shut down the engines and initiated an evacuation from the right side of the aircraft. They then completed the items on the evacuation checklist.

[5] **IRO:** The presence of an IRO extends the length of a Flight Crew's permitted flight duty period.
[6] **Purser:** Another term for the Senior Cabin Crew Member on the flight.

1.2.2 Co-Pilot

The Co-Pilot was the PF at the time of the occurrence. The Co-Pilot informed the investigation that the No. 1 main wheel on the left-hand main bogie and the No. 3 main wheel on the right-hand main bogie had been changed prior to the flight as the tyres had been observed to be close to wear limits. In addition, there was an open deferred defect relating to the Auxiliary Power Unit (APU), which meant that air conditioning was not available when the Flight Crew was carrying out pre-flight preparations. As a consequence, the cockpit became very warm and the left sliding window was opened. The APU defect was rectified before departure, and the Flight Crew closed the left cockpit window and observed that the window indicator showed '*closed*'.

The Co-Pilot said that during the take-off roll a rushing sound was heard after 80 kts and the Co-Pilot queried the status of the Commander's window, saying '*window ok?* ' but was not sure if the question was heard above the noise. The Co-Pilot believed the take-off was rejected at a speed of around 120 kts. The Co-pilot also informed the Investigation that on the subject aircraft EICAS[7] indications for wheel brake temperature were not available to the Flight Crew. The Co-Pilot observed that when the aircraft was taxiing back to stand after the rejected take-off, it appeared that the brakes were '*grabbing*'.

1.2.3 International Relief Officer (IRO)

The IRO informed the Investigation that he was sitting in the centre jump seat of the cockpit during the occurrence. He recalled hearing a rushing noise from the cockpit window at about 80 kts and also recalled hearing the normal call out of '*80 kts*'. He did not recall the speed at which the take-off was rejected but informed the Investigation that the brake cooling time was calculated to be 44 minutes using 120 kts as the rejected take-off speed.

1.2.4 Purser

The Purser informed the Investigation that he had not noted any anomalies during the initial taxi out to the runway. The cabin was secure and Cabin Crew members were seated. He stated that the Co-Pilot called the cabin and briefed them. The Commander subsequently briefed the passengers during the taxi to Taxiway C.

1.3 Injuries to Persons

One passenger sustained a minor injury during the aircraft evacuation.

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor	0	1	
None	10	144	

Table No. 1: Injuries to Persons

[7] **EICAS:** Engine Indicating and Crew Alerting System

1.4 Damage to Aircraft

The two forward wheels identified as No. 1 and No. 2 (**Figure No. 1**) and their associated brake units on the left main bogie[8] sustained substantial fire damage and burst tyres. The two aft tyres on the left main bogie sustained minor fire damage (**Photo No. 1**). The left main bogie and associated hydraulic lines sustained fire damage.

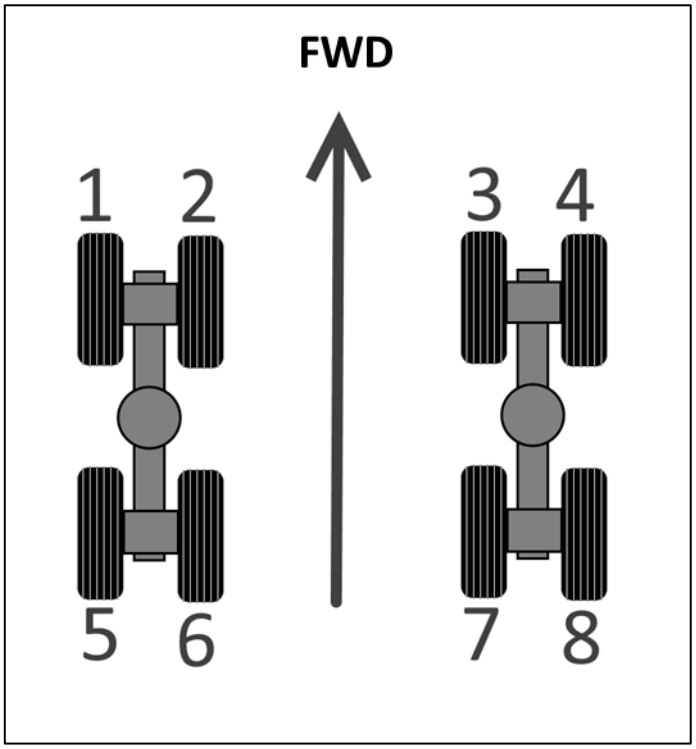


Figure No. 1: Wheel Position Numbering Convention

Photo No. 1: Fire Damage to Left Main Landing Gear (looking rearwards)

[8] **Bogie:** An aircraft undercarriage assembly consisting of two or more tandem wheels connected by a central strut.

1.5 Other Damage

No other damage was reported to the Investigation.

