Farnborough House
Berkshire Copse Road
Aldershot, Hants GU11 2HH

Tel:01252 510300
www.aaib.gov.uk

AAIB
Air Accidents Investigation Branch

AAIB Bulletin S1/2024 *SPECIAL*

Serious Incident

Aircraft Type and Registration:	Boeing 737-8K5, G-FDZS	
No & Type of Engines:	2 CFM56-7B27/3 turbofan engines	
Year of Manufacture:	2009 (Serial no: 35147)	
Date & Time (UTC):	4 March 2024 at 1104 hrs	
Location:	On takeoff from Bristol Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 6	Passengers - 163
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None reported	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	14,500 hours (of which 4,500 were on type) Last 90 days - 220 hours Last 28 days - 81 hours	
Information Source:	AAIB Field Investigation	

Introduction

A Boeing 737-800 completed a takeoff from Runway 09 at Bristol Airport with insufficient thrust to meet regulated performance. The autothrottle (A/T) disengaged when the takeoff mode was selected, at the start of the takeoff roll, and subsequently the thrust manually set by the crew (84.5% N_1) was less than the required takeoff thrust (92.8% N_1). Neither pilot then noticed that the thrust was set incorrectly, and it was not picked up through the standard operating procedures (SOPs).

This Special Bulletin contains preliminary information on this serious incident, information for pilots and operators of the Boeing 737 Next Generation (737NG) about the A/T disengage occurrence in this event, and the actions the manufacturer expects crews to take should such a disengagement occur.

History of the flight

The aircraft was prepared for a flight from Bristol Airport to Las Palmas, Gran Canaria with six crew and 163 passengers. The flight was a line training sector for a new captain who was sitting in the left seat, with a training captain, acting as aircraft commander, sitting in the right seat.

Having completed their pre-flight preparation, the aircraft left the stand at Bristol to taxi to Runway 09 at 1041 hrs. The A/T arm switch on the Mode Control Panel (MCP) had been set to ARM during the before start procedures in accordance with the operator's SOPs. The aircraft taxied onto Runway 09 at 1104 hrs and was cleared for takeoff shortly afterwards. The left seat pilot handed control of the aircraft to the right seat pilot who was to be PF for the sector. The PF advanced the thrust levers to 40% N_1 and paused for the engines to stabilise before pressing the Takeoff/Go-Around switch (TOGA) which engages both the A/T in N_1 mode and the autopilot/flight director system (AFDS) in takeoff mode. At this point, the A/T disengaged with an associated warning and the A/T arm switch on the MCP was re-engaged by the PM almost immediately afterwards. At the same moment the PF advanced the thrust levers manually towards the required takeoff setting before releasing the thrust levers for the left seat occupant to control in accordance with the SOPs.

