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AAIB
Air Accidents Investigation Branch

AAIB Bulletin S2/2017 *SPECIAL*

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-86J, C-FWGH
No & Type of Engines:	2 CFM56-7B26E turbofan engines
Year of Manufacture:	2011 (Serial No: 37752)
Location:	On takeoff from Belfast International Airport
Date & Time (UTC):	21 July 2017 at 1539 hrs
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 179
Injuries:	Crew - None Passengers - None
Nature of Damage:	Light fitting on runway damaged
Commander's Licence:	Canadian Airline Transport Pilot's Licence
Commander's Age:	38
Commander's Flying Experience:	8,234 hours (of which 2,817 were on type) Last 90 days - 170 hours Last 28 days - 45 hours
Information Source:	AAIB Field Investigation

Introduction

On 21 July 2017 at 1539 hrs, C-FWGH took off from Belfast International Airport with a thrust setting which was significantly below that required for the conditions of the day. Preliminary evidence indicated that, after the aircraft lifted off from the runway, one of the aircraft tyres struck a runway approach light, which was 35 cm high and 29 m beyond the end of the runway.

The event was not reported to the AAIB by the aircraft commander, aircraft operator or the tour operator on behalf of which the flight was being undertaken, although it was reported to the Transportation Safety Board in Canada by the aircraft operator. At 2053 hrs on 21 July 2017, ATC personnel at the airport filed a Mandatory Occurrence Report (MOR) and sent a signal using NATS's Aeronautical Fixed Telecommunications Network (AFTN), and the AAIB was one of the addressees on the signal. This system is only monitored by the AAIB during office hours and the message was not read until 0713 hrs on 24 July 2017 at which time an investigation was begun. The delay introduced by these circumstances meant that Flight Data Recorder (FDR), Cockpit Voice Recorder (CVR) and other recorded data sources were unavailable to the investigation.

This Special Bulletin contains preliminary information on this serious incident, clarification about the reporting of accidents and serious incidents and two Safety Recommendations relating to Flight Management Computer (FMC) software updates.

History of the flight

The aircraft was registered in Canada but was operating on behalf of a UK tour operator. The Canadian operator supplied the aircraft and flight crew to support the tour operator for the summer season.

The aircraft was departing for a flight from Belfast International Airport to Corfu, Greece. The crew boarded the aircraft and completed their pre-flight preparations before pushing back, intending to depart from Runway 07. After pushing back, the ground crew noticed that one of the tyres on the nose landing gear was worn and the aircraft returned to the stand. After both nose landing gear tyres had been changed, the aircraft once again pushed back and taxied out for departure.

The crew were cleared for takeoff on Runway 07 from Taxiway D (Figure 1), which gave a Takeoff Run Available (TORA) of 2,654 m. During the takeoff, at around 120 to 130 kt, the crew realised that the aircraft was not accelerating normally. They estimated, during post-flight interviews, that they reached V_1[1] with around 900 m of the runway remaining and rotated shortly afterwards. The aircraft was seen, by multiple witnesses, during rotation and took a significant time to lift off before climbing at a very shallow angle.

After the takeoff, airport operations staff conducted a runway inspection and a runway approach light for Runway 25 was found to be broken. Preliminary evidence indicated that the aircraft struck the light, which was 35 cm high, 29 m beyond the end of the runway in the stopway[2].

After takeoff, the crew checked the aircraft's FMC which showed that an N_1[3] of 81.5% had been used for the takeoff. This figure was significantly below the required N_1 setting of 93.3% calculated by the operator and shown on the pre-flight paperwork.

Footnote

1 V_1: The maximum speed in the takeoff at which the pilot must take the first action to stop the aeroplane within the accelerate-stop distance. It is also the minimum speed in the takeoff, following a failure of the critical engine, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance (European Aviation Safety Agency).

2 Stopway: Defined rectangular area on the ground at the end of the runway in the direction of takeoff prepared as a suitable area in which aircraft can be stopped in case of abandoned takeoff.