1.6 Personnel Information

1.6.1 Commander

The Commander held an Airline Transport Pilot Licence (ATPL) issued by the FAA on 24 June 2015. The licence specified that the Commander was rated for the Boeing 767 aircraft type. The Commander held a valid aviation medical certificate, first class, issued by the FAA on 8 March 2019.

The Commander's flying experience is outlined in **Table No. 2.**

Total all types:	6,623 hours
Total on type:	1,231 hours
Total on type P1:	266 hours

Table No. 2: Commander's flying experience

1.6.2 Co-Pilot

The Co-Pilot held an Airline Transport Pilot Licence (ATPL) issued by the FAA on 22 May 2016. The licence specified that the Co-Pilot was rated for the Boeing 767 aircraft type. The Co-Pilot held a valid aviation medical certificate, first class, issued by the FAA on 17 April 2019.

The Co-Pilot's flying experience is outlined in **Table No. 3**.

Total all types:	17,772 hours
Total on type:	2,987 hours
Total on type P1:	N/A

Table No. 3: Co-Pilot's flying experience

1.7 Aircraft Information

1.7.1 General

The Boeing 767-33A (ER) is a long-range, wide-body, twin-engine jet airliner. In the subject aircraft the passenger seating was in a twin-aisle seating configuration. The aircraft was equipped with a retractable tricycle landing gear, consisting of four wheels on each main landing gear bogie and two on the nose landing gear. The subject aircraft was configured with four main cabin doors, two at the front of the cabin, left and right, two at the rear, left and right. The aircraft was also equipped with four Type III over-wing emergency exits, two each side of the mid-cabin, left and right.

The ICAO Rescue and Fire Fighting code for the B767-33A (ER) is Aerodrome ARFF code 9.

1.7.2 Airworthiness Certification

The aircraft was issued with a Certificate of Airworthiness by the FAA on 16 April 2012. This certificate remained in effect whilst the aircraft was registered to the Operator.

1.7.3 Maintenance History

The Operator informed the Investigation that the aircraft was maintained on a *'Phase Check Program'*[9] and that prior to the occurrence the last maintenance *'Phase'* Check had been carried out in July 2019 at one of the Aircraft Manufacturer's facilities.

The Aircraft Log carried on board the aircraft stated that on the 13 August 2019, the No. 1 and No. 3 main landing gear wheel assemblies were replaced due to wear. Maintenance documentation shows that a daily service check was carried out on the day of the occurrence. During this check, a visual inspection of all of the aircraft wheels and tyres was carried out for '*wear and general condition'* and the air pressure in each tyre was checked and was found to be within normal service limits.

As part of the same daily service check a General Visual Inspection (GVI) of the cockpit was carried out with no anomalies noted. A weekly line maintenance check carried out on 12 August 2019 included a check of *'flight compartment windows for condition, sliding windows for proper operation […]'* with no anomalies noted.

The Aircraft Log also documented a defect with the aircraft Auxiliary Power Unit (APU). The log shows that the defect was cleared on the day of the occurrence.

1.7.4 Auto Brakes System

An auto brakes system was installed on the aircraft. **Figure No. 2** shows a schematic of the cockpit auto brake selector.

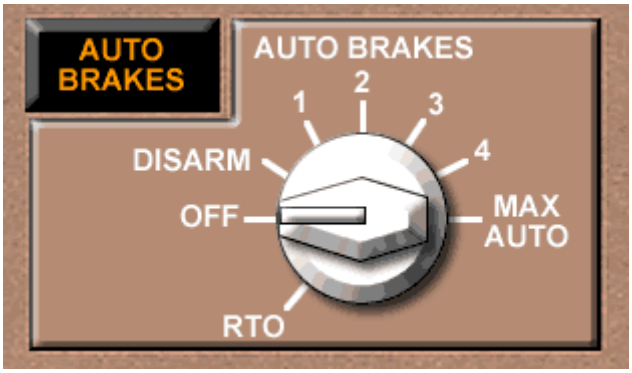


Figure No. 2: Auto Brake Selector

[9] **Phase Check Program:** A method of apportioning maintenance tasks to smaller equalized packages in order to even out workload and reduce aircraft downtime.

- RTO – Arms the Auto Brake system to provide maximum braking for a rejected take-off when the Throttles are retarded to idle above 80 kts.
- OFF – Removes power from the Auto Brake system.
- Disarm – Disarms the Auto Brake system and releases all auto brake pressure to the brake units.
- 1, 2, 3, 4, MAX Auto – Selects aircraft deceleration rates and arms the Auto Brake System for automatic braking on touchdown.

Flight Recorder data shows that the Auto Brake System was set to RTO at the time of the occurrence.

1.7.5 Aircraft Take-off Decision Speed

The gross take-off weight of the occurrence aircraft was 352,431 lb (159,860 kg). The Flight Crew had calculated the take-off speeds using this weight. According to the Operator's service documentation, the calculated V_1[10] at this weight was 146 kts.

