AAIB
Air Accidents Investigation Branch

AAIB Bulletin 1/2025

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AAIB Field Investigation Reports

A Field Investigation is an independent investigation in which AAIB investigators collect, record and analyse evidence.

The process may include, attending the scene of the accident or serious incident; interviewing witnesses; reviewing documents, procedures and practices; examining aircraft wreckage or components; and analysing recorded data.

The investigation, which can take a number of months to complete, will conclude with a published report.

Serious Incident

Aircraft Type and Registration:	ATR 72-202, G-NPTF
No & Type of Engines:	2 Pratt & Whitney Canada PW121 turboprop engines
Year of Manufacture:	1990 (Serial no: 192)
Date & Time (UTC):	7 March 2023 at 0138 hrs
Location:	Belfast International Airport
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None reported
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	45 years
Commander's Flying Experience:	6,750 hours (of which 92 were on type) Last 90 days - 65 hours Last 28 days - 25 hours
Information Source:	AAIB Field Investigation

Synopsis

During the flare to landing at Belfast International Airport the co-pilot, who was PF, discovered that the rudder was extremely difficult to move. The commander immediately took control of the aircraft and used the nosewheel steering for directional control on the runway. Examination of the aircraft on the following day showed that the rudder was almost immoveable from either set of rudder pedals in the cockpit or by physically pressing on the rudder outside the aircraft.

A number of faults with the rudder control system were uncovered during the investigation but the major cause of the extreme rudder stiffness was the degradation of the steel rudder rear quadrant support bearings due to corrosion. The sealed nature of the bearings and their installed location precluded visual inspection of their condition. Moisture ingress in the vicinity of the bearings had likely contributed to their degraded condition. The installation of the rudder damper may also have contributed to the rudder stiffness, albeit to a lesser extent.

A Service Bulletin which recommended replacement of all flight control bearings with corrosion-resistant stainless steel bearings had not been embodied on the aircraft.

The operator took actions to ensure the continued airworthiness of its ATR fleet. The manufacturer also took, or has committed to taking, a number of safety actions to address issues identified during the investigation. These include updating the Illustrated Parts Data for some flight control bearings to specify stainless steel equivalents as the preferred part number, updating troubleshooting guidance and publishing a communication to remind operators of the existing recommended Service Bulletin.

History of the flight

The flight crew reported for duty at 2320 hrs on 6 March 2023 to fly G-NPTF from East Midlands Airport to Belfast International Airport. The aircraft had been flown into East Midlands by another crew arriving at 2035 hrs. Having completed their pre-flight preparations and with the cargo loaded, the aircraft engines were started. The aircraft departed the stand at 0024 hrs on 7 March 2023. The aircraft checklist required the flight crew to complete a full and free movement check of the controls. During this check both the commander and the co-pilot commented that the rudder seemed to be very stiff to move. The co-pilot noted that the rudder seemed stiffer than the other aircraft in the fleet that he had flown. There was then a discussion about whether to continue with the flight, which included a conversation about the likely crosswind at the destination. They concluded that since both crew members could move the rudder (albeit with significant effort), and that the crosswind was very slight, they would continue with the flight.

The flight to Belfast was uneventful with cloud and icing encountered during the climb for around 15 minutes before the aircraft emerged into clear skies. The weather in Belfast was CAVOK with light winds. The co-pilot flew an ILS approach to Runway 25, disconnecting the autopilot at 700 ft aal. The co-pilot reported that as he flared the aircraft for landing, what little wind there was started to cause the aircraft to drift very slightly to the left of the centreline. He attempted to apply rudder to stop the drift but found the rudder pedals almost impossible to move. Having realised there was a problem, the commander immediately took control and placed the aircraft on the ground, rapidly de-rotating the nosewheel to allow him to use the nosewheel steering.

Once the aircraft was safely at taxi speed, both pilots tried the rudder pedals and described them as barely moving. At 0141 hrs the aircraft arrived at the parking stand, where it was shut down and the cargo was unloaded. Once the unloading was complete, the aircraft was moved to a remote stand. At this point the flight crew found the rudder pedals would not move at all.

Relevant checklist items

The flight crew were required to check the rudder for full and free movement as it was part of the flight controls check item on the before takeoff checklist. The Flight Crew Operations Manual (FCOM) for the ATR 72-200/210 requires the occupant of the left seat to '*move the rudder pedals to full travel in both directions and verify freedom of movement.*' The check is the final opportunity to identify a possible problem with the flight controls before the takeoff begins.

In flight the FCOM, which is applicable for G-NPTF, contains an Abnormal Procedure for use when the crew detects a rudder jam.

▶ DIFFERENTIAL POWER.................................. USE TO MINIMIZE SIDESLIP
● For approach
▶ STEEP SLOPE APPROACH (≥ 4.5 °) : PROHIBITED
▶ LAND AT AIRPORT WITH MINIMUM CROSSWIND
▶FLA
PS...30
● At touchdown before power reduction below FI
▶NOSE..DOWN

With the aircraft in the flare when the crew identified there was a problem with the rudder, the applicable checklist item is to put the nose down in order to be able to use the nosewheel steering for control of the yaw.

Meteorology

On the night of 6/7 March 2023 there was a cold front in the area of East Midlands Airport. The temperature was around 3°C during the period G-NPTF was on the ground and there was no precipitation shown on the METARs. The aircraft would have entered cloud after takeoff between 4,000 and 5,000 ft amsl. It would then have climbed through layers of cloud up to 18,000 ft amsl. These layers of cloud would have presented a moderate risk of icing. As the aircraft flew north of the Isle of Man it would have entered clear conditions which remained for the approach and landing at Belfast International Airport.

Conditions at Belfast were good with no cloud detected and a light north-westerly wind (less than 5 kt). The temperature was -2°C when the aircraft landed and remained below freezing until around 1000 hrs. It returned to below freezing overnight on 7/8 March 2023.

The aircraft was parked in Guernsey from 4 March 2023 to 6 March 2023, when it flew to East Midlands ready for the flight on which the event occurred. The temperature during this period had been around 5°C with some rain showers reported.

Airfield information

The aircraft landed on Runway 25 with the wind given to the crew when they were cleared to land as 320 at 5 kt. This gave a crosswind component of less than 5 kt.

Recorded information

Recordings from the aircraft's flight data and cockpit voice recorders were downloaded and analysed. The CVR recording corroborated the crew's recollections of the event. The FDR data, however, was unhelpful as there was no recording of forces detected by the force detector rod linked to the rudder pedals (see *Aircraft description* section). For 200 series ATR 42s and 72s manufactured since 2008, there is an option to record rudder pedal and other control forces. For all 600 series ATRs, these control forces are recorded as standard.

Aircraft description

The ATR 72-202 is a twin-engine turboprop, short-haul regional airliner.

Rudder and rudder control

Yaw control on the ATR 72 is achieved by a mechanically-actuated rudder linkage system, composed of quadrants, bellcranks, pulleys, rods and cables (Figure 1). Pilot inputs are made via two sets of rudder pedals in the flight deck. The rudder pedals are linked to a force detector rod which produces movement of the forward quadrant. A cable loop, which runs under the flight deck floor, vertically up behind the flight deck, above the cabin compartment ceiling panels and through the rear pressure bulkhead, links the forward and rear rudder quadrants.

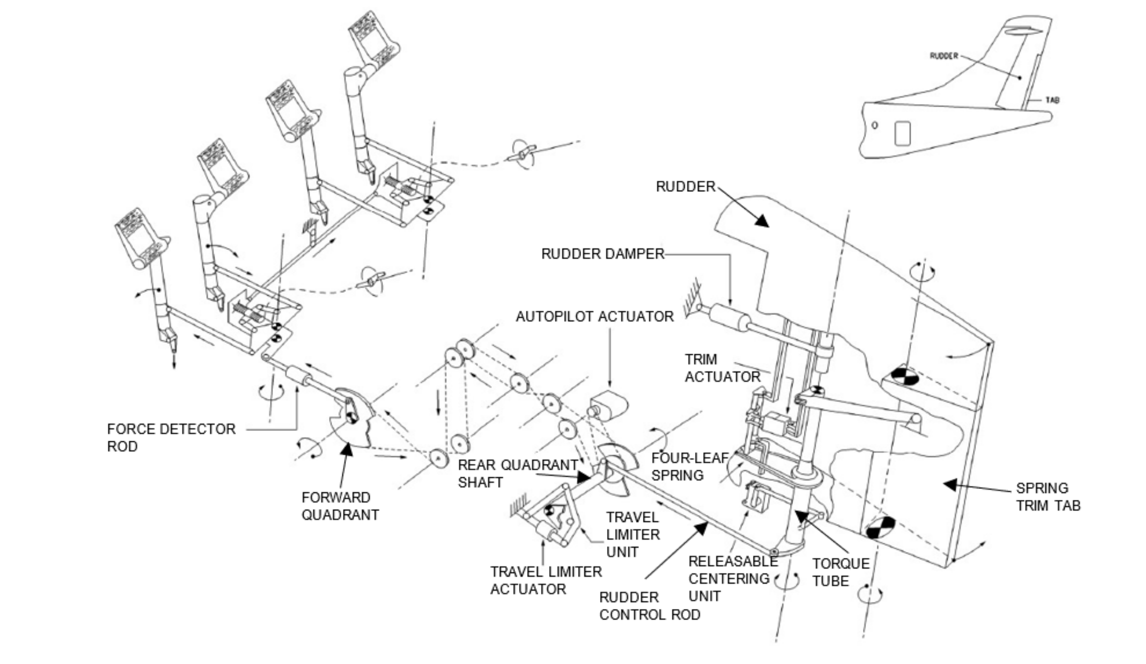


Figure 1

High-level schematic of ATR 72 rudder control system
(image modified and used with permission)

The linear movement of the cable loop drives a bellcrank mounted on the rear quadrant shaft, to rotate the shaft (Figure 2). Shaft rotation produces linear movement of the rudder control rod, which runs between a lever mounted on the rear quadrant shaft and the bottom pivot at the base of the rudder torque tube. Movement of the rudder torque tube acts directly on the spring trim tab, and via a four-leaf spring, on the rudder itself.

Autopilot yaw commands are transmitted to a yaw damper actuator (or autopilot actuator), which is connected to the rear quadrant by means of a short cable loop and a separate bellcrank mounted on the shaft. This rotates the shaft in the same way as the pedal bellcrank, to generate movement of the rudder surface.

The force detector rod linked to the pedals includes a microswitch which changes state when a 30 daN load is applied to the rudder pedals. This causes the yaw damper function, and consequently the autopilot, to disengage.

The yaw control system also contains a Travel Limitation Unit (TLU), a Releasable Centering (sic) Unit (RCU), a rudder damper and a trim system. The TLU mechanically limits rudder deflection to ensure that the rudder is not damaged by large inputs when the aircraft is flying at high speeds. The TLU system includes an electrical actuator, two v-shaped cams mounted on the rear quadrant shaft, and two rollers mounted on a pivoting bracket, which moves in response to actuator extension and retraction.

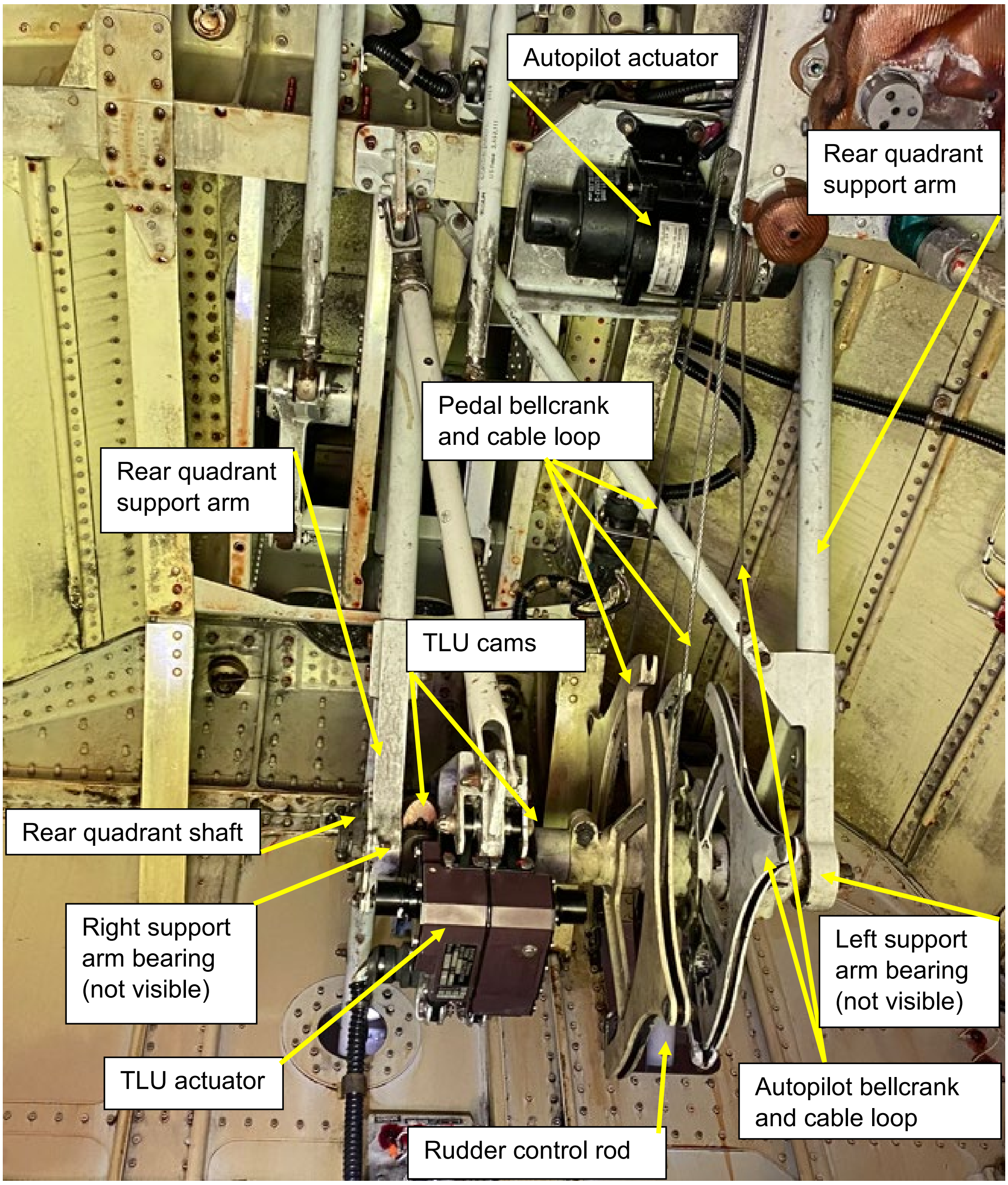


Figure 2

G-NPTF's rudder rear quadrant (view looking aft)

The RCU is installed in the tail cone, between the rudder and the linkage to the pilot pedals. It stabilises the rudder position when no action is applied on the pedals. This device is automatically centred on the linkage position every time a trim control command is applied and is inhibited when the yaw damper is active.

The rudder is linked to the aircraft structure by a rudder damper. This limits rudder travel speed when the aircraft is airborne and, when the aircraft is on the ground, it damps excessive rudder movement in response to wind gusts, preventing damage to the structural stops. When the aircraft is on the ground, the rudder is unrestrained and should move downwind with the trim tab in line with the rudder.

Yaw trim control is electrically controlled by the pilots using a control on the centre console. Use of the trim offsets the zero position of the trim tab on the rudder.

The rudder is hinged on the vertical stabiliser rear spar by means of four hinges (pivot points).

Initial aircraft examination

Initial examination of the aircraft in Belfast showed that the rudder was extremely difficult to move either using the rudder pedals or by hand on the rudder surface. The rudder pedals did not return to neutral after being displaced and the rudder did not appear to move in response to external wind inputs.

The rear bay, directly underneath the vertical stabiliser, and in which the rudder rear quadrant is located, appeared dry and there was no evidence of moisture or ice accumulation. The internal surfaces of the rear bay, rear quadrant shaft support structure and bellcranks were dirty, with a light film of old grease/dirt (Figure 2).

The rear quadrant shaft appeared to rotate in response to pedal inputs but there was a rubbing noise evident during parts of the quadrant's travel. The rudder pedal cable was observed to be rubbing against the right hand cable guide of the pedal bellcrank, but this did not appear to be the source of the noise.

The rudder control rod was disconnected at the rear quadrant shaft to isolate the 'command' side (rudder pedal circuit) of the system from the 'actuation' side (rudder circuit aft of the rear quadrant). In this configuration, considerable stiffness remained within the pedal circuit. While some stiffness remained in the rudder circuit, it appeared to be less than before.

The rudder pedal circuit pulleys and cables were inspected and found to be clean and free from debris, but there was no evidence of recent lubrication. The autopilot and rudder pedal cable tensions were checked and were within, or very close to, the normal range.