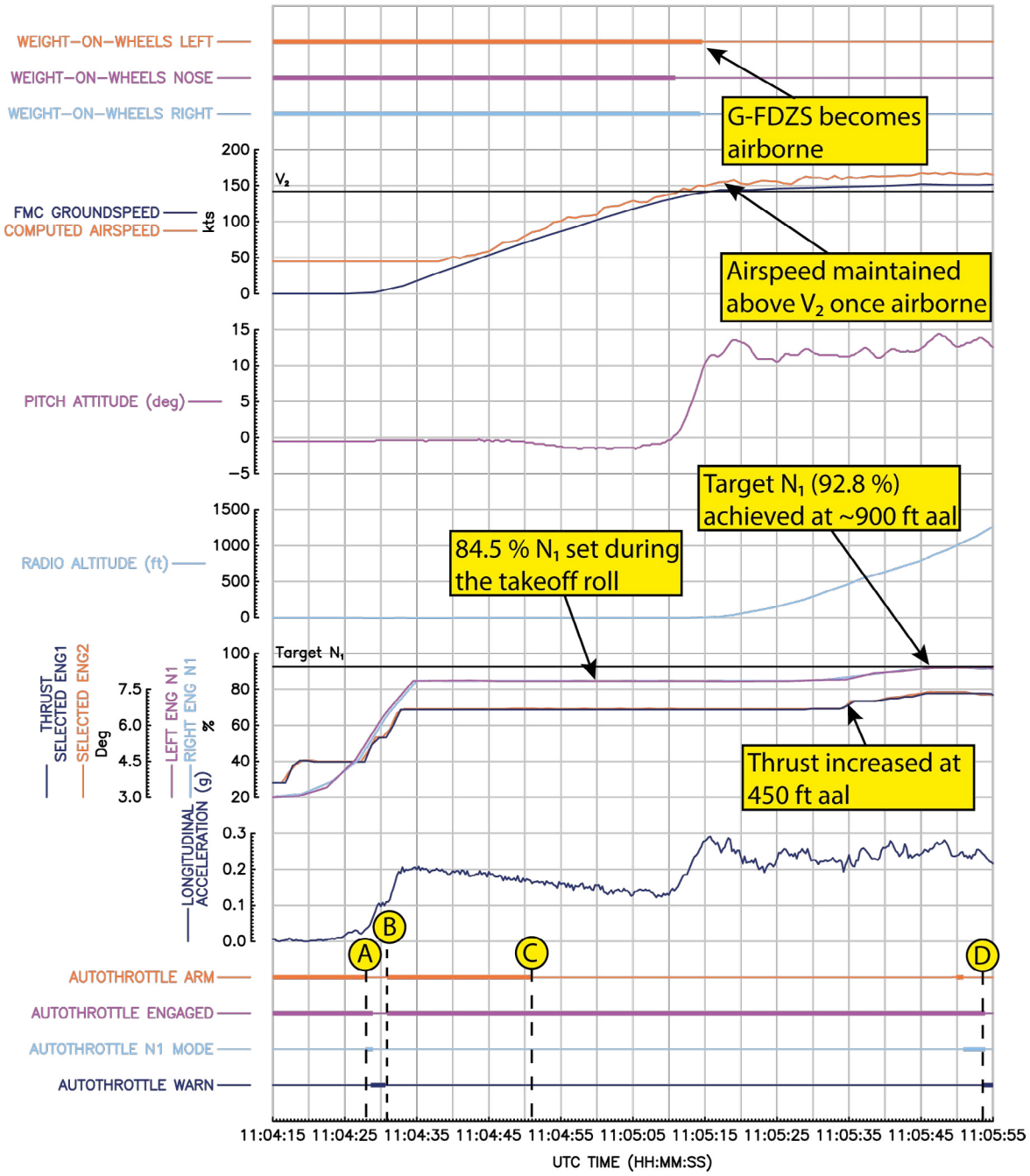
When the A/T arm switch was re-engaged on the MCP after initial A/T disengagement, it did not control the thrust lever servos as the pilots expected and instead entered an armed mode. As a result, the thrust levers did not advance to the required thrust setting and neither pilot moved them from the position the PF had set them to. Despite the SOP requiring that the thrust is set by 60 kt and checked as correct at 80 kt, the incorrect setting was missed by both pilots. This resulted in the aircraft takeoff being conducted with significantly less thrust than required, 84.5% N_1 was used instead of 92.8% N_1, with the associated reduction in aircraft performance.

The rotation point was 260 m from the end of the runway and the aircraft crossed the end of the runway at a height of approximately 10 ft. Both pilots had noted how close to the end of the runway they were. The flight to Las Palmas was uneventful apart from several attempts to re-engage the A/T and subsequent disengagements.

Recorded data

Flight recorders

G-FDZS was fitted with both an FDR and a CVR. The CVR fitted to G-FDZS was not removed from the aircraft as it continually overwrites itself, retaining only the last two hours of audio. As such, the recording of the takeoff would have been overwritten during the flight to Las Palmas. However, the FDR was removed and downloaded. Data from the FDR is shown below in Figure 1.