1.7.6 Brake Temperature and Cooling Schedule Following Rejected Take-off

The subject aircraft was not equipped with brake temperature sensors. In the event of a rejected take-off, the Non-Normal procedures require flight crew to refer to a Brake Cooling Schedule to assess the length of time necessary for the brakes to cool. The brake cooling schedule uses a number of parameters; aircraft weight, speed of the rejected take-off, outside air temperature, altitude, distance taxied, auto brake selection and use of thrust reversers to determine the cooling time required. The brake cooling schedule for the subject aircraft recommends a brake cooling time of approximately 44 minutes based on the speed that the Flight Crew believed they were travelling (approximately 120 kts). The Flight Recorders show that the aircraft was actually travelling at approximately 146 kts when the '*reject*' call was made which requires a longer cooling period and may be in the '*CAUTION*' zone of the Brake Cooling Schedule.

[10] **V_1:** Federal Regulation 14 Aeronautics and Space, Volume 1, Chapter I gives the definition of V_1 as '*the maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance. V1 also means the minimum speed in the takeoff, following a failure of the critical engine at VEF, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance'.*

1.7.7 Aircraft Cockpit Window

The Boeing 767 has six cockpit windows, three on each side. When the aircraft is depressurised, the centre windows on both sides can be opened by means of a latch and slide-rail mechanism.

Photo No. 2: Left Centre Window Latch

Photo No. 3: Left Centre Window Slide Rail

A crank is used to move the window along the slide rail (**Photo No. 3**). When the window is fully seated in the closed position, it is locked by a latch lever (**Photo No. 2**). The Aircraft Manufacturer informed the Investigation that when the window is fully closed, a '*Window not closed*' decal positioned below the window should not be visible. The Aircraft Manufacturer also stated that it is possible to move the latch lever into the closed position before the window is fully latched closed and for this reason Flight Crew Operations Manual (FCOM) (**Section 1.13**) specifies pre-flight checks to verify that the window is correctly closed.

An OPEN/CLOSED indicator is located above the window (**Photos No. 4 and 5**). The Aircraft Manufacturer informed the Investigation that this indicator indicates the position of the latch cam only and is a secondary method of verifying that the window is latched after carrying out the other checks listed in the FCOM.

Photos No. 4 and 5: Window Status Indicator

1.8 Meteorological Information

Met Éireann, the Irish meteorological service, was asked to provide details of the weather conditions prevailing at EINN on the day of the accident. Details from the report received are reproduced in **Table No 4**.

Meteorological Situation:	A stable, moderate northwest airflow covers Ireland with a weak high pressure ridge building from the west.	
Wind:	**Surface:**	Westerly, 8-12KT
	2000 feet:	Northwesterly, 15-20KT
	Between surface and 300ft:	West to northwest, 10-12KT
Visibility:	20km	
Weather:	Patchy light drizzle	
Cloud:	Few (1-2/8th of sky) of stratus with bases around 1,000-1,500ft and broken (5-7/8th of sky) stratocumulus layers with bases 2,500-3,000ft	
Surface Temp/Dew Pt:	14/12 degrees Celsius	
MSL Pressure:	1013hPa	
Freezing Level:	9,000ft	
Other Comments:	METAR reports: METAR EINN 150700Z 27007KT 9999 FEW023 BKN060 15/13 Q1013 NOSIG= METAR EINN 150630Z 27006KT 9999 BKN030 15/12 Q1013 NOSIG= METAR EINN 150600Z 27008KT 9999 FEW009 SCT030 14/12 Q1013 NOSIG= METAR EINN 150530Z 27008KT 9999 BKN027 14/12 Q1013 NOSIG= METAR EINN 150500Z 28011KT 9999 -DZ FEW017 BKN030 14/12 Q1012 NOSIG= METAR EINN 150430Z 27009KT 9999 BKN034 15/12 Q1012 NOSIG=	

Table No. 4: Weather conditions at EINN at the time of the occurrence

1.9 Aerodrome Information

EINN is an international airport with one 3,199 m long, grooved, asphalt runway, designated RWY 06/24.

The Irish Aeronautical Information Publication (AIP) shows EINN aerodrome category for firefighting as Category 9 available Daily 0600-2200 UTC, Category 7 available Daily 2200-0600 UTC, and Category 9 available by arrangement 12HR PN.

1.10 Flight Recorders

The aircraft was fitted with an L3, FA2100, solid-state Cockpit Voice Recorder (CVR). The CVR was capable of recording high quality audio, on four channels, for 120 minutes. The CVR was downloaded at the AAIU's recorder facility. The aircraft was also fitted with an AlliedSignal (subsequently Honeywell), solid-state Flight Data Recorder (FDR) capable of recording at least 25 hours of flight data. The FDR was downloaded in the UK with the assistance of the UK Air Accident Investigation Branch.