Detailed aircraft examination

After several days parked outside, the aircraft was moved to a hangar to allow a more detailed examination, with assistance of flight control and structural specialists from the aircraft manufacturer.

Command/rudder pedal circuit

When the rear bay door was opened a large volume of water which had been trapped above the door fell on the hangar floor. The entire bay was wet, with condensation present on all surfaces, including the rear quadrant shaft. Although a drain hole was located on the forward edge of the door moisture had accumulated in this area, indicating that the drain hole was not providing effective drainage.

The rudder pedals remained very difficult to move. Although not representative of normal rudder pedal operation, the force required to move the pedals by hand was measured using a hand-held dynamometer. A maximum of 97.7 lbf (43.4 daN) was measured, but it was not possible to achieve full pedal travel in this way.

With both sides of the rudder system isolated by disconnecting the rudder control rod at the rear quadrant shaft, the rudder pedals still did not move freely. The rubbing noise remained evident when the rudder rear quadrant shaft was operated and some dark coloured debris was noted at the left rear quadrant shaft support bearing.

The rudder pedal and autopilot yaw cables were disconnected from their respective bellcranks to remove any tension from the shaft. It was then possible to operate the rudder pedal cables freely using only finger pressure and the rudder pedals moved freely in response. This confirmed that the friction originated at the rear quadrant shaft.

Actuation/rudder circuit

The aircraft's tail cone was removed to allow inspection of the rudder torque tube. Moisture was present at the bottom of the torque tube and on the lower parts of the bulkhead. In places, the pooled moisture was clear and jelly-like in consistency. The sealant on the torque tube bottom pivot was broken in places, and it was softened or dis-bonded in others.

Some light resistance was detected by the flight controls specialist when attempting to manually move the rudder from the bottom of the torque tube, which was not particularly obvious to others in the investigation team; ordinarily the rudder should move freely. In order to remove any friction from other bearings in the system and assess rudder movement, the rudder control rod was completely disconnected from the torque tube, RCU arm and the bottom pivot. The light resistance was still evident when manually moving the rudder.

A subsequent torque check of rudder damper attachment bolts revealed that the torque on the forward attachment bolt (vertical stabiliser side) was within limits (allowable 8-10 daNm). However, the aft attachment bolt (rudder side) had been over-torqued and required more than 10 daNm to loosen it (allowable 4 – 6 daNm). When the bolt was removed, moisture was present on the bolt shank and within the attachment lugs and the bushing was seized to the bolt. There was no evidence of grease present at either attachment.

Having disconnected the rudder damper, the rudder then moved completely freely, without any resistance. The rudder continued to move freely when the RCU arm was reconnected and the RCU appeared to operate correctly to centre the rudder. This indicated that the rudder damper installation had also contributed to stiffness within the rudder circuit.

Examination of the four rudder pivot points showed some evidence of fresh grease (green/blue colour) on the grease nipples. However, only small amounts of fresh grease were present within the joints at the pivot points, with most of the grease being brown/red in colour and thick and lumpy in appearance. Moisture was present at all the pivot points, including on the surface of the grease. The gaps at the rudder pivot point locations were checked and found to be within limits.

External visual examination of the vertical stabiliser showed that sealant was absent at several locations on the top rib, which may have provided a path for moisture ingress to the rear bay.

Rear quadrant shaft

The rear quadrant shaft and its support bearings were removed, with some difficulty, for further examination. There was evidence of light distress on the left and right bearing surfaces on the rear quadrant shaft. The inner face of the right cable guide on the rudder pedal bellcrank displayed cable contact marks. There was evidence that the right TLU cam had been fouling against mounting bracket for the TLU actuator, and an adjacent conical washer appeared to be seized to the shaft.

The left support arm bearing was intact and could not initially be rotated. Later it could be rotated but was rough to turn. Some mechanical damage was evident on one face of the bearing which was probably caused during removal. The right support arm bearing was intact and was also rough to turn. The installed components on the rear quadrant were dirty; the side walls of both bearings were dirty and caked with a mixture of old grease and dirt.

Rudder rear quadrant support bearings

Both rudder rear quadrant support bearings, manufactured by Fafnir, were self-aligning bearings, although each bearing achieved this in a different way. Bearing No 1, was a conventional KSP10 self-aligning bearing with a grooved inner race and a spherical outer race, to allow for shaft misalignment. This type of bearing can self-align during service to accommodate movement of the shaft axis.

By contrast, self-alignment in bearing No 2, a KP16BS, was provided by an external self-aligning ring which had an internal spherically ground surface matched to the external spherically ground surface of the outer race. This type of bearing is designed to compensate for initial misalignment during installation.

The raceways and balls of both bearings were made from 52100 grade steel which does not have significant corrosion resistance. The exposed surfaces, the bore, cap and seals were cadmium-plated.

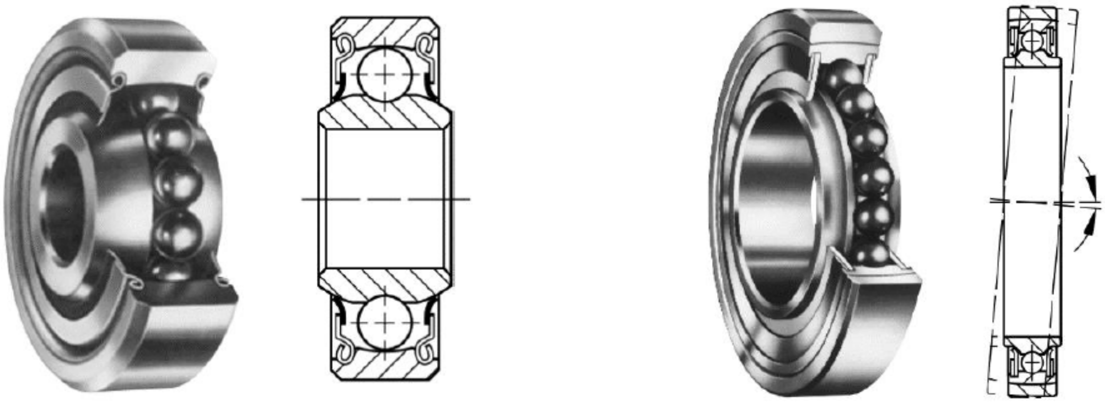


Figure 3

Original production standard rear quadrant shaft support bearings fitted to G-NPTF

Metallurgical examination of rudder rear quadrant support bearings

Visual examination

Bearing No 1 from the left support arm felt rough during rotation, while bearing No 2 from the right support arm was completely seized.

Deformation and scoring was present on the retaining ring of the seal on bearing No 1. This mechanical damage, which was fresh and consistent with contact from a hard object such as a tool. This likely occurred during removal of the bearing from the support arm, as the engineers encountered difficulty removing it. The bearing contained a full complement of balls, with balls and raceways appearing well greased.

Bearing No 2 displayed corrosion and a brown deposit on the outer surface. It contained a full complement of balls which appeared to be extensively corroded. No grease was present, although there was a thick brown deposit throughout, which appeared to be a combination of corrosion product and dried grease residue (Figure 4).

Figure 4

Rear quadrant support arm bearings from G-NPTF

After cleaning, visual examination of the inner surfaces of bearing No1 showed axial marks consistent with the ball positions and circumferential marks around the approximate mid-point of the outer race (Figure 5).

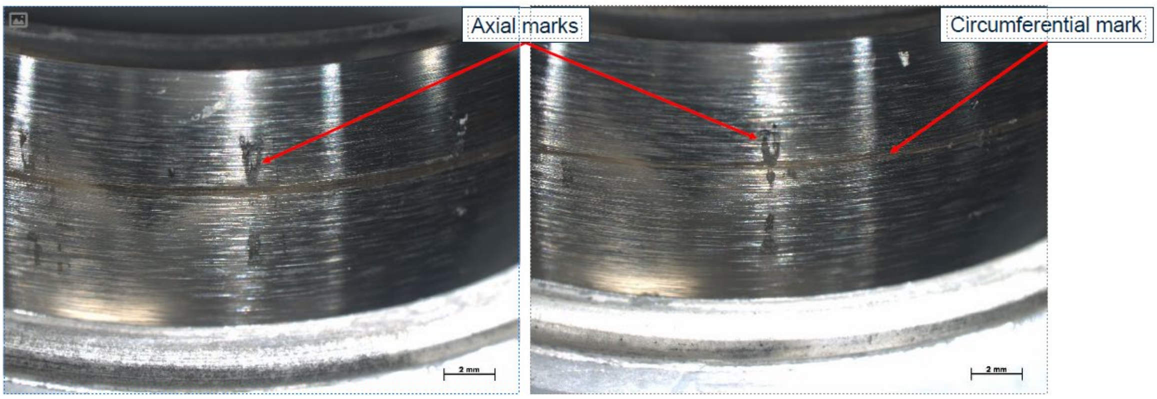


Figure 5

Bearing No 1 axial and circumferential marks

Axial misalignment, measured at 2.9°, was noted between the outer ring and outer race of the bearing No 2 (Figure 6).

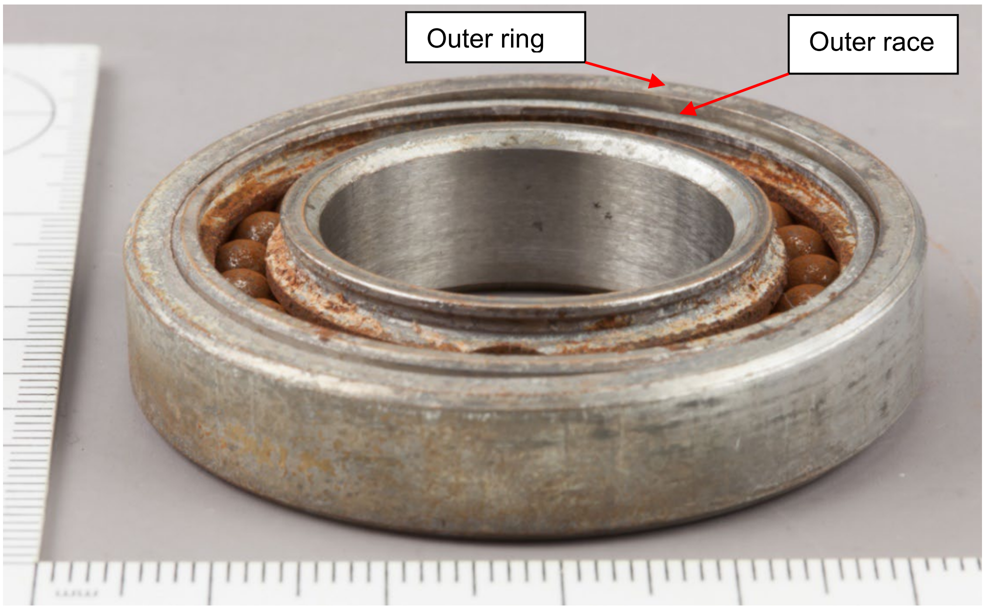


Figure 6
Bearing No 2 misalignment

After cleaning, extensive corrosion pitting was evident on the inner and outer bearing races and balls of bearing No 2 (Figure 7).

Figure 7
Bearing No 2 corrosion and pitting (outer race shown, inner similar)

Detailed examination

Examination of the bearing No 1 outer race in the scanning electron microscope (SEM) showed that the axial marks had resulted from a combination of corrosion and sliding in the axial direction. The track of circumferential marks had resulted from a combination of corrosion and wear. Within this track was a line where the machining marks on the outer race had been polished flat. This was considered consistent with the type of wear that occurs with in-service bearings. However, within this track, patches of corrosion were also observed, which is not typical. The corrosion is likely to have contributed to the rough running of the bearing.

Axial wear marks were observed at evenly spaced positions around both the inner and outer races of bearing No 1. The marks appeared to be the result of axial sliding of the balls. On the outer race, the axial wear coincided with corrosion damage. Corrosion damage was not observed at the axial marks on the inner race.

The spacing between the corrosion/axial marks was consistent with the ball spacing suggesting that the corrosion had occurred while the balls had been stationary for some time. The axial sliding damage had also occurred at fixed positions indicating that relative axial movement between the inner and outer races had occurred while the bearing was not rotating. It is possible that this axial damage occurred during removal of the bearing from the support arm.

Energy dispersive X-ray analysis of metallic swarf retrieved from left support arm adjacent to bearing No 1 identified it as aluminium alloy. Debris on the swarf contained multiple elements consistent with the corrosion deposit of a cadmium-plated steel component, such as would result from the corrosion of the steel bearings, which had cadmium plating on the exposed surfaces. The source of the aluminium swarf was not identified, but the left support arm was not examined by the laboratory.

Bearing No 2 was not examined in the SEM because of the extensive pitting corrosion that was observed during the visual examination.

Rudder rear quadrant examination

The rear quadrant shaft from G-NPTF was mounted in a test rig, using donor support bearings so that it could be rotated.[1] The findings from the aircraft examination were confirmed and in addition the following observations were made.

Closer examination of fouling/interference between one of the TLU cams and the TLU support arm revealed that while there was some paint loss on the TLU support arm, there was no damage to the underlying metal. The TLU support arm bearing felt somewhat rough to turn and had migrated slightly from its housing, probably contributing to the interaction with the adjacent TLU cam.

The rollers on the TLU pivoting bracket were seized and there were visual indications that the rollers had not turned for some time. Minor damage was also observed on the TLU actuator attachment points. Despite these observations, when a donor TLU actuator was installed and electrically powered, it functioned as expected to locate the rollers in the TLU cams. However, the test conditions were not fully representative of the installed aircraft configuration, because the shaft was isolated from the rudder linkage and therefore was not loaded.

Footnote

[1] The donor bearings were from aircraft serial number 98, which had the same original production standard steel bearings as G-NPTF. These bearings were in good condition and turned freely.

The rear quadrant shaft was disassembled and a dimensional check performed on all parts. Comparison with production drawings revealed no dimensional anomalies.

Based on the observed condition, the rear quadrant shaft and its associated components were declared unserviceable by ATR.

Aircraft maintenance history

G-NPTF was built in 1990 and entered service as a passenger aircraft. It was converted to its present cargo configuration in 2014. It had been in service with the operator since 28 May 2022, having previously been operated on the Spanish register by another organisation in the same group as the operator[2]. During its service with the previous operator there were no periods of long-term parking or storage. At the time of the occurrence G-NPTF was the third oldest ATR 72 in operation in the global fleet.

Previous reports of rudder stiffness on G-NPTF

Some of the operator's ATR pilots said that G-NPTF was known to have a much stiffer rudder than the other ATRs on the fleet. The rudder had been reported in the technical log on three previous occasions. These reports and the rectification action taken are shown in Table 1:

Date of entry	Wording of technical log entry	Rectification action
4 February 2023	Rudder is significantly harder to move than any other fleet ATR.	Operational test of rudder control and spring tab – all found to be operating as expected. Rudder damper fluid level checked and found to be in accordance with requirements. Rudder cable runs checked and found to be satisfactory.
7 February 2023	Rudder unusually heavy. Significant pressure required to move.	Rudder damper replaced.
9 February 2023	Left rudder pedal input on finals almost impossible to move. Tried from left and right side. Can be moved on ground but still rather stiff.	Aircraft on ground for 10 days while extensive maintenance troubleshooting performed TLU, rudder damper and RCU replaced. Substantial troubleshooting input from ATR.

Table 1

Previous G-NPTF technical log report and rectification action

Footnote

2 The aircraft was operated by the previous operator between June 2009 and 1 June 2011 and from 17 August 2012 until it left the fleet in 2022.

The rudder stiffness report on 9 February 2023 was reported to the AAIB, which monitored correspondence relating to the maintenance troubleshooting performed but did not open an investigation.

The troubleshooting and rectification work was undertaken at a maintenance facility in Guernsey. Various operational tests were performed including tests of the RCU and TLU; both units were replaced as a result. During a check of the rudder damper (which had been replaced two days previously) the engineer noted different stiffness in the rudder control between when the rudder damper was connected and disconnected. The rudder damper was therefore replaced once again, after which the engineer perceived that the rudder stiffness appeared to be reduced compared to the initial finding on 10 February 2023 but could still be considered more stiff (ie the rudder pedals were "heavier") than on other aircraft he had maintained. The worksheet relating to the replacement of the rudder damper correctly noted the applicable torque range for the forward and aft attachment points.

The operator contacted the manufacturer for assistance on 14 February 2023 asking for additional information to allow it to assess whether the perceived heavier feel of the rudder pedals was considered within an acceptable tolerance for aircraft operation or whether it could be indicative of an underlying problem.

The troubleshooting recommendations provided by ATR detailed various rudder system functional tests and visual inspections, amongst which were visual inspections of the rudder mechanical control[3] and the rudder control cables[4]. Both inspections require the flight crew seats to be removed for access.