(A) A/T transitions from ARM to N1 mode on TOGA selection, disconnects almost immediately with a warning

(B) A/T re-armed within five seconds but no active mode selected

(C) A/T transistions to ARM HOLD mode, as per design, at 84 kt

(D) A/T transistions from ARM to N1 mode, but disconnects with a warning almost immediately (2nd uncommanded disconnect)

Figure 1

FDR data for the takeoff

The data shows that 84.5% N_1 was set for the takeoff instead of 92.8% N_1 and, although the thrust setting was increased from 450 ft aal, the required takeoff thrust setting was not attained until passing approximately 900 ft aal. As a result, G-FDZS became airborne 260 m from the end of Runway 09 and the runway end was overflown at a height of approximately 10 ft. Further, as the correct thrust setting was not set until passing approximately 900 ft aal, the A38 road, adjacent to the boundary of Bristol Airport, was overflown at less than 100 ft.

Multipurpose Control and Display Unit (MCDU) Fault data

The MCDU allows maintenance personnel to interrogate the health of several aircraft subsystems, including the A/T, and to investigate any logged faults. The fault history for the A/T, (Figure 2), shows that 11 faults were logged for the incident flight to Las Palmas - LEG 02 - but no faults were logged on the return flight to the UK, or on the preceding day.

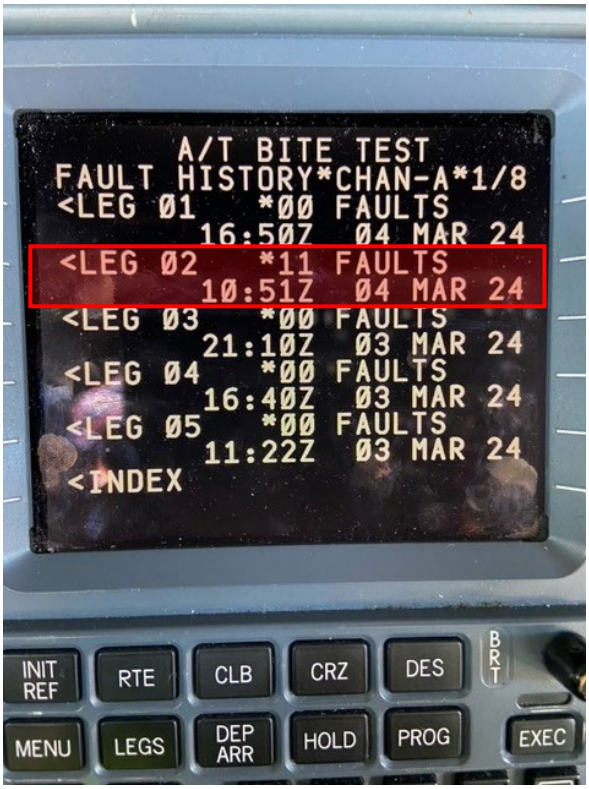


Figure 2

A/T fault history for the incident flight and the preceding day

Five of the 11 logged faults related to uncommanded A/T disconnections. The first of these fault records, is shown in Figure 3, and occurred at 1104 hrs when, from the FDR data, G-FDZS was on the runway at the beginning of the takeoff roll.

Figure 3

Detailed fault record for the initial uncommanded A/T disconnection, showing the suspected cause as ASM 1

The fault record indicates the suspected cause of the uncommanded A/T disconnection as ASM 1, the A/T servo motor for the number 1 engine throttle lever. A further four uncommanded A/T disconnections occurred during the flight to Las Palmas, two during the initial climb to altitude and two during the cruise. A series of other fault messages were logged, after the initial A/T disconnection, as G-FDZS accelerated for takeoff. These were generated passing 90 kt airspeed and all related to the mis-set thrust, indicating that the correct takeoff thrust had not yet been set.

Flight data monitoring (FDM)

The AAIB has investigated numerous other takeoff performance events and made several safety recommendations. One of these safety recommendations, Safety Recommendation 2022-019, relates to the use of FDM data to identify takeoff events that may otherwise go unnoticed and unreported.