The FDR for the subject aircraft did not record Indicated Airspeed (IAS) which the Pilots were using in the cockpit. The FDR recorded computed airspeed. However, the Aircraft Manufacturer informed the Investigation that computed airspeed is from the same data source as IAS and generally matches the IAS, unless there are data bus errors or malfunctions of the air data computer. The data for the occurrence does not show any such errors or malfunctions.

The FDR and CVR files were synchronised so that recorded verbal and flight data parameters could be correlated. Once synchronised, the data showed that when the callout of *'80 kts*' occurred on the CVR, the corresponding computed airspeed recorded on the FDR was 82 kts.

The CVR recorded the Pilots carrying out a '*Before Start'* checklist prior to taxiing the aircraft to the runway. During these checks the First Officer can be heard asking '*Windows*?', to which the Captain responds, '*Locked*'. The downloaded CVR and FDR data show that the *'reject'* call was made at a computed airspeed of 149 kts, and that the thrust levers were retarded and foot brakes applied less than two seconds later at a computed airspeed of 152 kts. The maximum computed airspeed recorded was 160 kts. A loud wind noise can be heard on the CVR recording after the standard '*80 kts'* callout. The CVR did not record any further speed callouts or verbalisation of V_1. The noise increases in volume and approximately 10 seconds after the callout, the Co-Pilot can be heard on the Co-Pilot's channel saying '*Window ok.*' The Co-Pilot's question is not acknowledged by the Commander and is not audible on the Cockpit Area Microphone channel of the CVR or the Commander's microphone channel. Approximately seven seconds after the question, the CVR records the Commander calling *'Reject'*.

Following the rejected take-off, the CVR recorded the Flight Crew discussing the speed of the rejected take off and the brake cooling schedule. On the recording, the Flight Crew can be heard estimating that the take-off was rejected at 120 kts, and from the estimated speed determining that a cooling time of 44 minutes was required. The Flight Crew also discussed the source of the noise which they believed was a cockpit window that had not been properly closed. During this discussion, the IRO states that '*it said locked*'. This appears to have been a reference to the indicator in the cockpit which shows the status of the window as '*open*' or '*closed*' (**Photos No. 4** and **5**). Later in the CVR recording the Co-Pilot tells the other Pilots about a previous experience on a different aircraft type where a window was open during the take-off roll.

The CVR also recorded the IRO calling the Operator and relaying the details of the occurrence to them. The IRO stated that the RTO occurred at 120 kts. The IRO then reported to the other Pilots that the Operator would like them to return the aircraft to the gate so that inspections of the wheels and brakes could be carried out. During the taxi back to stand the Commander commented that the aircraft was, '*pulling to the left*' and as a consequence he was taxiing slowly. The Flight Crew then discussed a rumbling noise (which is audible on the CVR), and the possibility that they may have a flat tyre. The Commander then asked the Co-Pilot to request a service vehicle to come out to the aircraft and check the tyres.

The Investigation reviewed the FDR for any evidence of brake dragging[11] after the rejected take-off. Brake dragging may be indicated by an unusually high temperature on the affected wheels. However, brake temperature sensors were not installed on the occurrence aircraft and therefore brake temperatures were not recorded by the FDR.

The Investigation provided the FDR data to the Aircraft Manufacturer and requested they provide an analysis of the wheel and brake system performance. The Aircraft Manufacturer's analysis concluded that:

- The longitudinal deceleration of the aircraft during the RTO was consistent with the expected deceleration characteristics for an aircraft of that weight, configuration and deceleration device usage.
- The commanded left and right brake pressures were consistently close during the taxi to and from the runway.
- The commanded peak left and right brake pressures during the rejected take-off were 1,595 and 1,155 psi respectively which is below the maximum of 3,300 psi.
- During the RTO the applied left brake pressure was an average of 500 psi higher than the applied right brake pressure and may have been commanded with intermittent brake applications.
- There was no evidence of a left yaw that would have resulted from a dragging or locked brake. The average rudder pedal position was neutral and the magnetic heading did not trend to the left.
- Data from the previous landing of the aircraft showed no evidence of a left yaw that would have indicated a dragging left brake.
- Based on a simulation analysis, there did not appear to be any erroneous brake behaviour.

1.11 Air Traffic Control Recordings

The Investigation obtained voice recordings and an occurrence report from Shannon Airport ATC and CCTV recordings from the AFRS for the time of the occurrence. The ATC recordings show that at 04.46 hrs the aircraft was cleared for take-off and at 04.47 hrs, the Co-Pilot contacted the AMC stating, '*And, er, we're rejecting on the runway for an open window*'. The aircraft was initially cleared to backtrack and line up for a second take-off, but following a request from the Flight Crew, the AMC permitted the aircraft to taxi to Taxiway A in order to carry out checks. At 04.53 hrs, the Co-Pilot asked the AMC if they could move to a holding point to cool their brakes and that this would take 35-40 minutes. ATC directed the aircraft to taxi to Taxiway C. At 05.06 hrs and whilst holding on Taxiway C the Flight Crew requested clearance to return to stand so that their maintenance team could carry out some checks on the brakes. At 05.08 hrs the AMC cleared the aircraft to taxi on to RWY 24 and turn left onto Taxiway A, holding short of the apron.