The rudder mechanical control visual inspection states: '*To correctly examine the mechanical parts, operate the rudder controls from stop to stop…Do a visual check of the rudder control mechanical-parts-assembly: rudder pedals, rods, torque shaft, bellcranks. Make sure that assembly shows no signs of corrosion, cracks or defects in surface protection (flaked paint).*'

The rudder control cable circuit visual inspection includes the instruction: '*To fully examine cables, pulleys, quadrants and regulators, operate rudder pedals from stop to stop.*'

In correspondence relating to the troubleshooting, the maintenance engineer performing the rudder mechanical control and rudder cable visual inspections reported that no faults were evident.

The troubleshooting guidance and visual inspections did not specifically mention the rudder rear quadrant shaft or its support bearings.

ATR also recommended isolating the command and actuation sides of the rudder control system and performing a full rudder travel, first with the rudder pedals and then manually to identify which side of the system the stiffness originated from. The maintenance engineer reported that the rudder could be moved by hand and that the rudder pedals had no resistance.

Footnote

[3] AMM Task MP ATR-A-27-21-XX-00001-281A-A.
[4] AMM Task MP ATR-A-27-21-XX-01001-281A-A.

G-NPTF rudder pivot point lubrication

The ATR 72 maintenance program requires that lubrication of the flight control pivot points (including the rudder and rudder tab hinge points) is performed every 3,000 flight hours. ATR maintains a Consumable Material Data (CMD) document which lists all consumable products (including fuels, oils, grease etc) approved for use on ATR aircraft. It includes applicable material specifications, usage notes and approved alternatives.

Maintenance records were reviewed for the previous four flight control lubrication tasks performed on G-NPTF. These were carried out in March 2018, March 2019, May 2020 and November 2021 at third party maintenance providers in Bulgaria and Hungary. The grease used alternated between Mobil Aviation Grease SHC-100 (CMD item 04-004C) in March 2018 and May 2020, and Aeroshell Grease 33 (CMD item 04-024A) in March 2019 and November 2021. SHC-100 is red in colour while Aeroshell 33 is green/blue. The grease observed on the G-NPTF rudder pivot points following the occurrence was visually consistent with a mixture these two grease products[5].

Of the two types of grease used on G-NPTF, only Aeroshell 33 was intended for use on flight control pivot points.

Similar products are grouped together within the CMD. When a new item is added it is given a five-digit item reference eg 04-004. When a similar, but not identical or interchangeable, product is added to the CMD, the original five-digit reference is retained but emptied. The initial product is transferred to a new reference based on the five digits but with an 'A' suffix eg 04-004A. The new product is created with the same five-digit reference but with a 'B' suffix eg 04-004B etc.

As the CMD evolved over time, AMM job instruction cards (JICs) which called up consumable items were not amended to take account that the original reference no longer referred to the expected consumable. Prior to January 2020, the AMM JIC for ATR 72 AMM task ATR-A-12-22-27-00001-240A-A *'Lubrication of flight controls pivot points'* called for consumable item 04-004. In the CMD there are three consumables with a 04-004* reference, including item 04-004C - SHC-100.

Separately, due to a historic absence of written guidance on how to interpret the CMD, there was an assumption within ATR and externally that items with a number-only reference referred to a family of consumables and therefore any product based on that number could be used interchangeably. For example, it was assumed that if item 04-004 was called up then any item with a 04-004* reference could be used. This was not the intention.

ATR identified this issue and in January 2020 the JICs for AMM task ATR-A-12-22-27-00001-240A-A were updated to reflect the correct and originally intended consumable: item 04-004A -MIL-G-23827 Type 1 grease (for which Aeroshell 33, item 04-024A was an approved replacement item).

Footnote

5 Samples of grease were collected from the rudder pivot points but the small sample sizes and the fact that more than one grease type was present would have prevented full analysis of the lubrication properties or conformance to specification. Therefore, the samples were not subjected to detailed laboratory analysis.

In the CMD usage notes for items 04-004A and 04-024A, it states that in the case where a replacement grease product was used, the two types of grease should not be mixed, the old grease should be completely purged by the new grease and the servicing interval should be temporarily reduced, for instance by half, for around 3 to 4 services. There is no evidence that this was done on G-NPTF.

Following this occurrence, the operator fully purged and regreased all the flight control pivot points on G-NPTF and its other ATR 72s, to reset the flight control lubrication status in accordance with best practice. Additionally, it instructed the organisation which provides its continuing airworthiness management organisation function to specify Aeroshell 33 as the only grease to be used for lubrication of the flight control pivot points.

Aircraft maintenance procedures

Rear quadrant shaft

At the time of the occurrence there were no prescribed maintenance procedures or inspections specifically relating to the bearings on the rear quadrant shaft. The area is subject to general visual zonal inspections and a scheduled detailed visual inspection of the rudder control cable circuit is required to be performed every eight years[6]. This is the same visual inspection of the rudder control cable circuit performed during the troubleshooting following the 9 February 2023 report of rudder stiffness. Prior to that, it was most recently performed on G-NPTF as routine inspection on 9 February 2022, one year before the first crew reports of rudder stiffness. A review of the associated maintenance workpack for that inspection did not reveal any defects or discrepancies.

The manufacturer stated an expectation that this inspection should be able to detect friction in the rear quadrant support bearings.

Rear damper installation

The ATR 72 maintenance manual[7] tasks for removal and installation of the rudder damper refer to a figure which includes an overview on sheet 1, showing the location of the rudder damper. Sheet 2 (Figure 8) shows a detailed view of the rudder damper and its attachment points, specifying the allowable torque values. While the overview on sheet 1 includes an orientation arrow to show the forward direction, the detailed view on sheet 2 does not include any orientation arrows, to differentiate the forward and rear aft attachment points and the detailed view is shown in the opposite orientation to the overview.

Footnote

6 Maintenance Review Board Report (MRBR) task 272100-01 relating to AMM Task MP ATR-A-27-21-XX-01001-281A-A

7 Revision number 006 dated January 01/23.

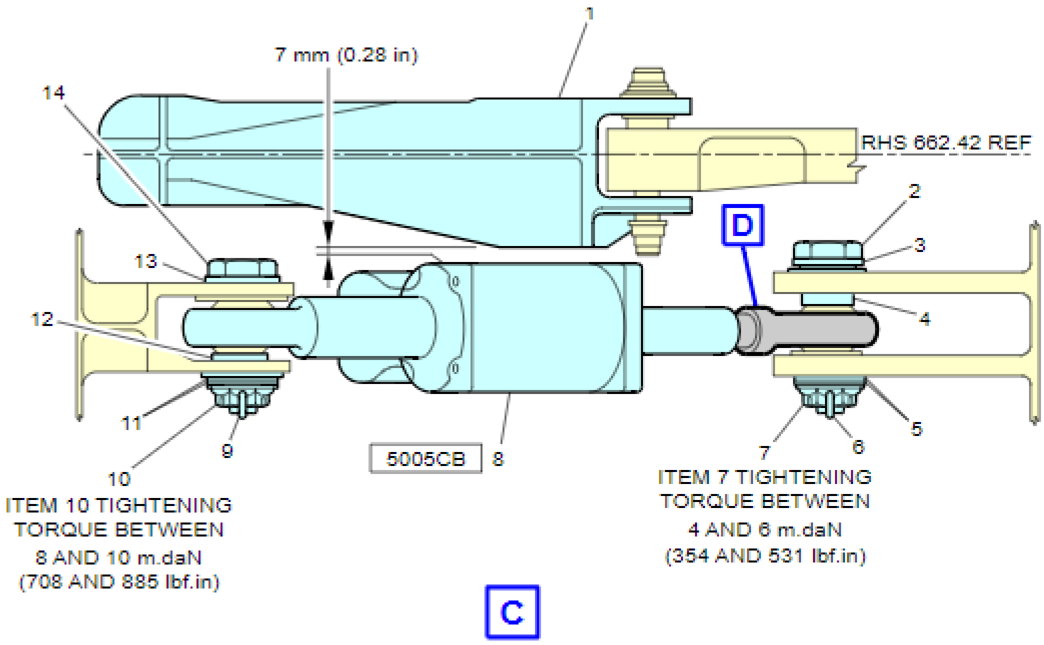


Figure 8

Extract from ATR 72 AMM figure showing rudder damper attachment allowable torque values

Rear bay drainage

Two routine inspections of the fuselage drain ports existed. Maintenance Planning Document (MPD) 122111-CLN-10000-1 task *'Fuselage drains (external)'* describes *'cleaning of draining holes/filters located on door thresholds and check for obstruction of holes of lower fuselage drain valves – external.'* The inspection interval was every two A check period/ nine months and it was last performed on G-NPTF on 1 July 2022.

MPD task 122112-CLN-10000-1 *'Fuselage drains (internal)'* describes *'cleaning of draining holes/filters located on door thresholds and check for obstruction of lower fuselage drain valves and drain pipes – internal.'* The inspection interval was every two C check/ four years and it was last performed on G-NPTF on 9 February 2022.

Both tasks instruct the engineer to ensure the drain hole is cleaned of debris and unobstructed. The manufacturer considered that any obstruction of the rear bay draining holes should have been detectable when performing these routine inspections.

In addition, the manufacturer referred to several other relevant sources of published guidance relating to moisture ingress. Among these were Technical Progress Status[8] (TPS) reports 30-11-002 and 55-36-001 which relate to protecting the tail cone from fluid ingress/ limiting glycol contamination for operators using de-icing fluids, installing a water deflector (SB ATR72-53-1052) and sealing vertical tailplane rear spar access panels with removable sealant. The manufacturer also published a Corrosion Improvements Booklet.

Footnote

[8] ATR TPS is a communication platform on the ATR online customer portal, on which the manufacturer advises the status, mitigations and corrective or improvement plan for known technical issues

G-NPTF rear bay drainage

ATR indicated that from in-service experience it is not unusual to have moisture ingress in the rear bay. It confirmed that according to the original design drawings, the rear bay access door drain hole should align with a corresponding drain hole on the fuselage door frame.

The drain hole on the rear bay door appeared to be correctly located in accordance with the design drawings. But when the rear bay door was closed, the door drain hole was entirely obscured by the fuselage door frame preventing effective drainage of any accumulated water. During a subsequent base maintenance check in 2024 after the aircraft had returned to service, the operator's maintenance organisation conducted a detailed survey of this area of the aircraft. It determined that the corresponding drain hole on the fuselage door frame was absent. It noted that there were 17 fastener holes in the door frame to retain a P-seal, when there should be 16. It appeared that an additional fastener hole had been added at some point in place of a drain hole. At the time of publication of this report, it had not been determined whether the drain hole was omitted at the time of production, or as a result of a post-production repair. ATR advised that it had no records of communication relating to a repair at this location on this airframe.

Flight control bearing modification

The rear quadrant shaft support bearings fitted to G-NPTF were the original bearings fitted at the time of manufacture. They complied with the original design standard for the ATR 72, which called for steel bearings in all flight control and engine systems.

In 1990, Aerospatiale[9] (which at that time provided the engineering function) launched modification 3102 which replaced the steel bearings with cadmium-plated, corrosion-resistant, stainless steel bearings, in all areas outside the pressurised fuselage. This was embodied at production for ATR 42 and 72 aircraft from serial number 332 onwards. Introduction of the modification followed a report of a seized flight control bearing due to corrosion on an in-service aircraft. ATR records did not indicate whether the seized bearing was on the rudder, aileron or elevator axis and there was no corresponding entry in its continuing airworthiness database.

Service Bulletin SB 72-27-1020 '*Flight controls … replace existing steel bearings by stainless steel bearings'* was published on 1 March 1993, to address bearing replacement for ATR 72 aircraft already in service[10]. As part of the process to introduce the Service Bulletin, the failure condition of a seized flight control bearing was classified as MAJOR and therefore did not prompt mandatory action. The Service Bulletin was categorised as RECOMMENDED and embodiment was therefore optional for operators.

Footnote

[9] ATR was formed in 1981 as a joint venture between Aerospatiale of France (succeeded by Airbus) and Aeritalia of Italy (now Leonardo).

[10] Corresponding SB 42-27-0060 for the ATR 42 was also published at the same time.

As of December 2023, SB 72-27-1020 was applicable to 78 ATR 72 aircraft, of which 43 were in operation[11] and SB 42-27-0060 was applicable to 248 ATR 42 aircraft, of which 88 were in operation. ATR records showed that accomplishment had been reported only on six aircraft, although it acknowledged that not all operators report accomplishment of Service Bulletins.

Full compliance with SB 72-27-1020 requires replacement of all flight control bearings, 47 in total (10 on the aileron, eight on the rudder and 29 on the elevator system), and therefore probably could only be accomplished at a major overhaul. But SB 72-27-1020 accomplishment instructions indicate that it can be embodied *"Partially, as required, on one or more specific component(s) of a control"* or *"Fully on a specific control (part A or B or C)"* where parts A, B and C refer to the aileron, rudder and elevator systems respectively. This information was probably included at the time to give operators flexibility to be able to partially embody the SB on an attrition basis.

ATR's preferred philosophy is to favour full accomplishment of an SB to ensure full traceability; it is not possible to track partial embodiment at fleet level and ATR considers an SB either fully embodied or not embodied. Accomplishment of any part of the SB requires each replaced bearing to be identified with a new part number, therefore partial accomplishment could be tracked by operators at an aircraft level.

Based on its 'full accomplishment' philosophy, during the investigation ATR indicated that partial compliance of SB 72-27-1020 was not permitted and that there was no interchangeability between pre and post-mod bearings.

Following this occurrence, G-NPTF's rear quadrant shaft and bearings were replaced prior to its return to service. As SB 72-27-1020 had not been embodied on G-NPTF, only the original standard steel bearings were approved for installation and so pre-modification bearings were re-fitted.

Since then, based on the findings of this investigation ATR has undertaken action to ease the replacement of rudder rear quadrant bearings by adding the post-mod bearings as the preferred part number, providing interchangeability. SBs 72-27-1020 and 42-27-0060 list six types (A to F) of bearing installations found in the flight control systems; the rudder rear quadrant shaft support bearings are Type F 'free-to-rotate' bearings. ATR considered that the replacement of free-to-rotate bearings can be relatively easily accomplished by operators. Therefore, in January 2024 the ATR 72 and 42 maintenance Illustrated Parts Data (IPD) was updated for Type F bearings covered by SBs 72-27-1020 and 42-27-0060, to include the post-modification corrosion-resistant stainless steel bearings as a preferred alternative part.

ATR indicated that following the G-NPTF event, the airworthiness classification for the failure condition of a seized flight control bearing remained as MAJOR and therefore the highest classification of the SB 72- 27-1020 is RECOMMENDED.

Footnote

[11] Based on ATR's fleet database.

Previous reports of bearing failure/corrosion

ATR indicated that in-service reports of problems with the rudder rear quadrant shaft support bearings are extremely rare. Its records showed that prior to this occurrence on G-NPTF, it was aware of only one previous in-service report of rudder stiffness where corrosion of the rear quadrant shaft support bearings was identified as the root cause. It was also aware of two reports of corrosion having been identified in steel bearings within the elevator system.

The investigation determined that this knowledge was not fed into the troubleshooting guidance on G-NPTF following the 9 February 2023 report of rudder stiffness, nor the investigation troubleshooting performed following the occurrence on 6 March 2023. ATR indicated that in its experience, reports of friction or stiffness within the rudder control system are typically related to the rudder damper, RCU or TLU and therefore these components were prioritised in the troubleshooting philosophy. It stated that it understood the relevance of this historic modification from steel to stainless steel bearings only when the AAIB shared the findings of the metallurgical examination of the bearings from G-NPTF.

Safety assessment considerations

ATR's flight controls System Safety Assessment (SSA), produced during the ATR 42 certification process and periodically reviewed[12], did not specifically include rudder stiffness as a failure scenario but did include a rudder jam failure condition, which takes account of a rudder jam within the normal rudder deflection range. A seized flight control bearing could lead to a rudder jam. The safety effects of this failure are described as: *'This loss can be the consequence of a single failure as [sic] jamming. Based on flight test results, the control of the aircraft is performed through roll axis.'*

This failure scenario does not meet the regulatory criteria for an unsafe condition and was therefore classified as having MAJOR[13] consequences. To arrive at a MAJOR categorisation, control of the aircraft must be demonstrated during flight test and for the ATR 72 an approach and landing were performed with a simulated rudder jam at approximately 5° deflection. Additionally, ATR published a specific operational procedure for the rudder jam case which requires the flight to land at an airport with minimum crosswind. ATR consider that the rudder jam failure condition is more conservative than the reported rudder stiffness scenario, and on that basis, it does not intend to review or update the SSA in response to this occurrence.

Footnote

[12] The ATA 27 (flight controls) SSA for the ATR 72 was originally produced during the certification for the ATR 72-101/201/101/202. ATR document reference 420.0101/95 Issue 1, dated 4 April 1995, documents the flight controls SSA as updated for ATR 42-500 certification. At the same time this document also became applicable to the ATR 72. This document was subsequently updated in April 2023 (new document reference EYG-3049/22) but the update was neither related, nor relevant to the occurrence to G-NPTF.