Safety Recommendation 2022-019

It is recommended that the UK Civil Aviation Authority encourage all UK Air Operator Certificate holders to implement into their flight data monitoring programme algorithms to detect the precursors relevant to the monitoring of takeoff performance detailed in the European Operators Flight Data Monitoring Document, Guidance for the implementation of flight data monitoring precursors.

Although this event was reported, the operator conducted a retrospective analysis using a simple statistical measure of other 737 takeoffs from Bristol and produced the plot shown in Figure 4. The X-axis represents the peak longitudinal acceleration at around 80 kt groundspeed and the Y-axis the number of takeoffs that are represented by each bar. The incident takeoff is shown by the red arrow in Figure 4, far to the left of the bulk of the data, whereas for a normal distribution of data 99.7% of all takeoffs would be expected to lie within the region marked by the two vertical red lines.

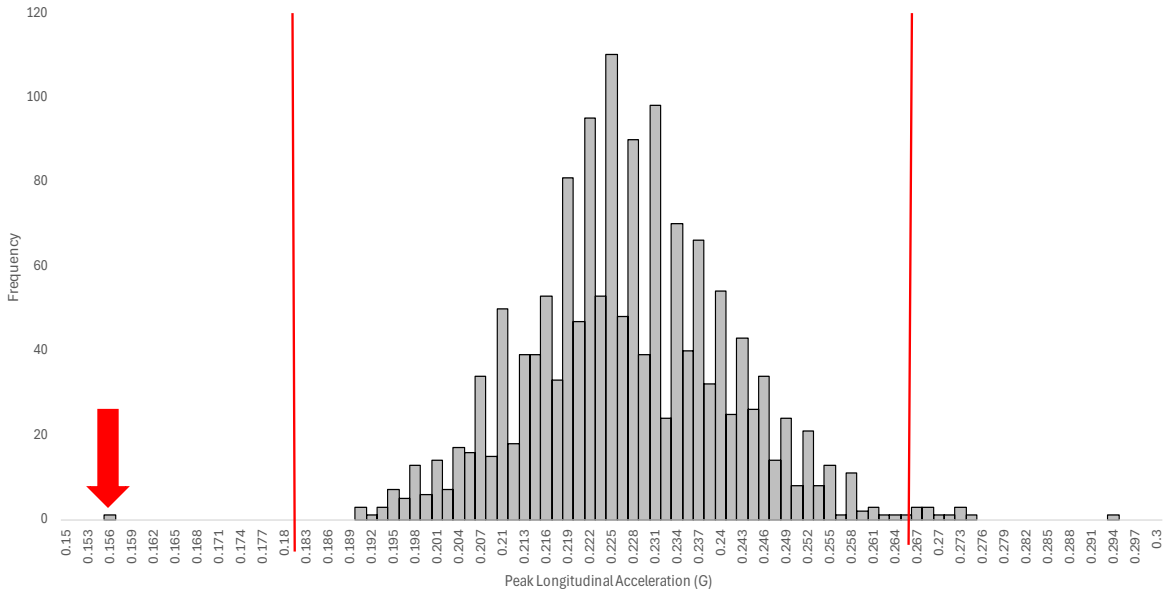


Figure 4

Histogram of 737 takeoffs at Bristol,
showing the normal spread of peak accelerations and the incident takeoff

Autothrottle system

The 737NG A/T system can control the thrust from takeoff to landing. Limiting N_1 values are normally provided by the FMC. Each thrust lever is moved with an independent autothrottle servo motor (ASM). The thrust levers can be moved manually or, if the A/T is engaged and active, the servo motors will position the thrust levers to comply with computed thrust requirements.