[11] **Dragging:** Refers to the condition where brakes do not fully release after application and remain in a partially applied position.

At 05.13 hrs, whilst the aircraft was taxiing along RWY 24, the AMC contacted the Flight Crew to inform them of smoke emanating from the left main landing gear. The Flight Crew requested that a fire truck attend the aircraft and the AMC passed on this request immediately. Airport CCTV evidence recorded at this time showed that the front two tyres, (No. 1 and No. 2, **Figure No. 1**) on the left main landing gear were deflated.

At 05.15 hrs, the AMC contacted the Flight Crew again and requested that they evacuate the aircraft due to a fire on the left main landing gear. The Co-Pilot repeated this information and stated that they would evacuate on the right, to which the AMC replied *'Affirm, affirm'*. The AMC immediately informed the AFRS of the fire and gave clearance for the emergency vehicles to attend the aircraft on the runway. At 05.19 hrs, the AMC called the AFRS again and asked if the fire was under control. The AFRS informed the AMC that the fire was out, the passengers had been evacuated to the side of the runway and that the AFRS was maintaining fire control. The AMC then contacted the Flight Crew who confirmed that they were leaving the aircraft and that no one else remained on board.

1.12 Examination by Wheel and Brakes Manufacturer

Following initial examination by the Investigation, the wheels and brake units from the main left bogie were removed from the aircraft, and with the assistance of the US National Transportation Safety Board (NTSB) they were shipped to the US-based wheel and brake manufacturer for detailed strip examination. The examination was carried out in the presence of an FAA representative who was acting on behalf of the NTSB.

Measurements taken during this examination showed that all brake units from the left and right bogies had an acceptable level of wear (**Table No. 5 and Figure No. 1**).

Brake S/N	Wheel Position number	% of Brake Wear Remaining
02564	1	83% Wear Remaining
09076	2	90% Wear Remaining
02087	3	24% Wear Remaining
02037	4	64% Wear Remaining
02438	5	79% Wear Remaining
04775	6	44% Wear Remaining
00482	7	44% Wear Remaining
04933	8	8% Wear Remaining

Table No. 5: Wear Remaining in the Wheel Brakes

The wheel and brake manufacturer concluded that a specific source of the brake fire could not be identified.

In addition, the left main gear bogie and associated hydraulic lines were sent to the respective manufacturers of those parts for inspection. The inspections found fire damage to all of the parts, but no ignition source for the fire was identified.

1.13 Operator's Procedures

The Operator's Flight Crew Operations Manual contains a rejected take-off procedure which states the following:

> *'The captain has the sole responsibility for the decision to reject the takeoff. The decision must be made in time to start the rejected takeoff maneuver by V1. If the decision is to reject the takeoff, the captain must clearly announce "REJECT", immediately start the rejected takeoff maneuver, and assume control of the airplane. If the Co-Pilot is making the takeoff, the Co-Pilot must maintain control of the airplane until the captain makes a positive input to the controls.*
>
> […]
>
> *Above 80 knots and prior to V1, the takeoff should be rejected for any of the following:*
> - *fire or fire warning*
> - *engine failure*
> - *if the airplane is unsafe or unable to fly.'*

The Operator's Quick Reference Handbook (QRH) contains a '*Before Start*' checklist. A laminated copy of this checklist is carried in the cockpit during operations. The checklist is shown in **Figure No. 3** below:

15

BEFORE START		
Seat Belts	Checked	C, F/O, ACM
Passenger Signs	_____	C
Fuel Panel	_____ Rls'd _____ Onboard	C
Red Anti Collision Light	ON	C
Windows	Locked	C, F/O
MCP	V2____, HDG____, ALT____	C
Takeoff speeds	V1____, VR____, V2____	C, F/O
CDU Preflight	Completed	C, F/O
Trim	____Units, 0, 0	C, F/O
Taxi and Takeoff Briefing	Completed	PF

Figure No. 3: Before Start Checklist

The Flight Crew can be heard on the CVR carrying out the check of the windows.