[13] Failure conditions are classified according to their severity. Classifications include: CATASTROPHIC, HAZARDOUS, MAJOR, MINOR and NO SAFETY EFFECT. The certification basis for the ATR 72 was Joint Aviation Regulation (JAR) 25 change 11, which in section 25.1309 defined MAJOR failure conditions as those which: '*would reduce the capability of the aeroplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example a significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency, or discomfort to occupants, possibly including injuries*'.

Testing and examination of rudder system components

No operational or functional checks were performed on the rudder system components during the onsite investigation, as initial findings indicated substantial mechanical resistance within the system. Checks performed during the subsequent return to service maintenance on G-NPTF did not indicate any anomalies with the TLU, RCU or rudder damper (other than that already noted) fitted at the time of the occurrence that could have contributed to the rudder stiffness encountered.

The rudder system components previously removed from G-NPTF during the troubleshooting for the rudder stiffness report on 9 February 2023 were sent to the respective manufacturers for examination and testing.

Minor discrepancies were noted on both the TLU actuator and the RCU, consistent with normal wear, but the units were otherwise functional and in good condition. The findings did not explain why the TLU failed the operational test during the 9 February 2023 troubleshooting.

The rudder damper was mildly out of tolerance in some respects but was also assessed as being in good condition. In summary, no issues were identified with these components that could have contributed to the history of rudder stiffness on G-NPTF.

Analysis

Background to the occurrence

Over a period of approximately one month several of the operator's pilots had intermittently reported stiffness within G-NPTF's rudder system on three occasions. Each report appeared to indicate the degree of stiffness was increasing over time, despite prompt maintenance intervention on each occasion. The resulting maintenance ranged from functional and operational tests to replacement of the rudder damper and, following the most recent occurrence, replacement of the TLU, RCU and the rudder damper for a second time and an extensive period of troubleshooting which included guidance from ATR. The operator indicated that these actions had, at least to some extent, alleviated the perceived stiffness in the rudder system.

Flight crew's acceptance of aircraft for flight

ATR indicated that the primary mitigations for any stiffness, resistance or jamming in the rudder control system are the full and free control check conducted before flight and the rudder jam procedure, if the condition is encountered in flight. The rudder jam procedure had limited relevance in this case, as the aircraft was already in the landing flare when the rudder stiffness was encountered.

During the full and free movement check of the flight controls after engine start, both flight crew commented that the rudder was very stiff to move. Despite this observation they continued with the flight. This meant that the last chance to prevent the aircraft flying with the stiff rudder was missed. Had the crew opted to return the aircraft to the stand, it is possible that further engineering investigations might have identified there was a significant issue with the rudder control system. However, the previous extensive engineering attention and the repeated clearance of the system as having no faults meant the flight crew were ready to accept the aircraft for the flight to Belfast despite feeling that the rudder was very stiff.

Condition of rudder control system following the occurrence

Examination of the aircraft the day after the occurrence confirmed the presence of significant resistance in the rudder system, with the rudder being extremely difficult to move both when using the rudder pedals and by hand. While there was no moisture or ice accumulation evident in the rear bay during the initial aircraft examination, subsequent examination after the aircraft had been parked outside for several days revealed an accumulation of water and condensation in the rear bay.

By isolating the command and actuation sides of the rudder system and disconnecting the rudder pedal and autopilot yaw cables from the rear quadrant, the predominant source of the stiffness/friction was determined to originate from the rudder rear quadrant shaft. Removal of the shaft revealed that both rear quadrant shaft support arm bearings were in a degraded condition.

Some residual stiffness remained in the rudder/actuation circuit and the investigation identified that the aft attachment bolt for the rudder damper had been over-torqued. Its installation had contributed to stiffness with the rudder circuit, albeit to a much lesser degree that the degraded bearings.

Additionally, examination of the rudder and vertical stabiliser identified the presence of moisture and degraded sealant, and the grease on the rudder pivot (hinge) points had a degraded appearance.

Rear quadrant support bearings

The predominant source of stiffness/friction in the rudder system was determined to be the degradation of the rear quadrant support bearings. Both bearings showed evidence of corrosive attack. The No 2 bearing was completely seized when examined in the laboratory and there was a complete absence of fresh grease, despite being a sealed bearing. The No 1 bearing was rough when rotated and had also suffered from corrosion, although to a lesser extent.

The degradation of the bearings would have substantially reduced or prevented their ability to rotate freely and thus resisted the movement of the rear quadrant shaft, which would have resulted in the difficulties reported in the rudder operation.

SB 72-27-1020 was issued by ATR in March 1993 recommending replacement of steel flight control bearings with corrosion-resistant stainless steel bearings but had not been embodied on G-NPTF.

Following this event, ATR took steps to ease the installation of some post-mod flight control bearings, including the rudder rear quadrant bearings, as an alternative to the SB. This change took effect in February 2024. This means that it will be possible for operators to replace the original steel bearings on the rear quadrant shaft and in other flight control Type F bearing locations, on an on-condition/opportunity basis, without the need to embody the entire SB.

Moisture ingress

While G-NPTF's flight control bearings were not corrosion-resistant, many older aircraft in the ATR 42/72 fleet similarly equipped with the original steel bearings, continue to operate without reported problems. Regardless of whether original steel or the post-mod corrosion-resistant bearings are installed, bearings perform better when operated in a mostly dry environment.

Ordinarily, internal bearing components should not be exposed to moisture since the bearings are sealed and covered with grease; in this case, the presence of excessive moisture in the rear bay undoubtedly contributed to the corrosion on the bearings. The rear bay is not intended to be a fully sealed area and it is not unusual to encounter moisture here, but not to the extent observed on G-NPTF. Degraded and missing sealant on the vertical stabiliser provided a path for moisture ingress.

The horizontal and vertical stabilisers and the rudder are areas of the aircraft subject to external de-icing, and pressurised jets are sometimes used to ensure de-icing fluid reaches the upper part of the rudder. ATR is aware of reports de-icing fluid residue being found in the rear bay in the past. Some of the moisture accumulations in G-NPTF's tailcone area had a gel-like consistency, visually consistent with a mixture of water and glycol-based de-icing fluid. It is therefore probable that de-icing fluid entered this area as well as rain and could also have contributed to the corrosion.

Once in the rear bay, accumulated water/de-icing fluid was unable to effectively drain away due to an absent drain hole in the door frame, which obscured the corresponding drain hole in the door. An additional fastener hole had been added instead of the drain hole, at some point in the aircraft's history, but the investigation did not determine when. The resulting trapped moisture would have created an environment conducive to corrosion.

The manufacturer considered that any obstruction of the rear bay drain holes should have been detectable by two routine inspections of fuselage drain ports, which required ensuring that drain holes were clear of debris and unobstructed. While these inspections had been performed on G-NPTF, the inspection tasks assume that the drain holes are present and correctly located. On G-NPTF, it is feasible that the absence of the drain hole in the door frame would not have been detected, particularly if the inspections were performed with the rear bay door in the open position.

Following the occurrence, the operator resealed the vertical stabiliser on G-NPTF and restored the drain hole in the rear bay door frame. ATR has undertaken to remind operators of existing maintenance requirements and best practice regarding rear bay sealing to minimise moisture ingress and glycol contamination in a customer communication.

Why was the cause of the rudder stiffness not identified sooner?

The first crew report of rudder stiffness was made on 4 February 2023. Given the extent of the corrosion exhibited on the rear quadrant shaft support bearings, it is likely that this degradation would have developed over an extended period of time. Despite this, it seems that it was only in the month leading up to the incident flight that the condition of the bearings became such that the friction in the rudder control system was detected by flight crew. The most recent routine visual inspection (of the rudder cable circuit) was performed approximately one year earlier, under the previous operator's tenure with no issues identified.

Neither the rudder rear quadrant shaft nor its support bearings were specifically examined or considered during the maintenance interventions which took place in response to the history of rudder stiffness reports on G-NPTF. Initial troubleshooting by the operator's maintenance organisation following the 9 February 2023 report of rudder stiffness was perceived to have had reduced the stiffness in the rudder system.

Further troubleshooting performed in response to guidance provided by the manufacturer, did not result in the identification of any findings which explained the rudder stiffness. This guidance was in-part informed by the operator's feedback from the troubleshooting, which did not include information about the overall maintenance condition of the rear bay, as observed post-incident. The guidance did not specifically direct the operator or its maintenance organisation to look at the rear quadrant shaft bearings. While corrosion/degradation of the bearings was an issue historically known to ATR and addressed by SB 72-27-1020, the absence of numerous or recent in-service reports of difficulty with these bearings together with the lack of findings from the troubleshooting, meant that it was not included as a consideration in the ATR troubleshooting process for reports of stiffness within the rudder system. The operator was not aware of SB 72-27-1020 and therefore did not consider it in the troubleshooting for G-NPTF.

The manufacturer considered that the visual inspections of rudder mechanical control/rudder cable circuit (either performed routinely or during troubleshooting) should have identified the friction at the quadrant shaft. The manufacturer indicated its expectation that the maintenance condition of the rear bay, in combination with the reports of rudder stiffness should have prompted further examination.

The investigation noted that neither of the visual inspections directly referred to the rear quadrant shaft or its support bearings. They did not require the rear quadrant shaft to be rotated by hand, but rather operated by moving the rudder surface or the pedals.

The investigation considered that even a detailed visual inspection, without further examination, may not identify any problems with the bearings. The sealed nature of the bearings and their installed location on the rear quadrant shaft precludes visual inspection of their condition without some level of disassembly. It's likely that friction or degradation in the bearings may therefore only be reliably detected by rotating the rear quadrant shaft by hand, after isolating it from the rest of the rudder control system and confirmed by removal/inspection of the bearings.

Both inspections required the flight crew seats to be removed, so operation of the pedals would not be performed in the normal manner. ATR did not specify a maximum permissible force on the rudder pedals and the force sensed by the force detector rod was not recorded on G-NPTF's DFDR. While the force to move the pedals could be measured by a hand-held dynamometer during the aircraft examination, this is not representative of how the force would be applied to the pedals in normal use. There was therefore an element of subjectivity in the perception of the force required to move the pedals before and after the maintenance interventions and during the post-incident aircraft examination.

As a result of the findings of this investigation, ATR has proposed to create a new Aircraft Fault Isolation (AFI) task to be followed by operators in the event of a problem with the rudder command. The point of entry to the AFI will be an unsatisfactory pre-flight check, for example a hard point detected on the rudder command. The instructions will provide a troubleshooting sequence based on the most probable root causes eg disconnect the rudder control system to isolate the fault on the command or actuation side of the system, RCU, rudder dampers, check the condition of the rear quadrant support bearings, TLU etc. ATR plans to implement this change in the next revision of ATRNavX[14] scheduled for January 2025.

ATR has also launched a review of the rudder mechanical control/rudder cable circuit visual inspection tasks.

Rudder damper

The bolt attaching the rudder damper to the rudder surface was found to be over-torqued, a bushing was seized to the bolt shank and there was absence of grease at both rudder damper attachment points. During the aircraft examination it was noted that the rudder damper installation created some subtle but detectable resistance in the rudder/actuation circuit, which disappeared after the bolt was loosened.

The rudder damper had most recently been replaced following the 9 February 2023 report of rudder stiffness. The investigation therefore concluded that this was the only opportunity during which the over-torque could have occurred.

ATR indicated that it did not fully understand how an over-torqued bolt could contribute to stiffness in the rudder circuit, but due to difficulty in obtaining a rudder damper for testing, had not at the time of publication of this report taken action to test or model the possible effects of this condition.

At the time the rudder damper was replaced, the detail view on the relevant AMM figure which showed the allowable torque at each attachment bolt, did not include an arrow to indicate direction or orientation to differentiate the forward and rear aft attachment points. The orientation of the detail view was also opposite to that presented in the overview of the same AMM figure. While it is not known if this directly contributed to the maintenance engineer's understanding of the required torque at each attachment point when the rudder

Footnote

[14] ATR's electronic maintenance data application.

damper was replaced, the investigation considered that the presentation of information on the figure could lead to uncertainty. As a result, ATR has amended the AMM figure to include an orientation arrow and this change was incorporated in the AMM in January 2024.

Rudder pivot point lubrication

Examination of the rudder pivot points showed that while there was some evidence of fresh grease on the grease nipples, most of the grease within the joints was thick, lumpy and degraded in appearance and was brown/red in colour. Additionally, there was evidence of moisture at all the pivot points, including on the surface of the grease.

A review of G-NPTF's maintenance records showed that two different grease products, Aeroshell 33 and SHC-100 had been used alternately on the previous four occasions that the rudder pivot point lubrication task had been performed. Of these, only Aeroshell 33 was approved and intended for use on flight controls, while the other was approved for use in wheel bearings. The grease observed on the G-NPTF rudder pivot points was visually consistent with a mixture of these two grease products, but the presence of water or de-icing fluid may also have contributed to its appearance.

Historical inconsistencies between the numbering convention for consumable items in the ATR CMD and how consumables were called up in AMM tasks created a situation where ATR and maintenance organisations believed consumable items with similar item numbers were interchangeable, when that was not the intent.

The ATR CMD indicated that when a replacement grease product is used, the two types of grease should not be mixed, the old grease should be completely purged and the servicing interval should be temporarily reduced for around 3 to 4 services. There is no evidence that this was done on G-NPTF. Old or degraded grease can develop hygroscopic properties, where it actively attracts water.

It was not determined to what extent, if at all, the degraded, moisture-saturated grease found on G-NPTF's rudder pivot points contributed to the rudder stiffness encountered by the flight crew. No discernible effect was observed during the on-ground examination in a hangar environment but given the in-flight temperatures the aircraft encountered during the occurrence flight the potential for any moisture to freeze could not be discounted.

The condition of the grease indicated that pivot points had not been lubricated in accordance with best practice. Following this occurrence, the operator took steps to ensure that all old grease will be purged on its ATR fleet and that only Aeroshell 33 grease would be used for lubrication of the flight controls. The intent of this standardisation is to ensure a consistent lubrication philosophy and avoid the need for third party maintenance providers to interpret the approved products in the ATR CMD, and thereby reduce the chance of different grease products being mixed.

Other observations

The rudder stiffness was detected by the crew at stages of flight during which the TLU would not have been active. When tested, neither the TLU actuator, RCU or rudder damper fitted to the aircraft during the occurrence, or those fitted during the previous occurrence on 9 February 2023, revealed any defects which could have contributed to the rudder stiffness.

Several mechanical anomalies were noted on the TLU system components during examination of the rear quadrant shaft, including that the rollers were seized. While this appeared to have no negative impact on the operation of a donor TLU actuator, the investigation did not rule out that these mechanical discrepancies influenced the result of the TLU operational test during the 9 February 2023 troubleshooting. While in some cases the condition of the components was consistent with operating in a high moisture environment, the investigation determined it had no, or negligible, contribution to the rudder stiffness. But the condition of the rear quadrant shaft and its installed components was such that the ATR declared it unserviceable.

Cable fouling noted on the pedal bellcrank could have resulted from the observed misalignment on the outer ring on bearing No 2, the migration of the TLU support arm bearing, a cable routing issue or a combination of these. But in any case, stiffness or friction imparted to the rudder system as a result of the cable fouling would have been negligible.

Safety assessment and continuing airworthiness considerations

ATR indicated that the primary consequence of rudder stiffness such as that resulting from corrosion in the rear quadrant shaft bearings did not result in an unsafe condition and was already covered by the more conservative RUDDER JAM failure condition. It further stated that the very low number of reports of rudder stiffness or corrosion in the rear quadrant support bearings did not indicate a fleetwide unsafe condition.

It therefore stated that there was no evidence to consider upgrading the SB from its existing status of RECOMMENDED, nor to revise the SSA.

Conclusion

Following an extensive history of reports of stiffness within the rudder control system, the flight crew experienced rudder stiffness during the full and free control check prior to the flight. Aware of the recent maintenance interventions which were considered to have resolved the problem, the flight crew elected to continue with the flight. They subsequently encountered excessive rudder stiffness during the landing flare which rendered the rudder pedals almost immovable.

Two support bearings on the rudder rear quadrant shaft were found to be corroded. Trapped moisture in the aircraft's rear bay probably contributed to the condition of the bearings. Unable to rotate freely, the bearings would have resisted the movement of the rudder rear quadrant shaft leading to the stiffness. Other anomalies observed in the rudder control system may have contributed to the stiffness, but to a lesser extent.

A Service Bulletin published in 1993 existed to replace the affected bearings with corrosion-resistant equivalents, but had not been embodied on G-NPTF. In February 2024 the manufacturer updated the IPD to allow interchangeability for some flight control bearings (including those on the rudder rear quadrant) with corrosion-resistant bearings, as an alternative to the Service Bulletin.

The manufacturer will also issue an operator communication emphasising existing operational and maintenance procedures to prevent reoccurrence.

Safety actions

Manufacturer completed safety actions

ATR has amended the figure referenced in the AMM tasks for removal/installation of the rudder damper, to include an orientation arrow. This change was incorporated in the AMM in January 2024.