3 N_1: Engine fan or low pressure compressor speed.

Recorded data

The aircraft had flown for 16 sectors before the AAIB became aware of the event and, when the FDR was downloaded, it was found that the data from the incident flight had been overwritten by subsequent flights. The aircraft was also fitted with a Quick Access Recorder, but the operator was troubleshooting this installation and the memory cards contained no data. The CVR installed on the aircraft had a 30 minute recording capability and would have been overwritten due to the elapsed time since the event so was not removed from the aircraft.

The radar installation at Belfast International Airport tracked the aircraft along Runway 07 and during initial climb-out, when altitude data also became available from the aircraft's transponder. The radar returns allowed groundspeed for the aircraft to be calculated which was supplemented by both groundspeed and altitude data transmitted from the aircraft over its ADS-B[4] data link. This data is shown in Figure 1 for the ground roll, where the text in yellow represents calculated groundspeed data from the radar track and, in green, the received ADS-B groundspeeds. Orange lines show the approximate position where the aircraft achieved airspeeds equivalent to V_1 and V_R,[5] taking into account a 7 kt headwind component.

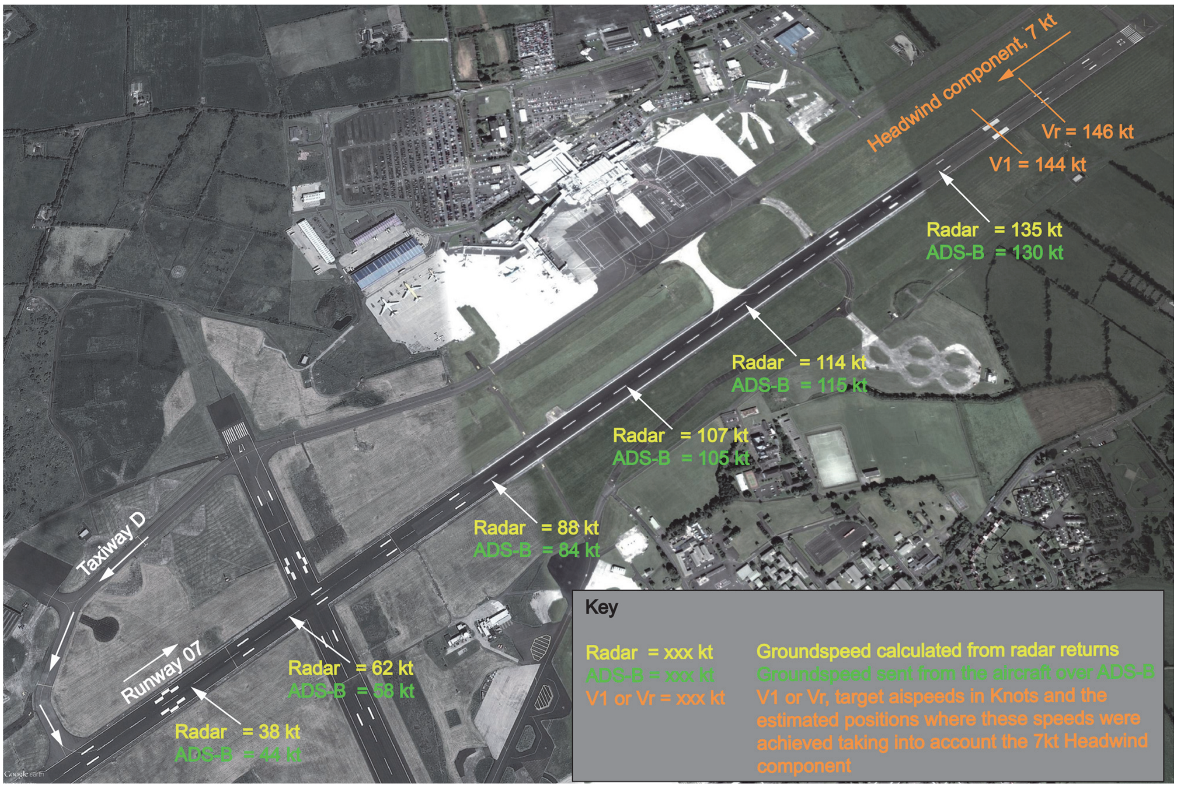

Figure 1

Groundspeed data for the takeoff in relation to V_1 and Vr

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Footnote

4 Automatic Dependent Surveillance – Broadcast: a technology whereby an aircraft broadcasts its location and other information enabling it to be tracked.

5 V_R: The speed at which the handling pilot rotates the aircraft in pitch during the takeoff.

Figure 2 shows spot heights above the elevation of Belfast International Airport (268 ft amsl) for the aircraft's initial climb, derived from the aircraft's ADS-B reports (these heights are annotated 'above airfield level' (aal)). At no time during the climb-out was the aircraft's Enhanced Ground Proximity Warning System Mode 3 aural alert ("DON'T SINK") triggered[6].

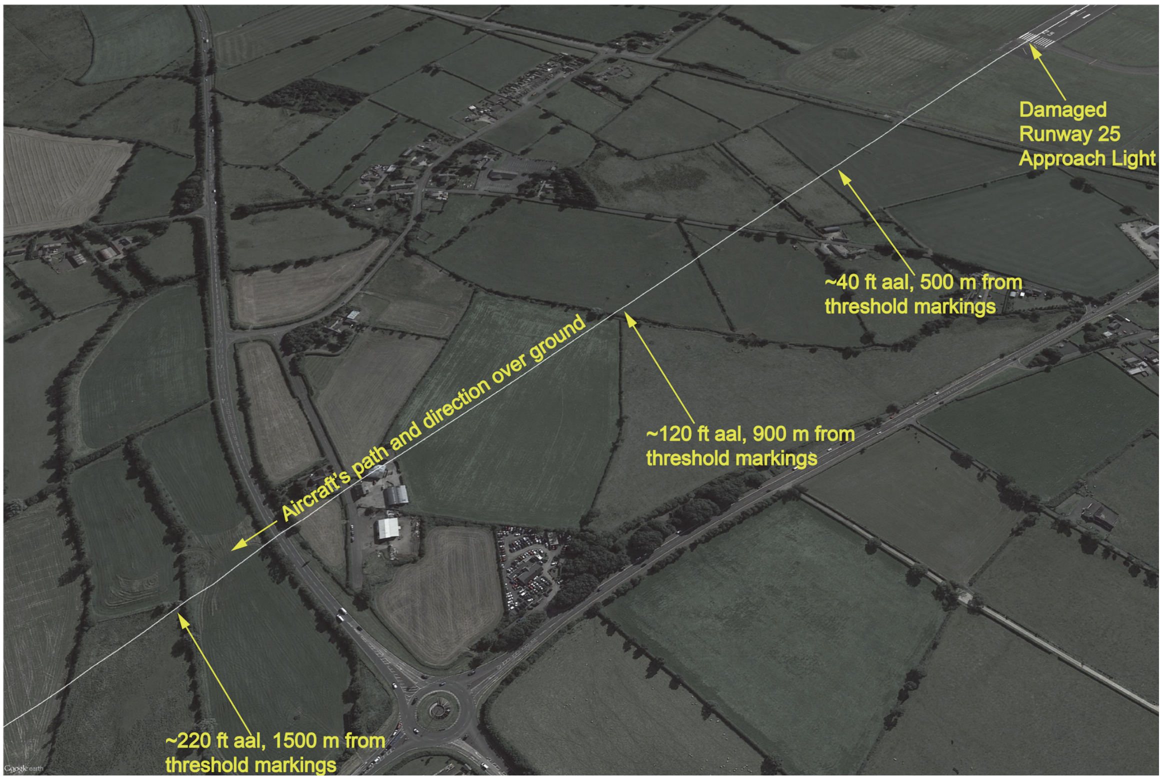

Figure 2

Vertical profile for the initial climb-out

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Passing the upwind end of the runway the aircraft's ACARS[7] sent a takeoff report, which confirmed that the engines were at an N_1 of approximately 81.5%. Other ACARS messages confirmed that the correct weights for the aircraft had been entered into the FMC.