The A/T system is armed as part of the before start procedures after the performance figures have been entered into the FMC. Once the takeoff begins, the pilot advances the thrust levers manually to 40% N_1 and waits for the engine power to stabilise before pressing the TOGA switch. Pressing this switch moves the A/T from ARM mode to N_1 mode and the ASMs will automatically advance the thrust levers to the FMC takeoff thrust figure. At 84 kt IAS the A/T mode changes to throttle hold and the ASMs are isolated from the thrust levers. This is to prevent any uncommanded movement of the thrust levers during the rest of the takeoff roll and initial climb. The A/T returns to ARM mode at 800 ft above airfield elevation. The A/T becomes active again when the pilot selects N_1 mode at thrust reduction altitude to set climb thrust. The A/T will automatically disengage when a system fault is detected.

The manufacturer described the A/T system on the 737NG as having a long history of nuisance disconnects during takeoff mode engagements. When the fault history of the A/T is checked they often show fault messages for the autothrottle servo motor (ASM) for either throttle lever 1 or 2. Usually, subsequent functionality checks on the system find no faults. Investigations by the aircraft manufacturer together with the manufacturer of the ASM found that an earlier model of the motor was more susceptible to power on or power transfer events which can cause the ASM to shut down internally and cause a disconnect of the A/T when the TOGA switch is pressed.

A newer model of the ASM is more robust to the power quality issues associated with power on and power transfer events and the manufacturer recommends that any operators of the 737NG who are affected by these disconnects should retrofit their aircraft with the newer model of ASM and associated Flight Control Computer software. The manufacturer released a Fleet Team Digest in October 2021 detailing the issue and the available service bulletin (SB) for replacement. At the time of this event G-FDZS was fitted with the earlier model of ASMs.

Information for pilots

The manufacturer's Quick Reference Handbook (QRH) covers actions to be taken by the crew when there is an emergency or system failure on the aircraft. The QRH lists the reason that crew should reject the takeoff and this list includes system failure(s) as one of the reasons to reject below 80 kt. The manufacturer includes the disconnection of the A/T when the TOGA switch is pressed as a systems failure and expects the crews to stop as a result. This allows the crew time to assess the failure and decide on their actions rather than potentially continuing the takeoff roll without a functional A/T system. The crew in this event continued their takeoff using manual thrust, at a setting below that calculated for takeoff performance.

The Flight Crew Training Manual (FCTM) applicable to the 737NG and 737 MAX contains details on the operation of the aircraft type. The section on takeoff details the actions the crew should take when using derated or reduced thrust for takeoff if additional thrust is required to complete the takeoff after V_1. With both reduced thrust and derated thrust, the FCTM recommends the selection of full rated thrust if required after V_1. This was a change introduced in 2022 to the previous policy which suggested that crews should increase thrust no more than the full derated thrust setting.

It is well known that humans are poor at detecting acceleration rates and recognising that their takeoff run is not matching the calculated performance. Performance issues can be insidious and invisible to the crew until very late in the takeoff roll. A previous report from the AAIB covered the reasons for this in detail[1]. However, it is very unlikely that any crew will recognise there is an issue until they approach the end of the runway, and few crews then select an increase in power to try and mitigate their performance issues.

Footnote

[1] https://www.gov.uk/aaib-reports/aircraft-accident-report-aar-2-2018-c-fwgh-21july-2017 [Accessed April 2024].

Analysis

The aircraft took off from Runway 09 with a thrust setting significantly below that required to achieve the correct takeoff performance. Rotation for the takeoff occurred only 260 m before the end of the runway and the aircraft passed over the end at a height of approximately 10 ft. The N_1 required to achieve the required takeoff performance was 92.8% but, following an A/T disconnect when the crew selected TOGA, 84.5% was manually set instead. Despite an SOP requirement to check the thrust setting on takeoff, the crew did not realise that the thrust was not set correctly until after the takeoff although they had noted how close to the end of the runway they were.

The A/T had disconnected when the TOGA switch was pressed due to a fault with the ASM associated with the thrust lever for engine 1. This disconnect was a known issue with the older type ASMs fitted to the aircraft type. The manufacturer has issued a Fleet Team Digest for operators detailing the issue and the SB for replacing the ASMs with a newer model.

Further investigation

The investigation continues to examine all pertinent factors associated with this serious incident and a final report will be issued in due course.

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