ATR took steps to ease the installation of some post-mod flight control bearings, including the rudder rear quadrant bearings, so that they can be replaced on an on-condition/opportunity basis, without the need to embody the entire SB 72-27-1020. This change took effect in January 2024.

Manufacturer planned safety actions

ATR has launched a review of the rudder mechanical control and rudder cable circuit visual inspections.

ATR has committed to publish an operator communication which will emphasise existing operational and maintenance procedures to prevent reoccurrence, including MRBR tasks and recommended Service Bulletins. The OIM will incorporate recommendations on maintenance procedures and reiterate in-service experience.

ATR has launched the creation of a new AFI task to apply in cases of rudder stiffness, with an unsatisfactory flight control check as the entry point. The troubleshooting instructions will include, among other potential causes, consideration of the condition of the rear quadrant shaft support bearings.

Operator safety actions

Following this occurrence, the operator undertook the following safety actions:

- Resealed all gaps and areas of degraded sealant on G-NPTF's vertical stabiliser.
- The operator's CAMO issued instructions to specify Aeroshell 33 as the only grease to be used for lubrication of the flight control pivot points to ensure a consistent lubrication philosophy and avoid mixing different products. It took steps to ensure this change was implemented during maintenance planning, by the organisation it subcontracts to provide partial CAMO services.

Published: 28 November 2024.

Serious Incident

Aircraft Type and Registration:	Boeing 737-8200, EI-HET
No & Type of Engines:	2 CFM LEAP-1B27 turbofan engines
Year of Manufacture:	2019 (Serial no: 62310)
Date & Time (UTC):	4 December 2023 at 1103 hrs
Location:	London Stansted Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 122
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	5,300 hours (of which 2,800 were on type) Last 90 days - 235 hours Last 28 days - 29 hours
Information Source:	AAIB Field Investigation

Synopsis

After an unstable ILS approach, a manually flown go-around (GA) was initiated at 1,940 ft amsl and 3.6 nm from touchdown. During the approach the mode control panel altitude display was set to 100 ft, but not reset to the missed approach altitude (MAA), prior to the GA being commenced. In the GA the aircraft committed a level bust as it climbed through the MAA of 3,000 ft amsl. Upon recognising this the PF pitched the aircraft down and entered a descent, having reached a maximum altitude 4,030 ft amsl. During the descent the aircraft reached a nose-down attitude of 17.7° and 295 KIAS, with Flaps 5 extended before a recovery and climb was initiated, during which its lowest recorded height was 1,740 ft agl. After the recovery was commenced the EGPWS warning sounded. The entire event occurred with the aircraft in IMC.

Prior to the GA the MAA was not checked by either pilot and during the GA the PF was fixated on the flight directors and expected them to command the aircraft to level off.

There have been several serious incidents which occurred during go-arounds with similar factors to that found in this investigation involving EI-HET. Although EI-HET is a Boeing 737-8200 [MAX], the incident could have occurred in any variant of the Boeing 737, or any other type of aircraft with similar autopilot and flight director systems.

As a result of this serious incident the operator has taken three safety actions including informing its pilots about this event and introducing a Discontinued Approach procedure.

History of the flight

The crew were operating a scheduled flight from London Stansted Airport to Klagenfurt Airport, Austria, and return, reporting for duty ahead of their rostered report time of 0555 hrs. The outbound flight was uneventful.

For the return flight to Stansted the commander was the PF and the co-pilot the PM. The departure and cruise proceeded without event. Prior to the descent the crew conducted an approach brief where they planned to conduct a radar vectored CAT I ILS approach to Runway 22 (Figure 3) for a Flaps 30 manual landing. They noted Stansted's ATIS information 'November' which stated the surface wind was from 130° at 12 kt. The visibility was in excess of 10 km, with overcast cloud at 400 ft aal and a QNH of 997 hPa. The initial part of the descent was uneventful. During the approach when the aircraft was below 6,000 ft, height changes were flown with a single autopilot (A/P) and the autothrottle (A/T) engaged, using Level Change mode (LVL CHG).

When the crew transferred to the Stansted Approach/Director[1] frequency, ATC cleared the aircraft initially to descend to FL80, followed shortly thereafter to 6,000 ft amsl and advised that they had 24 track nautical miles to touchdown[2]. At this point the aircraft was passing FL86 (about 7,800 ft aal) and at about 235 KIAS. About one minute later ATC then cleared the aircraft to descend to 4,000 ft amsl, advising that it was now 20 nm[3] from touchdown. At this point the aircraft was passing FL76 (about 6,800 ft aal) and still at 235 KIAS. About 90 seconds later, the ATCO noticed that the aircraft was a bit high for a continuous descent arrival[4] (CDA), possibly due to a tailwind, so the aircraft was instructed by ATC to turn slightly away from the runway in order to give it some extra track mileage. At about 15.5 track nautical miles from touchdown, as the aircraft descended through about 6,000 ft amsl (5,650 ft aal) the speedbrakes were extended for about 35 seconds until the aircraft passed through about 5,200 ft amsl. The aircraft was then instructed by ATC to establish on the localiser (LOC) and was cleared to descend to 2,000 ft amsl, before being cleared to capture the ILS. At 12 nm, Flaps 1 was selected and the speedbrakes were extended again. The aircraft was then instructed by ATC to reduce speed to 180 KIAS. Flaps 5 was selected about 20 seconds later. Figure 1 shows EI-HET's radar flightpath as it approached Stansted, the GA, level bust and descent, and second approach and landing.

Footnote

[1] Stansted Approach and Director were combined on to one frequency due to low traffic levels.
[2] Stansted Airport MATS Part 2 stated '*The director is to calculate the optimum point at which to issue descent clearance from stack levels to enable the pilot to achieve an approximate 3° glide path. On receipt of descent clearance, the pilot will descend at the rate they judge will be best suited to the achievement of continuous descent without recourse to level flight.*'
[3] Analysis after the event showed that the aircraft was 20.5 nm from touchdown at this point.
[4] A CDA is an aircraft operating technique in which an arriving aircraft descends from an optimal position with minimum thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions.

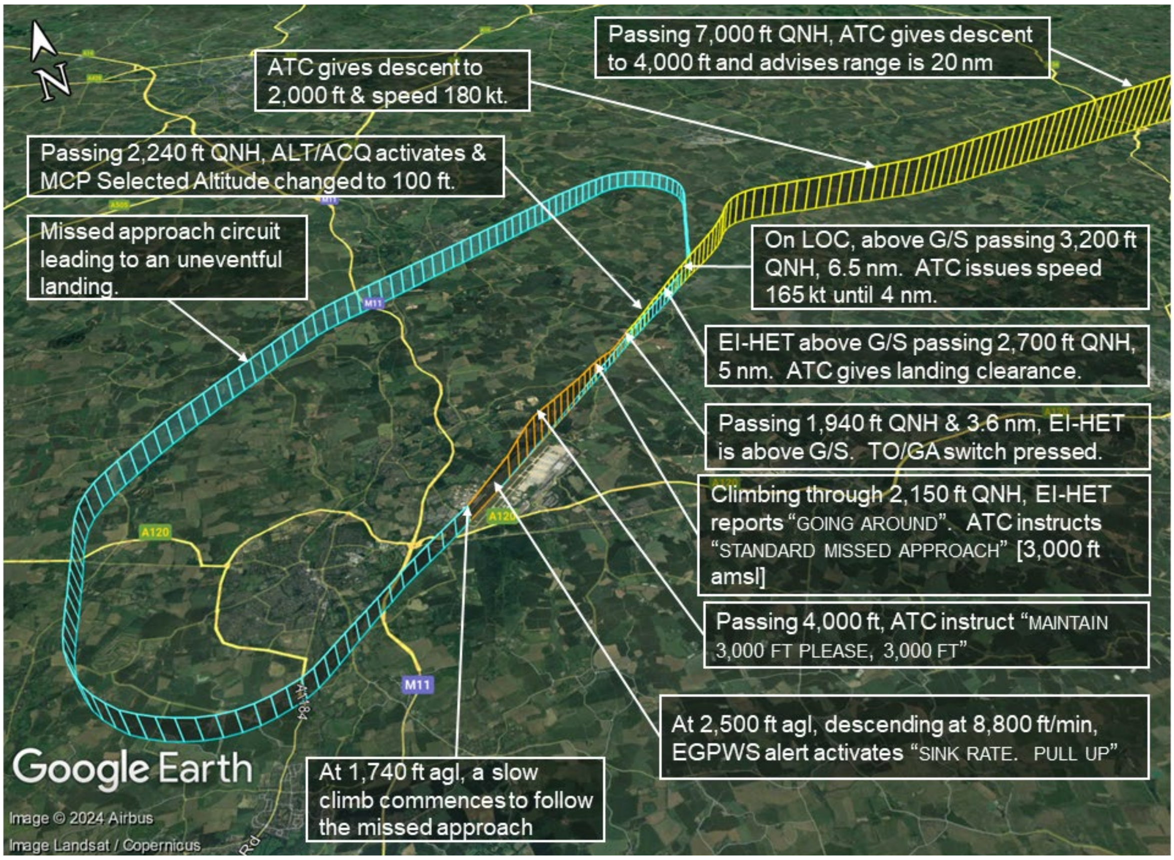


Figure 1

EI-HET's radar flightpath as it approached Stansted (yellow), the GA, level bust and descent (orange), and second approach and landing (blue)
© 2024 Google Earth, image © Airbus

The LOC was captured at about 9 nm when the aircraft was 3,863 ft aal, with flaps 5, speedbrakes extended and at 195 KIAS. At this point the glideslope (G/S) was indicating full scale deflection below the aircraft. Flaps 10 was then selected. About 30 seconds later, when the aircraft was at 7 nm, ATC instructed the aircraft to reduce its speed to 165 KIAS until 4 nm and to contact Stansted Tower.

At 6 nm, as the aircraft passed 2,650 ft aal, the landing gear was lowered, the speedbrakes were extended and Flaps 15 selected. The speedbrakes were then retracted. At this point the airspeed was 186 KIAS. At about 5 nm ATC cleared the aircraft to land. The commander then commented that "IF WE DON'T CATCH IT [the G/S] WE'LL HAVE TO GO AROUND." As the aircraft was passing 2,240 ft amsl, at 171 KIAS, ALT/ACQ (altitude acquire) Flight Mode Annunciation (FMA) was displayed on the primary flight display (PFD) and Flaps 25 was selected. As a result, the commander set 100 ft in the mode control panel (MCP) altitude display, and selected LVL CHG. Shortly thereafter the commander said "LET'S GO AROUND".

At 1,940 ft amsl (1,579 ft aal) and 3.6 nm from touchdown, the commander initiated a go-around (GA) and the co-pilot advised ATC of this. See Figure 2 for EI-HET's approach from radar data, showing the path before the GA was initiated, and the aircraft's subsequent track.

ATC replied, "STANDARD MISSED APPROACH". The commander took manual control, as the A/P automatically disengaged[5], and followed the flight directors (F/D) that commanded 15° nose-up. The A/T advanced the thrust levers to a GA thrust[6] of 82% N_1 on each engine. The co-pilot then selected Flaps 15 and the landing gear UP. Flaps 5[7] was then selected as the aircraft passed 2,700 ft amsl.

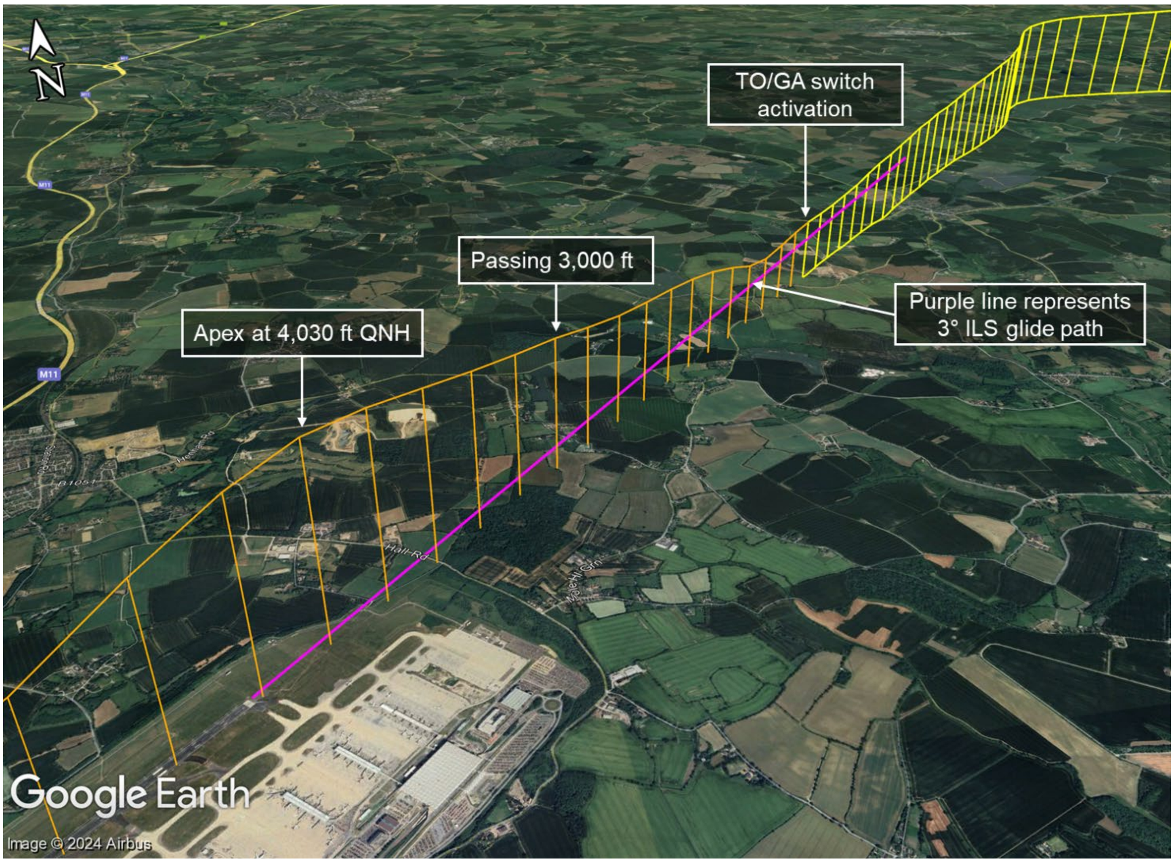


Figure 2

EI-HETs approach from radar data, showing path before TO/GA switch activation (yellow track), and subsequent track (orange track). 3° ILS G/S illustrated by purple line

Shortly after, the ATCO noticed on his aerodrome traffic monitor that the aircraft was at about 3,400 ft and climbing. During a GA at Stansted the aircraft has to remain below 3,000 ft amsl; as the aircraft had now exceeded that altitude (level bust) ATC instructed the aircraft to "MAINTAIN 3,000 FEET [AMSL] PLEASE, 3,000 FEET", to which the copilot replied "MAINTAINING 3,000 FEET WILCO". During this time, the speed remained relatively stable at about 180 KIAS.

Footnote

5 See *Aircraft Information* section below for more information on the A/P during a single channel approach and a GA.

6 See section on *Aircraft information* below for more details on the A/P.

7 The crew had planned to leave flaps 5 extended during the initial part of the missed approach procedure (MAP) until the right turn to BARKWAY was complete, as the MAP required a maximum of 185 KIAS, until the aircraft was established inbound on the 171° radial.

The commander then pitched the aircraft to about 5 to 10° nose-down, and made a nose-down trim input, to initiate a descent, during which 0.40 vertical g was recorded.

During the missed approach procedure (MAP) the aircraft reached a maximum pitch of 16° nose-up, a maximum climb rate of 4,100 fpm and an altitude of 4,030 ft amsl, before a descent was commenced, in manual flight, with the A/T engaged and GA thrust still set. The aircraft then started a descent during which the commander noticed the MCP altitude display was set at 100 ft, so reset it to 5,600 ft. As the IAS was now increasing, the co-pilot said to the commander, "WATCH YOURSELF…SPEED…SPEED", with the first call coming at about 235 KIAS. The commander then extended the speedbrakes and manually retarded the thrust levers to idle. However, as the A/T was still engaged they advanced back to GA thrust. The commander then manually retarded the thrust levers to idle again, but they advanced again so, on the co-pilot's suggestion, they were held at idle by the co-pilot. The commander then pitched the aircraft nose-up, during which a vertical acceleration of up to 1.89 g was recorded. Just after the recovery was initiated, the EGPWS "SINK RATE" and "PULL UP PULL UP" aural and visual warnings on the PFD were annunciated. The MCP altitude display was then set to the missed approach altitude (MAA) of 3,000 ft and the A/T was then disconnected. During the descent the pitch of the aircraft reached a maximum of 17.7° nose-down, a rate of descent of -8,880 fpm, and 295 KIAS with Flaps 5 extended[8]. The lowest altitude recorded was 2,078 ft amsl, 1,740 agl. The aircraft was subsequently recovered and stabilised in a shallow climb before it levelled at 3,000 ft amsl. The entire event occurred with the aircraft in IMC.