The aircraft's auto-throttle BITE[8] history showed two messages generated during the climbout. Both messages were consistent with the crew having manually advanced each throttle to a power setting above an N_1 of 81.5% when the aircraft was approximately 800 ft aal.

The Electronic Flight Bags (EFB) used by the crew to calculate the performance figures for entry into the FMC were provided to the AAIB. Initial examination of these devices indicated that the correct figures were calculated by the EFB performance software prior to the aircraft's departure.

Footnote

[6] A Mode 3 aural alert is triggered by excessive altitude loss after takeoff or go-around.
[7] Aircraft Communications Addressing and Reporting System: a digital datalink for the transmission of short messages.
[8] Built-in Test Equipment.

Simulator assessment

The AAIB and operator carried out independent assessments of how the incorrect thrust setting might have been programmed into the FMC. Both assessments concluded that the only credible way to achieve a grossly low N_1 setting was to enter an extremely low value into the outside air temperature (OAT) field on the N1 LIMIT page. It was found that the takeoff N_1 setting used on the flight (81.5%) would be calculated by the FMC if:

a. The expected top-of-climb outside air temperature (OAT) was entered into the OAT field on the N1 LIMIT page instead of the OAT at the airport (a figure of - 52°C as opposed to +16°C); and

b. The correct assumed temperature[9] of 48°C was entered into the FMC.

No other combination of data entries was found which would achieve the same result.

During the simulation carried out by the AAIB, the aircraft's performance was assessed following an engine failure immediately prior to V_1, with the pilot making a decision by V_1 to either abandon or continue the takeoff. In the simulator, the aircraft was able to stop in the runway remaining following a decision to abandon the takeoff, but was unable to climb away safely following a decision to continue the takeoff.

Erroneous FMC entries of OAT

As a result of previous events involving erroneous OAT entries during FMC programming, Boeing published a Flight Crew Operations Manual Bulletin in December 2014. This document discussed three events where incorrect values for OAT had been entered into, and accepted by, the FMC. In two of these cases, the incorrect OAT had been sent to the FMC via datalink, but in the third case the crew made a manual entry error. The bulletin stated:

> *'An incorrect reduced thrust target may result in slower acceleration to V1, which may invalidate the takeoff performance calculations and/or result in decreased obstacle clearance margins after liftoff.'*

The bulletin also states that:

> *'flight crews should verify the OAT entry on the N1 LIMIT page is correct.'*

It then described how this check was to be carried out.

In addition, from revision U12.0 of the FMC software, a crosscheck was added that compares the OAT entered by the crew against either that fed to the Electronic Engine Controls or, on older Boeing 737s, sensed by the aspirated Total Air Temperature probe (if fitted)[10].

Footnote

[9] The assumed temperature, which is higher than the actual OAT, limits the target takeoff thrust when entered into the FMC.

[10] Aspirated Total Air Temperature probes are not fitted to all Boeing 737s that predate the B737NG series of aircraft.

The crosscheck runs once, approximately one minute after engine start, and establishes whether a difference of more than 6ºC exists between the value entered into the FMC and that sensed by the external temperature sensor. If the difference is more than 6ºC it rejects the OAT entry, deletes the takeoff reference speeds and indicates on the FMC displays that the reference speeds have been deleted. C-FWGH, and the simulator used for the AAIB trial, had an earlier revision of FMC software installed, U10.8A, which did not include this crosscheck. Revision U12.0 of the FMC software became available in February 2016[11], but the crosscheck functionality also required Next Generation Boeing 737 (B737NG) aircraft to have the Block Point[12] 15 (BP15) standard of the Common Display System[13] (CDS) installed, which became available in January 2017[14].