1.14 Aircraft Manufacturer's Procedures

The Aircraft Manufacturer's Flight Crew Training Manual for the subject aircraft type contains the following guidance with regards to open cockpit side windows:

> *'The inadvertent opening of an unlatched flight deck window by air loads during the takeoff roll is not considered an event that warrants a high speed RTO. Although the resulting noise levels may interfere with crew communications, it is safer to continue the takeoff and close the window after becoming airborne and the flight path is under control.'*

The '*Before Start Procedure*', which is part of the Aircraft Manufacturer's FCOM contains the following check:

767 Flight Crew Operations Manual

Flight deck windows.....Closed and locked	C, F/O
Verify that the lock lever is in the forward, locked position.	
Verify that the WINDOW NOT CLOSED decal does not show.	

Figure No. 4: Extract from Aircraft Manufacturer's Before Start Procedure

1.15 Relevant Regulation

Federal Regulation 14 Aeronautics and Space, Volume 1, Chapter I gives the following definition of V1:

> *'V_1 means the maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance. V_1 also means the minimum speed in the takeoff, following a failure of the critical engine at V_{EF}, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance.'*

The certification requirement in the United States for rejected take-offs is 14 CFR 25.109. The heat management guidance for the Max Brake Energy test is given by Advisory Circular (AC) 25-7, which contains a guide to flight testing an aircraft for Part 25 certification. The AC contains guidance on 25.109, and the following passage in section 4.3.5.4 states:

> *'A satisfactory after-stop condition is defined as one in which fires are confined to tires, wheels, and brakes, such that progressive engulfment of the rest of the airplane would not occur during the time of passenger and crew evacuation. The application of firefighting means or artificial coolants should not be required for a period of 5 minutes following the stop.'*

2. ANALYSIS

During the take-off roll, the Flight Crew became aware of a loud and increasing noise. The Co-Pilot suggested the noise may be coming from a cockpit window and was heard commenting '*Window ok*' on one channel of the CVR recording. However, the Commander did not appear to hear the Co-Pilot and was unaware of the source of the noise. Data from the flight recorders shows that the Commander's callout to reject the take-off occurred at a computed airspeed of 149 kts. The thrust levers were retarded and foot brakes applied two seconds later when the aircraft was travelling at 152 kts. The Aircraft Manufacturer informed the investigation that the recorded parameter *'computed airspeed'* generally matches the IAS used by pilots in the cockpit unless there are data bus errors or air data computer malfunctions. There were no recorded errors or malfunctions recorded for the subject occurrence. Therefore, it is probable that the action to retard the thrust levers occurred above V_1.

The Aircraft Manufacturer's Flight Crew Training Manual advises Flight Crews that an open flight deck window does not warrant a high speed RTO. However, the same paragraph also notes that the noise from an open window may interfere with crew communications. The Operator's Flight Crew Operations Manual states that above 80 kts and prior to V_1 a rejected take-off should be performed if, '*the airplane is unsafe or unable to fly'*. In this occurrence the Commander, who has sole responsibility for rejected take-offs, decided not to continue because of the unidentified, increasing noise. Unfortunately, as forewarned in the Manufacturer's Flight Crew Training Manual, the noise itself prevented effective communications between the Co-Pilot and the Commander. It is therefore probable that the Commander did not hear the Co-Pilot querying the status of the left sliding window. A few minutes after the occurrence the Co-Pilot told the other Pilots of a previous experience where a window was open during the take-off roll. This previous experience may have assisted the Co-Pilot in quickly identifying the source of the noise.

The '*Before Start Procedure*' contained in the Aircraft Manufacturer's FCOM requires a Flight Crew to carry out two checks to confirm that a cockpit sliding window is closed and locked; the lock lever must be in the forward position and the '*window not closed*' decal located under the window must not be visible. Subsequent to the occurrence the Commander confirmed that the normal procedure was carried out. In addition, the Commander stated that the Flight Crew also checked the window indicator located above the window. The Aircraft Manufacturer informed the Investigation that this window indicator indicates the position of the latch cam only, and is a secondary method of verifying that the window is latched after the checks required by the FCOM procedure have been completed.

Following the rejected take-off there was a period of approximately 28 minutes during which time the Flight Crew calculated a brake cooling time, carried out checks, and communicated with both the AMC and the Operator's engineering team. During this time the aircraft taxied from the runway to a Taxiway, then to a holding point on a second Taxiway and then back onto the runway in order to taxi back to stand. These movements involved a number of left turns and would have required the use of the aircraft's brakes to control the aircraft's speed. It is possible that, following the high speed rejected take-off, the use of the brakes during taxi and stopping may have further increased the temperatures of the brake system.

There were no brake temperature sensors installed on this aircraft, nor were they required to be. This meant that the Flight Crew had no means of monitoring brake temperatures. In accordance with Operator's procedures, the Flight Crew used the Aircraft Manufacturer's Brake Cooling Schedule to calculate a cooling time for the brakes. However, the Flight Crew underestimated the speed of the aircraft at the time the take-off was rejected. The underestimated value of 120 kts corresponds to a brake cooling time of approximately 44 minutes on the brake cooling schedule. The Flight Recorders show that the aircraft was actually travelling at approximately 146 kts when the '*reject'* call was made which requires a longer cooling period and may be in the '*CAUTION'* zone of the Brake Cooling Schedule.