Once stabilised at 3,000 ft, the A/P was engaged and the flaps retracted. The A/T was then engaged. The aircraft was then radar vectored for an uneventful ILS and landing on Runway 22.

Pilots' comments

Commander

The commander commented that he did notice the aircraft was high on a 3° CDA, during the initial part of the descent prior to establishing on the LOC. He added that whilst this was not unusual, he believed we would be able to achieve the required approach path to continue with the ILS approach and landing. Also, he was not aware of any perceived time pressure from ATC that may have led to the aircraft becoming high on the 3° CDA.

The commander added that during the GA, as the aircraft was passing about 1,800 ft amsl, he believed he disconnected the A/T, but when the aircraft started to descend he realised this was not the case. As he had become fixated on the F/Ds during the GA, he did not notice the high rate of climb and believed 3,000 ft was set in the MCP altitude display. However, he did not have the capacity to check it and expected the F/Ds would command a level off at 3,000 ft. Whilst he recalled ATC's instruction to maintain 3,000 ft, it was then that he noticed the aircraft had already climbed through it. The commander accepted that he was startled during the descent.

Footnote

8 The Flaps 5 limit speed is 250 kt.

He added that he has previously flown "several" uneventful approaches where the G/S was captured from above in an aircraft and in the simulator. His training records indicated that he completed a minimum of 73 GA in various configurations and training and checking situations, over the past four years with the operator. Of these, four were completed in a 'non-standard' configuration. This included a specific 'High Energy Approach Recovery' exercise, detailing a GA from a similar situation, in 2021. Whilst he had flown several GA during his recurrent training in a simulator as PF and PM, this was the first one he had flown as PF in an aircraft. He had been PM during two other GA in an aircraft.

Co-pilot

The co-pilot commented that when the aircraft was descending through 5,000 ft amsl he thought the aircraft was "a bit high", which was not unusual for Stansted, but they would be able to catch the profile further into the approach.

He did not recall he had practised a G/S from above during a recurrent simulator check but had manually flown GAs during most of his recurrent simulator checks[9]. His training records indicated that he had flown at least 46 GAs as either PF or PM in various configurations during training and checking situations, over about the past two years with the operator. Two were completed in a 'non-standard' configuration.

Airport information

London Stansted Airport is 348 ft amsl and has two runways orientated 04/22. The ILS approach chart for Runway 22 is at Figure 3. It stated that when an aircraft was on the 3° G/S it will descend at 320 ft/nm.

The MAP for Runway 22 was to climb straight ahead to not above 3,000 ft amsl, turning right at 3.1 DME, measured off the ILS, and then establish on the BARKWAY VOR 171 radial. The maximum speed for the turn is 185 KIAS until established on the radial.

Footnote

[9] The operator subsequently confirmed that the co-pilot's training records indicated that he had completed this training.

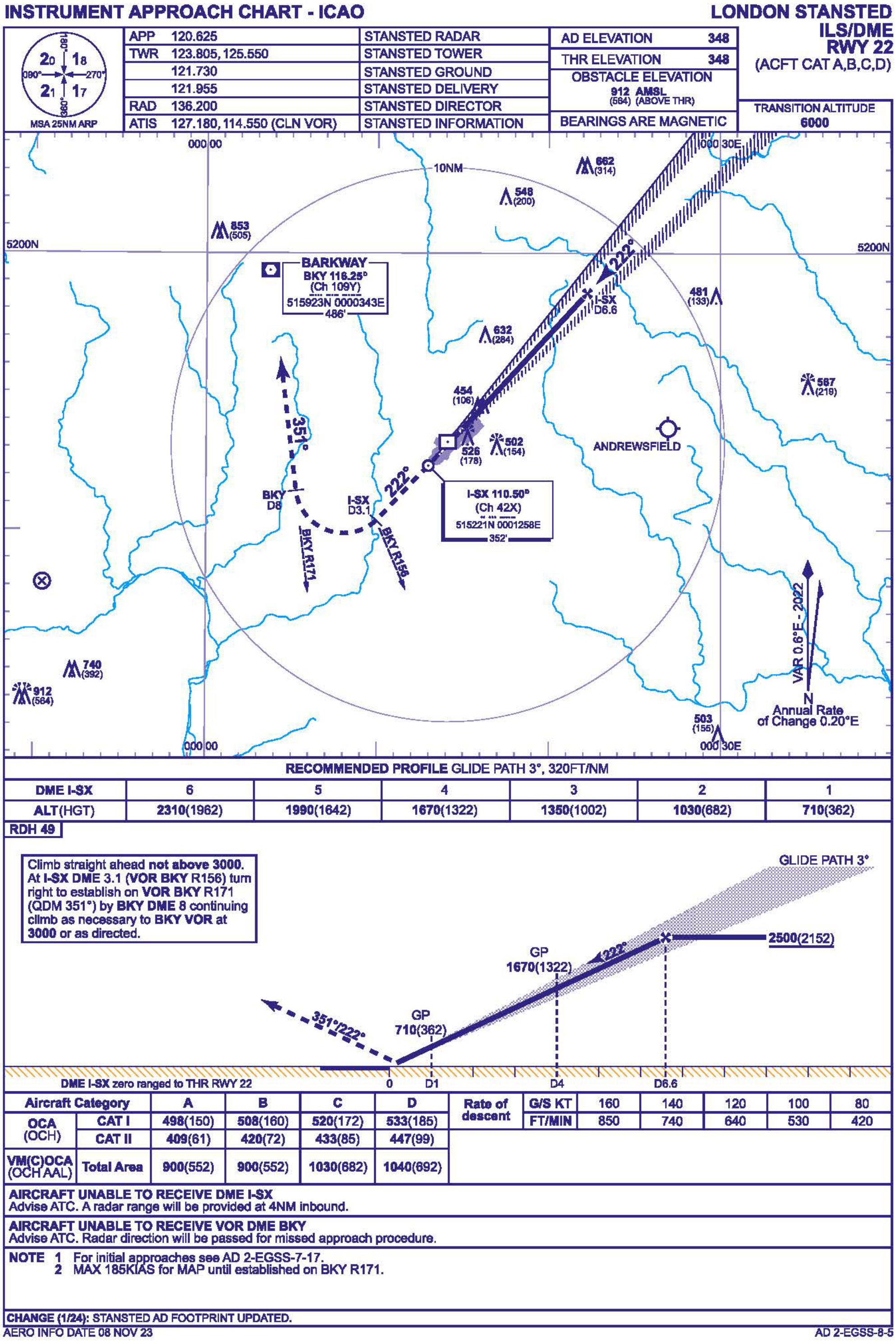


Figure 3

Approach chart for ILS to Runway 22 at London Stansted Airport (UK AIP)

There were three standard instrument departures (SID) from Runway 22 at Stansted that have a similar routing to the MAP; BARKWAY 5R, NUGBO 1R and UTAVA 1R. These route to the north inbound to the Barkway VOR and all have an initial climb clearance of 4,000 ft amsl.

Recorded information

Data sources

The Flight Data Recorder (FDR) and the Cockpit Voice Recorder (CVR) were isolated by the operator immediately following the incident. The EGPWS fitted to EI-HET was removed from the aircraft two days after the incident. All three items were recovered by the AAIB to its laboratory in Farnborough.

Recordings were obtained from Stansted Airport's Radar Surveillance System (RSS), which first detected EI-HET as it overflew the English Channel. Mode-S transponder information, including the altitude selected on the autopilot MCP altitude display, was present in the recordings.

Recorded R/T transmissions captured ATC relaying track distances to the airport while providing radar vectors to the approach to EI-HET's flight crew. FDR position recordings were used by the AAIB to confirm that the track distance information provided by ATC radar during EI-HET's approach was accurate.

FDR

Figure 4 shows the pertinent FDR parameters for the event, with recorded RTF transmissions made by the flight crew to ATC. Activations of the EGPWS and Autopilot and Flight Director System (AFDS) modes are also shown. Each square along the x-axis represents 10 seconds.

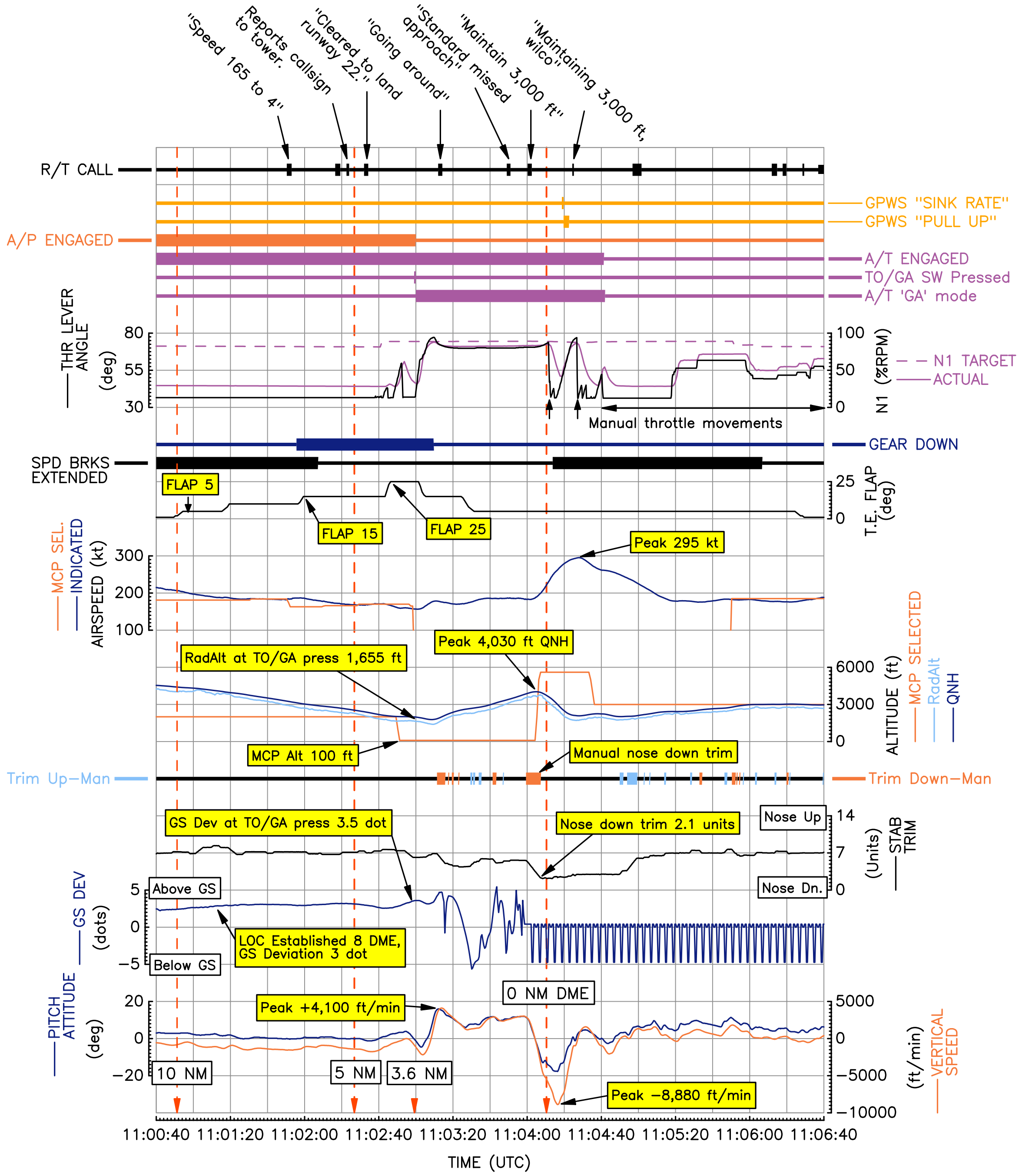


Figure 4

Pertinent parameters from the FDR, with R/T transmissions to ATC

At the time of the descent during the MAP, the FDR recorded a forward control column input by the PF. The FDR also recorded pilot-commanded nose-down stabiliser trim movements, until the stabiliser reached about 2.5 units of trim, and the spoilers being extended.

Stabiliser trim movements

The FDR recorded Flight Control Computer (FCC) 'up' and 'down' stabiliser trim commands, and manual (pilot) trim-switch 'up' and 'down' commands, as discreet parameters. The data indicated that the FCC commanded trim changes were normal. Manual trim inputs, and the position of the stabiliser trim (ranging from 0 units representing full nose-down trim, and 14 units representing full nose-up trim) are both shown in Figure 4.

The FDR indicated that the trim was manually commanded to a significant nose-down value of approximately 2.2 units, following ATC's prompt to maintain 3,000 ft following the level bust.

EGPWS Alerts

Logs were extracted from the EGPWS's memory and decoded with assistance from the manufacturer. The data indicated no faults, terrain inhibit events or inoperative statuses.

The data decoded for the incident flight was consistent with EGPWS activations recorded on the FDR, logging a single activation of the Mode 1 Inner Curve "PULL UP" warning, followed 0.03 seconds later by a single activation of the Mode 1 Outer Curve "SINK RATE" warning. Both activations occurred while EI-HET was above the runway flying on the runway heading, and after the commander had taken corrective action.

CVR

During the approach, there was no discussion to indicate that the flight crew were sharing their mental model as to where the aircraft was on a 3° CDA or considered the need to request additional track mileage to successfully intercept the ILS G/S. The first mention of how the approach was progressing, and that they might need to GA, was as the aircraft reached about 5 nm from touchdown, which is the point at which the operator's procedures required the approach to be discontinued if it was unstable, or not fully established on the ILS.

On the CVR, the EGPWS warning "SINK RATE. PULL UP, PULL UP" was heard during the recovery from the steep nose-down attitude.

Aircraft information

The operator's designation for this aircraft type is the Boeing 737-8200. It is a high-density seating version of the Boeing 737 MAX 8.

Autopilot and flight director

The automatic flight control system consists of the AFDS and the A/T. The AFDS and the A/T are controlled through the MCP and the flight management computer (FMC). The status of the AFDS and A/T are displayed to both pilots through Flight Mode Annunciators at the top of the PFDs. The F/D displays command bars on the primary flight display when a pitch and/or roll mode is selected on the AFDS.

The LVL CHG mode coordinates pitch and thrust commands to make automatic climbs and descents to pre-selected altitudes at selected airspeeds; these are displayed by the F/D. The A/T engages automatically when LVL CHG is engaged.

In manual flight, all MCP mode selections will be called for by the PF and made by the PM.

The operator's Flight Crew Operations Manual (FCOM), stated that the A/P can be reengaged during a GA once the aircraft has levelled off at the MAA after the flaps have been retracted. The MAA is to be set in the MCP altitude display once the G/S is captured.

Go-around mode

The Boeing 737-8200 is a dual A/P, CAT III approach and landing capable aircraft. Normal manual landing procedures require the use of a single A/P on an ILS approach unless the intention is to conduct an automatic CAT II or III approach and landing. Automatic GA are only available from a dual A/P approach. The AFDS GA mode is engaged by pressing one of the TO/GA switches located on the thrust levers. Pressing either of the switches when the engagement criteria are met will disconnect the single A/P (if connected) and place the F/D in GA mode. The A/T (if engaged) will move to GA thrust, and the F/D will then command 15° nose-up pitch. The handling pilot would then follow the F/D commands and level the aircraft at the altitude selected in the MCP altitude display. Below 2,000 ft radio altitude, one press of a TO/GA switch will cause the A/T (if engaged) to advance to a power setting for a climb rate between 1,000 and 2,000 ft/min. With two presses of a switch, the A/T (if engaged) will advance to the full GA N_1 limit. Above 2,000 ft radio altitude, one press of a TO/GA switch commands thrust to the full GA N_1 limit. The GA was initiated below 2,000 ft.

Autopilot altitude modes

The AFDS can capture and hold an altitude pre-selected in the MCP display window. These modes are ALT ACQ and altitude hold (ALT HOLD). When the AFDS is engaged in TO/GA mode, the pitch mode will change to ALT ACQ when approaching the altitude selected on the MCP. ALT HOLD commands pitch to hold the selected altitude.

Flaps

The aircraft has eight stages of flaps; 1, 2, 5, 10, 15, 25, 30, 40. The speed limits for each stage of flaps are in Table 1:

Flaps	Limit (kt)	Flaps	Limit (kt)
1	250	15	200
2	250	25	190
5	250	30	175
10	210	40	166

Table 1

Boeing 737-8200 Flaps Limits

Organisational information

The operator flies both the Boeing 737-NG [Next Generation] and Boeing 737-8200 [MAX] variants with its pilots being qualified to fly both. The following procedures are the same for both types.

Operations Manual (OM) Part A

The operator's OM states that for approaches flown in IMC, the aircraft should be stabilised for landing before reaching 1,000 ft above the landing runway threshold elevation.