Analysis

The aircraft took off from Runway 07 with a thrust setting significantly below that required to achieve the correct takeoff performance, and struck a Runway 25 approach light shortly after lifting off.

The N_1 required to achieve the required takeoff performance was 93.3% but 81.5% was used instead. Independent assessments by the AAIB and operator showed that the only credible way for this to have happened was for an error to have been made whilst entering the OAT into the FMC. If the top-of-climb OAT was mistakenly inserted into the OAT field on the N1 LIMIT page (a figure of -52°C as opposed to +16°C), and the correct assumed temperature of 48°C was entered, the FMC would have calculated a target takeoff N_1 of 81.5%. The investigation will consider how such a data entry error could have been made, and whether actual aircraft performance matched that which would be expected given the N_1 power setting used.

The simulator trial examined aircraft performance following an engine failure immediately prior to V_1 with the pilot making a decision to either abandon or continue the takeoff. Although the simulator results cannot be considered definitive, and aircraft performance will be investigated further with the manufacturer, they suggest that, in similar circumstances on the incident flight:

a. Had the pilot decided to abandon the takeoff, the aircraft could have stopped in the runway remaining.

b. Had the pilot decided to continue the takeoff, the aircraft might not have had sufficient performance to climb away safely.

Footnote

11 Boeing Service Bulletin 737-34-2600 refers; this was originally released in February 2016 but was then revised in January 2017 to recommend compliance within 24 months.

12 A Boeing term used to reference a set of changes that are packaged together and applied to an aircraft as one update, bringing either new functionality, fixes to the aircraft's systems or a combination thereof.

13 Common Display System: This consists of 6 Display Units and their associated electronics on the Boeing 737NG; two for each pilot to show the Primary Flight Display and Navigation Display and a further two for Engine and System status information.

14 Boeing Service Bulletin 737-31-1650 refers; this was released in January 2017 and also recommended compliance within 24 months.

The FMC software fitted to C-FWGH, U10.8A, predated revision U12.0, which features the crosscheck between the OAT entered by the crew and that sensed by the external temperature sensor. In this event, had C-FWGH been updated with U12.0 and CDS BP15, the entry of a top-of-climb OAT instead of the ambient OAT at ground level would have been prevented, the crew would have received feedback on their erroneous entry, and the serious incident would have been prevented. The updates to the CDS and FMC software are offered by Boeing as upgrade service bulletins at nominal cost. Fleet embodiment of software revision U12.0 (or later revision incorporating the outside air temperature crosscheck) would reduce the likelihood that this type of data entry error was repeated. Therefore:

Safety Recommendation 2017-016

It is recommended that the Federal Aviation Administration, mandate the use of Flight Management Computer software revision U12.0, or later revision incorporating the outside air temperature crosscheck, for operators of Boeing 737 Next Generation aircraft.

Flight Crew Operations Manual Bulletins are inserted by aircraft operators into the Flight Crew Operations Manual (FCOM) upon receipt, but are temporary in nature and removed when the FCOM is next updated as part of the regular FCOM revision cycle. In this particular case, the operator's FCOM had been revised and incorporated the text showing how the flight crew should verify the OAT entry. However, the removal of the whole Bulletin meant that the background material about the reasons for the existence of this check was no longer present. Given the serious potential consequences of this type of data entry error, it was considered important to inform Boeing 737 operators of this event (including operators of aircraft which are not 'Next Generation'). Therefore:

Safety Recommendation 2017-017

It is recommended that The Boeing Company promulgates to all 737 operators the information contained within this Special Bulletin and reminds them of previous similar occurrences reported in the Boeing 737 Flight Crew Operations Manual Bulletin dated December 2014.