Had the Flight Crew been aware of this, they may have adopted a more cautious approach, in particular with regards to taxiing the aircraft. The underestimation of speed, coupled with taxiing and further brake applications, within the calculated cooling period increased the risk of an adverse event such as a fire.

There are inherent risks associated with carrying out a high speed RTO, with runway excursions, loss of control, and brake fires amongst the possible outcomes. Above 80 kts a pilot has very little time for decision making. Both the Operator's Flight Crew Operations Manual and the Federal Regulation definition of V_1 state that the first action to stop the aircraft must be made by V_1. It is therefore critical that the IAS is monitored closely so that if an RTO is required, the required actions can be initiated prior to V_1 and the correct actions can be taken following the RTO. These actions include the calculation of the brake cooling time. However, in this occurrence the Commander had a significant distraction in the form of an unidentified, increasing noise, just before V_1, a critical point in the take-off roll. This distraction may have contributed to the subsequent underestimation of the speed of the RTO.

During the cooling period following the rejected take-off, and whilst the aircraft was taxiing on RWY 24, Shannon ATC Tower advised the Flight Crew that smoke was observed to be emanating from the aircraft's left main landing gear. A fire on the left main bogie was observed at 05.15 hrs by the AMC who immediately informed the Flight Crew and requested they evacuate the aircraft. The Co-Pilot acknowledged that the fire was on the left side and that they would evacuate to the right, to which the AMC answered *'Affirm, affirm'*. The Commander immediately directed the passengers and cabin crew to evacuate, using the exits on the right side of the aircraft. The AMC subsequently informed the AFRS and gave them clearance to attend the aircraft. Five minutes later the AFRS reported that the fire had been extinguished. The Commander then reported that all passengers and Cabin Crew of the aircraft had been evacuated and that the Flight Crew were leaving the aircraft.

FAA 14 CFR 25.109 states that:

> *'A satisfactory after-stop condition is defined as one in which fires are confined to tires, wheels, and brakes, such that progressive engulfment of the rest of the airplane would not occur during the time of passenger and crew evacuation. The application of firefighting means or artificial coolants should not be required for a period of 5 minutes following the stop.'*

In this occurrence the AFRS had responded and extinguished the fire within five minutes and therefore the certification requirements are not pertinent to the analysis of this occurrence.

An examination of the main landing gear bogie, wheels, brakes and hydraulic lines carried out by the respective Manufacturers and witnessed by the FAA, found that there was no identifiable source of the fire. The examination found that all of the brakes on the left main gear were found to be within acceptable limits. Analysis of the flight recorder data by the Aircraft Manufacturer showed that the brakes functioned as expected for the weight and speed of the aircraft at the time of the occurrence and there was no evidence of brake '*dragging*'.

In summary, following a high-speed rejected take-off, and subsequent period of taxiing, a fire started in the left main landing gear area. The fire was rapidly extinguished by the AFRS, and passengers and crew were evacuated. Subsequent examination of the wheels, brakes and flight recorder data found no identifiable cause of the fire. It is therefore probable, that the combination of a rejected take-off at high speed, combined with a lengthy period of taxiing where brakes, particularly on the left side were used, caused the brake system to overheat and a fire to ignite in the left main gear bogie.

3. CONCLUSIONS

3.1 Findings

1. The aircraft had a valid certificate of airworthiness.
2. The Flight Crew were appropriately licensed for the flight.
3. The Flight Crew had valid medicals.
4. The calculated V_1 speed for the flight was 146 kts.
5. The maximum computed airspeed recorded by the FDR was 160 kts.
6. A V_1 call was not audible on the CVR.
7. A call to reject the take-off was made at a recorded computed airspeed of 149 kts.
8. Both Flight Crew members believed that the aircraft was travelling at an IAS of less than 120 kts when the decision was made to reject the take-off.
9. The Flight Crew calculated a cooling time for the brakes, but underestimated the maximum speed achieved during the attempted take-off.
10. Following the rejected take-off the aircraft taxied first to a hold position and subsequently started to taxi back to stand. These manoeuvres involved several left turns and use of the aircraft brakes.

11. During the taxi back to stand a fire started in the left main landing gear.
12. The AMC observed the fire and informed the Flight Crew advising them to evacuate on the right side of the aircraft.
13. AFRS dispatched to the aircraft in a timely manner having observed the occurrence on the runway and being dispatched by the AMC.
14. Four minutes after the fire was initially observed, the AFRS reported to the AMC that the fire was extinguished and all passengers and Cabin Crew had evacuated. The Flight Crew evacuated shortly afterwards.
15. Analysis of data from the Flight Data Recorder by the Aircraft Manufacturer showed that the performance of the wheel and brake assemblies was as expected for the weight of the aircraft and the speed of the rejected take-off.
16. Disassembly and Inspection of the wheels and brakes by the Manufacturer did not identify a source of the fire.