Boeing 737-8200 FCOM

The operator's FCOM stated in '*Landing Procedure – ILS…*', that after the G/S is captured, the MAA is checked in the FMC and then set by the PF, after which the PM cross-checks it. It also stated that when the aircraft is being flown manually, all MCP mode selections will be called for by the PF and made by the PM.

It also states that "SPEED" is to be called whenever the IAS is greater than V_{FLY} +10 kts or when the speed trend shows a significant tendency to exceed either of these parameters and thrust lever position is inappropriate for the phase of flight. V_{FLY} is the airspeed that is either selected by the crew, requested by air traffic or commanded by the FMC.

The operator's FCOM also stated the following:

'***Approach Procedure***

The configuration of Flaps 5, Speedbrake at Flight Detent and a speed of 220 knots is an effective initial speed/configuration mix. To assist further deceleration use 180 knots, flaps 10, and Speedbrake to Flight Detent, if necessary. This will give the best rate of descent per nautical mile.

Intercepting the Glide Slope From Above

Technique:

The following technique will assist the crew intercept the G/S safely and establish stabilized approach criteria by 1,000 ft AFE [above field elevation].*in IMC and 500 ft AFE in VMC:*

1. *Establish on LOC.*
2. *Set the MCP altitude no lower than 1,000 ft AFE. [1,400 ft for Stansted].*
3. *When cleared for approach, take time to validate G/S (distance/height cross check).*
4. *Arm APP Mode when within 1 dot above G/S.*
5. *Configure the aircraft to establish at least Flap 5 configuration, Flap 5 speed (maximum Flap 5 speed + 10 kts) by 2,000 ft AFE or the altitude specified on the approach chart if higher when conducting a procedural ILS approach.*

6. *Achieve G/S or Path capture by 5 nm…from the RW [runway] point for all ILS/GLS approaches and be fully stabilized by 1,000 feet AFE in IMC...*

Note: It is policy to establish on the glideslope by 5 nm…from the RW point for all ILS/GLS Approaches.

This procedure provides a 'stabilized' glideslope capture target of 5 nm…from the RW point for all ILS/GLS approaches, at or below 180 kts, while the 1000 ft AFE in IMC and 500 ft AFE in VMC landing gate limits remain in place.'

There was no mention of resetting the MCP altitude display to the MAA in the above '*technique*'. However, the operator commented that as the *Landing Procedure* should still be completed after the G/S has been captured, the MAA should be set and checked.

As a result of this serious incident the operator has introduced a *Discontinued Approach* procedure in its FCOM. This new procedure was reviewed by the manufacturer and approved by the operator's National Aviation Authority. See Appendix A.

Fatigue

The commander and co-pilot were both on their fourth day of five days consecutive work, all with report times before 0700 hrs. Prior to this they were on leave for three weeks, which the co-pilot spent in a time zone five and a half hours ahead of the local time in Stansted.

On the day of the incident the crew reported for duty before 0555 hrs. This was the first time they flew together during this block of work.

The co-pilot stated that although he felt he had adequately rested and was fit to fly, he did feel tired. He added that he probably felt like this as his period of leave was spent in a hotter climate and a few days after this incident he became unwell with a cold.

The investigation collected and analysed sleep and work history and physiological information for both flight crew. This information did not indicate the presence of any fatigue risk factors on the day of the incident, or in the days prior.

Somatogravic illusion assessment

Somatogravic illusion[10] is one of the most common forms of vestibular or 'false sensation' illusions which is typically experienced during linear acceleration or deceleration when climbing or descending. In an acceleration case, this can cause a pilot to perceive that the aircraft is pitching up more than it actually is, leading them to push on the control column to overcome their perception.

Footnote

[10] More information on somatogravic illusions can be found here: https://skybrary.aero/articles/somatogravic-and-somatogyral-illusions [accessed September 2024].

The aircraft manufacturer reviewed the flight data using its ‘Spatial Disorientation Investigation Tool’ (SDiT) to see what the potential was of the GA to induce spatial disorientation to the pilots. The results of this indicated that the perceived pitch angles and pitch rates may have been different from the recorded values, indicating the potential for spatial disorientation during this GA. It is important to note that these results are not a guarantee that disorientation did take place, only that the recorded conditions indicated it was a possibility.

Other events

The AAIB has investigated other GA incidents which have similarities to EI-HET[11], and the Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile (BEA) published a report into a similar incident at Paris Orly Airport[12].

The operator had a GA incident at Eindhoven Airport, the Netherlands, in May 2013 that was investigated by the Dutch Safety Board[13]. As a result of this event the operator issued guidance in its FCOM on capturing a G/S from above.

Aircraft inspection

Following this event, the operator’s engineers completed overspeed checks including on the aircraft’s flaps and slats. No damage was discovered, and the aircraft was returned to service two days later.

Analysis

Initial approach

EI-HET was conducting a radar vectored CAT I ILS approach in IMC to Runway 22 at Stansted Airport, where its crew were based. As the aircraft was in IMC throughout this serious incident, there were no external visual cues with which to assist the crew in maintaining spatial orientation. They were thus reliant on the aircraft’s flight instruments. The volume of air traffic in the area at the time was described as low, and there was no perceived pressure on the flight crew or the ATCO’s. Between approximately 20 and 15.5 nm from touchdown the aircraft was close to being on a 3° CDA. During this period, believing that the aircraft was a little high for a CDA, the ATCO gave the aircraft a heading adjustment to give it more track mileage to lose some height.

Footnote

[11] Report into the serious incidents involving G-FDZF, https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-737-8k5-g-fdzf [accessed September 2024], G-THOF, https://www.gov.uk/aaib-reports/aar-3-2009-boeing-737-3q8-g-thof-23-september-2007 [accessed September 2024], and I-NEOT, https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-737-86n-i-neot [accessed September 2024].

[12] https://bea.aero/en/investigation-reports/notified-events/detail/serious-incident-to-the-boeing-737-registered-7t-vjm-operated-by-air-algerie-on-06-12-2019-at-paris-orly/ [accessed September 2024].

[13] https://onderzoeksraad.nl/en/onderzoek/stick-shaker-warning-on-ils-final-eindhoven-airport/ [accessed September 2024].

By the time the aircraft was established on the LOC at 9 nm, the aircraft was at 3,863 ft aal, about 1,000 ft above the G/S, with Flaps 10 selected and with the G/S indicator showing 3-dots below. Had more stages of flaps been deployed, and possibly the landing gear lowered, prior to the LOC being captured this would have increased the aircraft's drag, and rate of descent, assisting it to capture the G/S.

At about 4 nm, and having recognised that they would be attempting to capture the G/S from above, the MCP altitude was incorrectly reset from their last descent clearance to 100 ft, about 10 seconds before the GA was initiated. It should have been set to 1,400 ft (1,000 ft AFE). Had it been reset earlier in the approach it would have offered the crew more time to notice the incorrectly set MCP altitude. This too would have avoided the aircraft entering ALT ACQ as it approached the last ATC cleared altitude of 2,000 ft amsl. This caused a distraction and a peak in the commander's workload as he had to reset the MCP to a lower altitude and select LVL CHG to keep the aircraft descending. Given these multiple MCP selections it is possible that the commander set the MCP altitude in haste without checking it. Whilst the crew may have believed they could have captured the G/S within the limits specified in the operator's OM, this was not achieved, and they correctly decided to conduct a GA. As the MCP altitude was still set to 100 ft, and not the MAA, the F/Ds would not have commanded a level off. Whist the operator's *Landing Procedure - ILS* stated that the MAA should be set and checked at G/S interception, there was nothing explicit in the G/S from above technique to give the crew guidance on when to set the MAA. However, the operator commented that it was implicit given it is to be checked as part of the Landing Procedure.

At no point during the approach did either crew member share their mental model as to where they thought the aircraft was on the 3° CDA profile until the likelihood of a GA was mentioned by the commander at about 5 nm. It is essential that flight crew share their mental model throughout all phases of flight so that if there is a discrepancy this can be discussed in good time so prompt action can be taken to resolve the issue, before more positive action, like a GA, is required.

Missed Approach Procedure (MAP)

The initial part of the GA was correctly flown, despite the commander stating he was fixated on the F/Ds. This fixation was probably a result of the high workload experienced during the instrument approach, which subsequently increased, along with some startle factor, when the GA was initiated. Had the MAA been set correctly it is likely the commander would have followed the F/Ds and levelled the aircraft at the required altitude of 3,000 ft. However, with an MCP altitude below that of the aircraft, the F/D continued to command a climb until either an altitude above the aircraft was set or there was some manual flying intervention by the PF, with the latter being the case in this event. Once the crew recognised they had flown through the MAA they established a descent to correct the situation.

The GA was initiated at 3.6 nm and 1,940 ft amsl. Once the aircraft was in the climb, with GA power applied, there was little time to recognise the lack of guidance from the flight director to capture the altitude and level off at 3,000 ft without guidance from the F/Ds. However, as there was no urgency to commence the GA at this point, had the crew continued with the approach for about another 2 nm, it would have given them about 40 seconds to conduct a 'mini-brief' in which they could remind themselves of their actions in the GA and given them the opportunity to check the MAA was set correctly.

Whist the commander recognised he needed to lower the nose to descend, which he initially set between 5 and 10° nose-down, the subsequent nose-down attitude was probably a result of the push on the control column, a nose-down trim input and a pitch/power couple when the thrust levers were closed from a high-power setting to idle. At this time the MCP altitude was reset by the commander, initially to 5,600 ft, probably in haste, before being correctly set to the MAA of 3,000 ft. Had he requested the co-pilot to do this, as stated in the FCOM, he would have had more of his limited capacity available for his primary task of flying the aircraft.

During the descent the aircraft reached a maximum pitch of 17.7° nose-down, a descent rate of 8,880 fpm, and an airspeed of 295 KIAS with Flaps 5 extended; the lowest recorded height was 1,740 ft agl. The commander recognised the excessive nose-down attitude and initiated a recovery just before the EGPWS was triggered. Had he not initiated the recovery before the warning occurred, the EGPWS's aural and visual warnings were a safety barrier that would have alerted the crew to the high rate of descent close to the ground, and this should have caused them to take appropriate recovery actions.

The co-pilot's first call of "SPEED" was during the descent from 4,000 ft, when the aircraft was at about 235 KIAS and accelerating. This was about 40 kt greater than the OM requirement to call "SPEED" at 195 KIAS (V_{FLY} +10). This delay in calling "SPEED" could be explained by the co-pilot experiencing some form of startle and surprise by the dynamic nature of the manoeuvre. His attention may also have been focused elsewhere in the cockpit before he recognised the situation.

The GA was initiated at 3.6 nm. Given there was no urgency to initiate it, the crew could have elected to continue with the approach until about 1 nm from touchdown, assuming the MCP altitude had been reset to the MAA. Given the aircraft was flying at about 180 kt, it gave the crew about 40 seconds in which to compose themselves and brief what actions they were each going to perform during the GA, including a check that the MAA was set correctly. Had it been set when the GA was initiated this serious incident probably would not have occurred.

There are three SIDs, from Runway 22, that route to the north of the airport, all with an initial climb clearance of 4,000 ft amsl. Had an aircraft departed close to the time EI-HET initiated the GA there was a possibility that the two aircraft may have come into conflict with each other.

Somatogravic illusion

The manufacturer's study of this event suggested that there was potential for spatial disorientation during this GA. However, given that the commander was predominately fixated on the F/D during the GA and there was no significant pitch down input until after the level bust, it is more likely that the push on the control column was a response to the PF realising they had flown through their cleared altitude of 3,000 ft amsl, rather than any perceived visual illusion. Hence it is unlikely that the commander experienced spatial disorientation.

Conclusion

This serious incident occurred because the Missed Approach Altitude (MAA) was not set in the Mode Control Panel (MCP) before a go-around was performed. It was not set to the MAA because the flight crew were attempting to intercept the glideslope from above. This required the MCP selected altitude to be set to a height below the aircraft, and the MCP selected altitude was not adjusted to the MAA following the decision to go-around before it was executed.

The approach and go-around were flown in instrument metrological conditions (IMC) and hence the pilots had no external visual references. During the go-around the pilot flying was fixated on the Flight Directors and did not recognise that they did not command a level off at the MAA until it had flown through it.

The subsequent recovery manoeuvre from the level bust was probably exacerbated by the thrust levers being moved from a high-power setting to idle resulting in an excessive nose-down attitude, rate of descent and IAS for the aircraft's configuration. Given the aircraft's height during this descent the Enhanced Ground Proximity Warning System was triggered just after the commander had initiated a pitch up into a climb back to the MAA.

This serious incident involved a Boeing 737-8200 [MAX]. It could have occurred in any variant of the Boeing 737, or any other type of aircraft with similar autopilot and flight director systems. There have been other serious incidents, with similarities to the EI-HET that have been investigated.

Safety actions

As a result of this serious incident the operator has taken the following safety actions:

Re-emphasised to all pilots the correct go-around procedure via a mandatory learning module.

Introduced a training package covering high energy approaches and all engines go arounds, demonstrating non-standard or unexpected go-around conditions, in their 'summer 2024' recurrent training package.

Introduced a 'Discontinued Approach Procedure' in June 2024 that can be used when an approach is ceased prior to glideslope capture or if the approach gate requirements in its operations manual cannot be achieved. This was backed up with a *Chief Pilot Alert* to all pilots, via their portable electronic devices, highlighting this serious incident and the new procedure. This procedure is included in Appendix A below.

Appendix A

Discontinued Approach

As a result of this serious incident the operator introduced the following procedure in the *Normal Procedures* of its FCOM.

> ‘***Discontinued Approach***
>
> *The Discontinued Approach procedure shall be utilised to confirm AFDS selections and aircraft configuration prior to commencing a Go Around above the 500’ stabilized approach call when:*
>
> - • *Not in the landing configuration and,*
> - • *Above minimums.’*

Pilot Flying	Pilot Monitoring
Call “Discontinued Approach”.	
Retract speedbrakes.	
The PF shall point to the Missed Approach Altitude on the FMC LEGS page and call “XXXX FEET”. The PF shall then set the Missed Approach Altitude in the MCP Altitude, point to it and call “SET”.	
	Verify correct MAA displayed on the PFD and call “XXXX CHECKED”.
Confirm landing gear configuration.	
Confirm flap configuration.	
Call “Ready?”.	
	Verify all needed actions have been completed and callout any omissions. Call “Ready” once confirmed.
If below the MAA: • Push TO/GA, • Call “GO-AROUND FLAPS __.” • Conduct the go-around procedure appropriate to the current configuration*. If at or above the MAA: • Confirm AFDS status. • If required, de-tune ILS frequencies. • Select / verify appropriate roll mode. • Select / verify appropriate pitch mode. • Level off at the MAA. • At ALT HOLD, bug up, retract flaps & gear on schedule. • Perform the AFTER TAKEOFF checklist.	
* Note: If Flaps greater than 15, call/select 15. If Flaps are at 15 or less, initially leave flaps at current setting. Retract flaps & gear on schedule.	

Published: 21 November 2024.

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 take off 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	

Synopsis

When the crew began their takeoff, the autothrottle (A/T) disconnected when the Takeoff/Go-Around switch (TOGA) was selected. As a result, neither thrust lever advanced automatically towards the calculated N_1 takeoff setting. Despite attempting to re-engage it, the A/T remained in an inactive mode. The takeoff was conducted with 84.5% N_1 instead of 92.8% N_1, with the associated reduction in aircraft performance. The rotation occurred close to the end of the runway and the aircraft climb rate was initially very slow. The crew increased power on the engines towards the takeoff setting from 450 ft aal. The rest of the flight to Las Palmas was completed without incident although the A/T remained unavailable. The uncommanded disconnect was likely the result of the voltage being supplied to the autothrottle servo motor (ASM) being too low which was a known problem with the B737 A/T and the older revision of the ASM part fitted to G-FDZS.

The operator has taken a number of safety actions to address both the actions to be taken in the event of an uncommanded disconnection of the A/T at takeoff, and their monitoring of events through flight data monitoring.

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 stabilize before pressing the 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. Both pilots believed that the A/T was engaged, and they expected it to function as if in TOGA mode from this point.