Reporting accidents and serious incidents

The reporting requirements for accidents and serious incidents flow from provisions within Annex 13 to The Convention on International Civil Aviation (Chicago Convention), and are brought into UK law through Regulation (EU) 996/2010 and The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996.

Annex 13, Attachment C defines a serious incident as:

'involving circumstances indicating that there was a high probability of an accident.'

It gives a list of examples of serious incidents which includes:

> *'Gross failure to achieve predicted performance during take-off or initial climb.'*

This is mirrored in EU and UK regulations.

When informed of this event, the AAIB considered the worst credible outcome, had the event escalated, and the barriers which remained between the actual event and that outcome. It was considered that, in slightly different circumstances, this event could have resulted in the loss of the aircraft with multiple fatalities. Examples of such circumstances considered were: the same event taking place on a slightly shorter runway than was actually the case with the aircraft unable to lift off before the end of the runway; obstacles or terrain in the takeoff path; or engine failure just after V_1 with a decision by the commander to continue the takeoff. It was also considered that, once the thrust had been set for takeoff, there were no effective barriers in place to prevent the worst credible outcome above. This was because, once an incorrect thrust is set, there is no performance monitor which will highlight the error during the takeoff, and previous similar events suggest that pilots often do not notice the aircraft's slow acceleration and do not apply maximum thrust during the takeoff run. The seriousness of the potential outcome, and the lack of barriers remaining to prevent it had the event escalated, persuaded the AAIB that this was a significant event requiring an in-depth investigation.

The event was reported by air traffic control personnel at Belfast International Airport who filed an MOR and sent a signal using the AFTN. The AAIB has access to this system but only monitors it during working hours because it maintains a 24-hour reporting line as the primary means for reporting accidents and serious incidents. The fact that the AAIB became aware of this event only through the AFTN signal delayed its response by 58 hours and meant that some sources of recorded data from the aircraft were unavailable. This has been detrimental to the investigation and may hinder the identification of all the safety issues. It was considered necessary, therefore, to use this Special Bulletin to highlight reporting obligations within the UK for accidents and serious incidents.

Regulation (EU) 996/2010, Article 9, *Obligation to notify accidents and serious incidents* is directly applicable in the UK. It states:

> '*Any person involved who has knowledge of the occurrence of an accident or serious incident shall notify without delay the competent safety investigation authority of the State of Occurrence thereof.'*

The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996 states that, should an accident or serious incident occur:

> *'the relevant person and, in the case of an accident or a serious incident occurring on or adjacent to an aerodrome, the aerodrome authority shall forthwith give notice thereof to the Chief Inspector by the quickest means of communication available…'*

It goes on to define relevant person to mean:

> *'in the case of an accident or serious incident occurring in or over the United Kingdom or occurring elsewhere to an aircraft registered in the United Kingdom, the commander of the aircraft involved at the time of the accident or serious incident.'*

Civil Aviation Publication (CAP) 493, *The Manual of Air Traffic Services (MATS) Part 1,* contains in Section 6, Chapter 3 information on how Air Navigation Service Providers should meet their obligations to report accidents and serious incidents. Following an accident or serious incident at an aerodrome, the senior controller is required to telephone the Area Control Centre (ACC) Watch Manager and, subsequently, submit an MOR. On receiving a report of an accident or serious incident, the Operational Supervisor at an ACC is required to telephone the AAIB.

Further guidance on the AAIB website lists the people who must notify the AAIB without delay if they have knowledge of an aircraft accident or serious incident which occurred in the UK, a UK Overseas Territory or a Crown Dependency. These include the crew, and the owner and operator of the aircraft. In circumstances where there is doubt about whether or not an incident should be classified as serious, and therefore reported, the AAIB recommends that it is reported.

Further information is available at: https://www.gov.uk/guidance/report-an-aircraft-accident-or-serious-incident.

The AAIB 24-hour reporting line number is:

01252 512299

(+44 1252 512299 from outside the UK).

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