3.2 Probable Cause

Fire in the brake assembly during taxi, following a high-speed rejected take-off which occurred 28 minutes earlier.

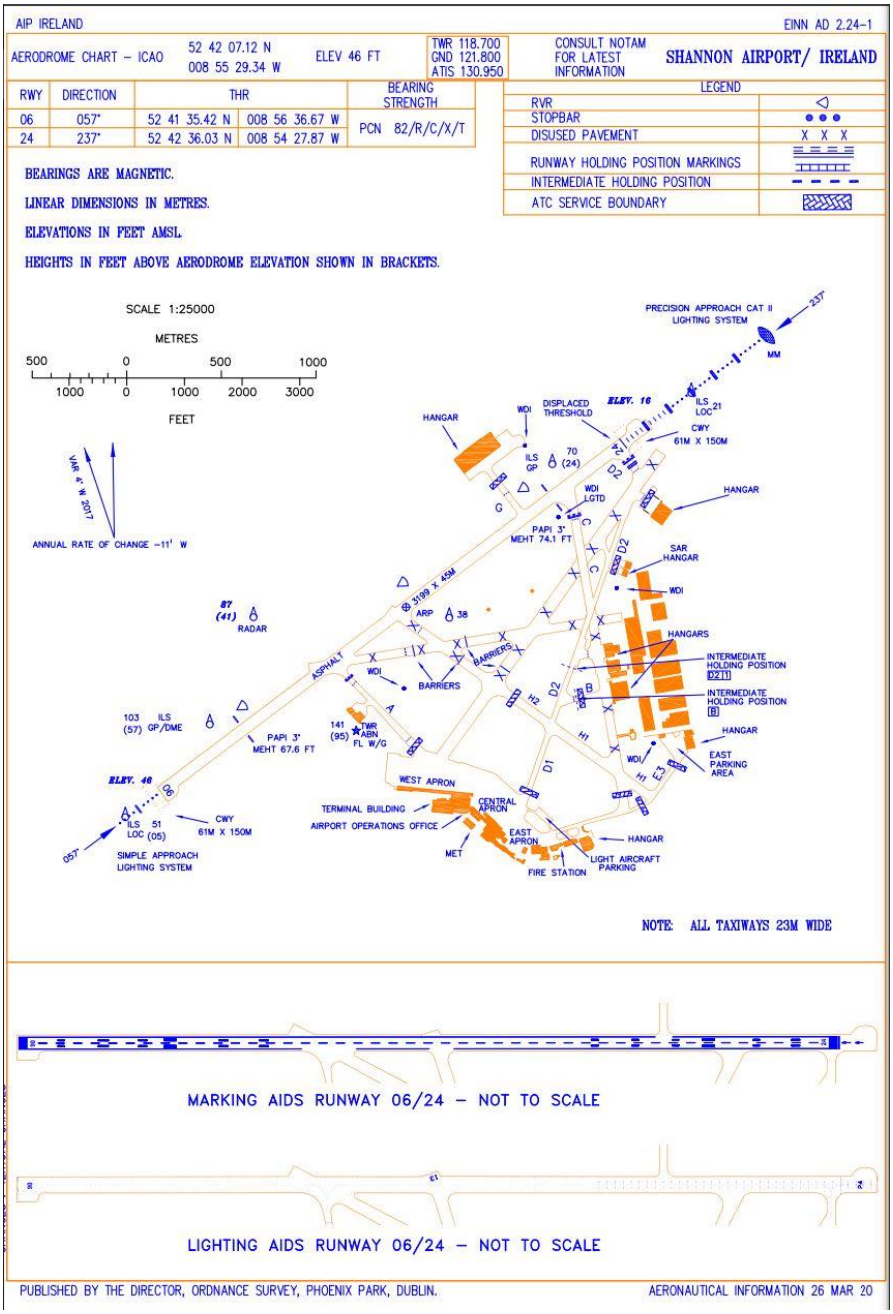
4. SAFETY RECOMMENDATIONS

This Investigation does not sustain any Safety Recommendations.

- END -

5. Appendix

Appendix A: Shannon Airport Ground Chart



In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

Produced by the Air Accident Investigation Unit

AAIU Reports are available on the Unit website at www.aaiu.ie

An Roinn Iompair
Department of Transport

Air Accident Investigation Unit,
Department of Transport,
2nd Floor, Leeson Lane,
Dublin 2, D02TR60, Ireland.
Telephone: +353 1 604 1293 (24x7): or
+353 1 241 1777 (24x7):
Fax: +353 1 604 1514
Email: info@aaiu.ie
Web: www.aaiu.ie
Twitter: @AAIU_Ireland