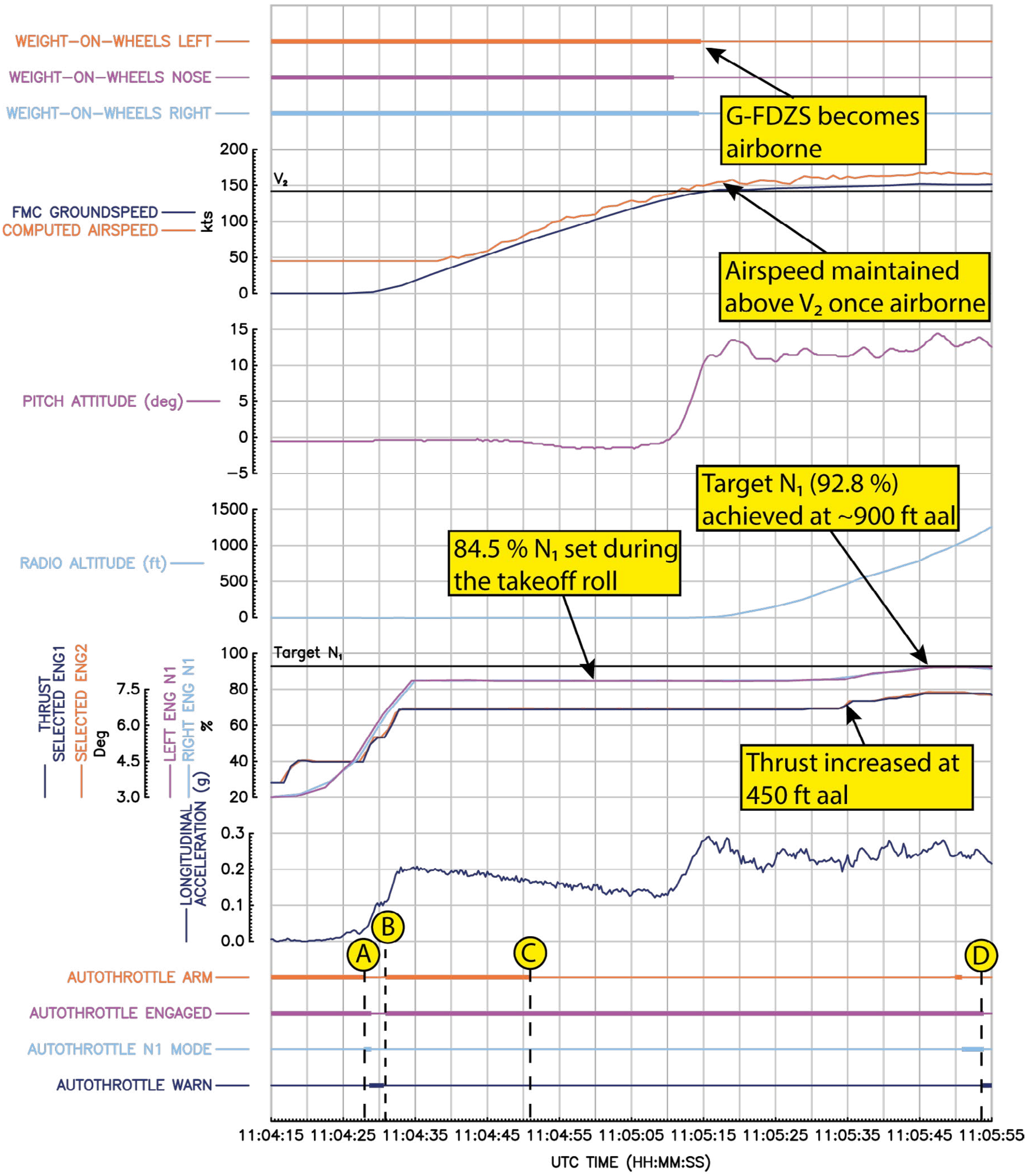
When the A/T arm switch was re-engaged on the MCP after initial A/T disengagement, it did not control the thrust lever servos as the pilots expected and instead entered an armed mode. As a result, the thrust levers did not advance to the required thrust setting and neither pilot moved them from the position 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 information

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 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 transitions 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.

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 the rate monitor logic within ASM 1

The fault record indicates the suspected cause of the uncommanded A/T disconnection as the rate monitor logic within ASM 1, the A/T servo motor for the No 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.

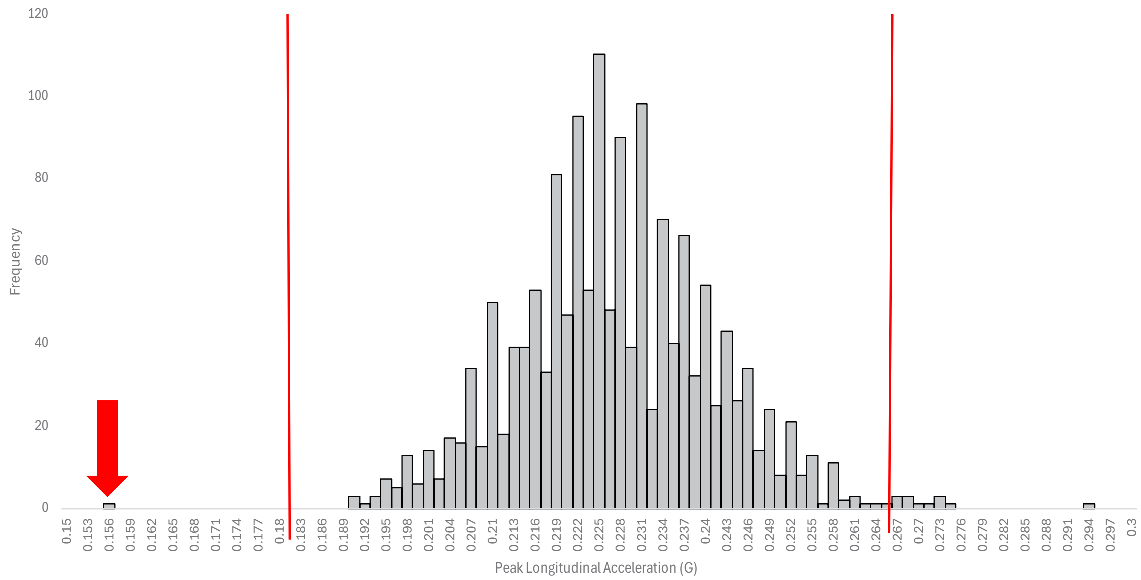


Figure 4

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

Aircraft information

The Boeing 737-800 is a twin turbofan narrow body aircraft used mainly in short and medium haul flights. The B737-800 is part of B737 Next Generation[1] (B737NG) series of aircraft. G-FDZS is fitted with 189 passenger seats.

Arrangement of displays

The B737-800 has six LCD screens arranged with two screens in front of each pilot and the remaining two in the middle, one on top of the other (Figure 5). The engine gauges are displayed on the top screen of these two, in the middle on what is called the Upper Display Unit (Upper DU). The aircraft N_1 gauges are displayed at the top of the upper DU and are visible all the time. The Upper DU also displays the engine gas turbine temperature and the fuel flow for both engines as well as some warning lights and the fuel gauges.

Footnote

[1] This was the third generation derivative of the Boeing 737 and includes the B737-600,-700,-800 and -900

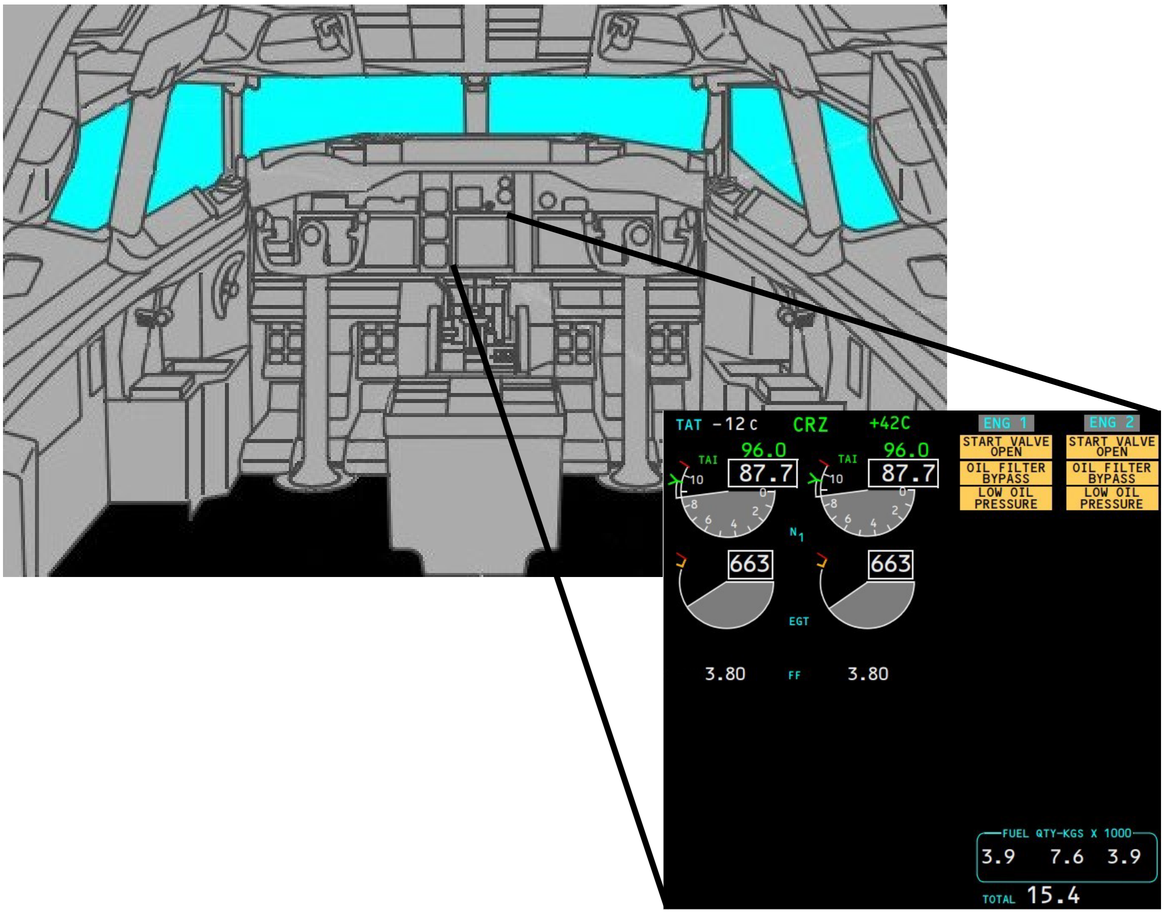


Figure 5

B737-800 screen arrangement with Upper DU location and display

N_1 Gauges

The N_1 gauges at the top of the Upper DU display a large amount of information to the pilots in both pictorial and digital formats (Figure 6). The actual N_1 is indicated on the gauge by the white needle with a grey shaded area behind it. The difference between the actual N_1 and that commanded by the thrust leaver position is showed with a white arc (not shown on the diagram). The reference N_1 is shown as a green bug. Both the actual N_1 and reference N_1 are also shown in digital figures. The maximum N_1 is indicated by an orange line and is the N_1 for full rated thrust, whilst the N_1 operating limit is indicated by a red line.

During takeoff the green bug and green reference digital reading should match the calculated N_1 to be used for takeoff. With the AT engaged and TOGA switch pressed, thrust levers should move toward the bug and the white needle and white digital readout of actual N_1 should then match the green bug and green digital figure.

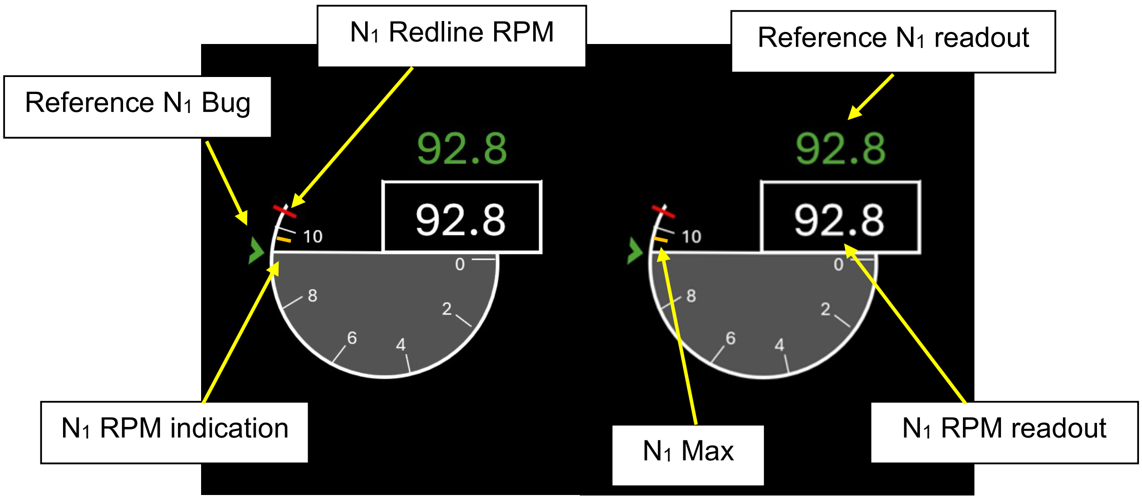


Figure 6

N_1 gauges G-FDZS

A/T system

The B737-800 A/T system provides for automatic thrust control during all phases of flight from takeoff to landing. The A/T moves each thrust lever with a separate servo motor to comply with the computed thrust requirements except when in either throttle hold (THR HLD) or ARM modes. The ASMs are supplied with two power sources via the flight control computer (FCC) one to power intern electronics (logic power) and one to power the internal motor (motor power). Motor power is only provided when a change of throttle position is required. The ASMs internal electronic control has a minimum power supply voltage level below which the motor part will not respond; leading to the FCC disengaging the A/T function. There needs to be a higher voltage restored for the motor to start responding to the FCC's demands for movement.

A/T modes on takeoff

The A/T is armed by selecting the switch on the mode control panel (MCP) to ARM. Although the A/T is armed, the ASM logic is powered but the separate motor remains unpowered as the FCC is yet to demand a change in throttle position. When the PF pushes the TOGA switch, the A/T will enter N_1 mode and the FCC will command the ASMs to move the thrust levers to the position required by the calculated FMC takeoff thrust at the same time providing power to the ASM motors. At 84 kt during the takeoff run, the A/T engages THR HLD mode. This mode removes power from the ASM motors, although the ASM logic is still powered, to ensure that there is no uncommanded movement of the throttles during the rest of the takeoff. The A/T remains in this mode until 800 ft above airfield elevation when the mode changes to ARM and a reduction to climb thrust at the FMC selected thrust reduction altitude can be made automatically by the AFDS with the A/T engaging in N_1 mode. Power is only restored to the ASM motors by the FCC when N_1 mode becomes active and a change in throttle position is commanded. The A/T will automatically disengage when a system fault is detected.

These modes are displayed to the pilots, as well as those of the AFDS, on the top section of the pilots primary flying display as flight mode annunciations.

Airfield information

Bristol Airport has a single runway orientated east/west. Runway 09, which was the one in use for the takeoff has an Accelerate/Stop Distance Available (ASDA)[2] and Takeoff Run Available (TORA)[3] of 2,011 m. The Takeoff Distance Available (TODA)[4] of 2,133 m. This gives a runway clearway[5] of 122 m. Beyond the end of runway 09 (ASDA/TORA) is 296 m until the airfield perimeter fence which includes the 122 m of clearway. On the other side of the perimeter fence is the A38 road.

Meteorology

The weather at Bristol airport was good with no cloud detected and visibility more than 10 km. The wind was south-easterly and gave between 5 and 15 kt headwind throughout the period that the aircraft was on the ground at Bristol.

Aircraft performance

The crew calculated the aircraft performance using an electronic flight bag tool provided by the manufacturer. The crew entered the passenger and baggage details to generate the aircraft weight and balance before entering the details of the weather at Bristol. The program then generated detailed performance such as flap setting, any derating (fixed or assumed temperature), as well as V speeds and the airborne procedure to be followed in the event of an engine failure.

The performance calculation done by the crew was correct, and the details were correctly entered into the flight management computer (FMC). This gave a flap setting of 15, a fixed derate to TO-2[6] with no assumed temperature reduction and speeds of V_1 136, V_R 136 and V_2 142.

The takeoff performance using the thrust that was actually set was to the extreme left of the normal distribution curve in post-incident analysis conducted by the operator (Figure 4) and the aircraft did not make the regulated performance requirements. The aircraft passed the upwind threshold of the runway at approximately 10 ft with both engines operating.

Footnote

2 Accelerate-stop distance available means the length of the takeoff run available plus the length of stopway, if such stopway is declared available by the State of the aerodrome and is capable of bearing the mass of the aeroplane under the prevailing operating conditions.
3 Takeoff run available means the length of runway that is declared available by the State of the aerodrome and suitable for the ground run of an aeroplane taking off.
4 Takeoff distance available in the case of aeroplanes means the length of the takeoff run available plus the length of the clearway, if provided.
5 Clearway means a defined rectangular area on the ground or water under the control of the appropriate authority, selected or prepared as a suitable area over which an aeroplane may make a portion of its initial climb to a specified height.
6 Fixed derate is a derated takeoff thrust and is a certified takeoff thrust rating lower than full rated takeoff thrust. TO-2 is a 20% reduction.

Unfactored calculations by the aircraft manufacturer indicated that with no increase in thrust, had an engine failed at V_1 and the crew decided to stop, the aircraft would probably have stopped on the runway as long as the crew had used maximum reverse thrust. Had the crew elected to continue or if the engine failed above V_1, calculations indicate that the aircraft would not have been able to climb away without the application of more power. Figure 7 shows some of this data on a graphic of Bristol Airport.

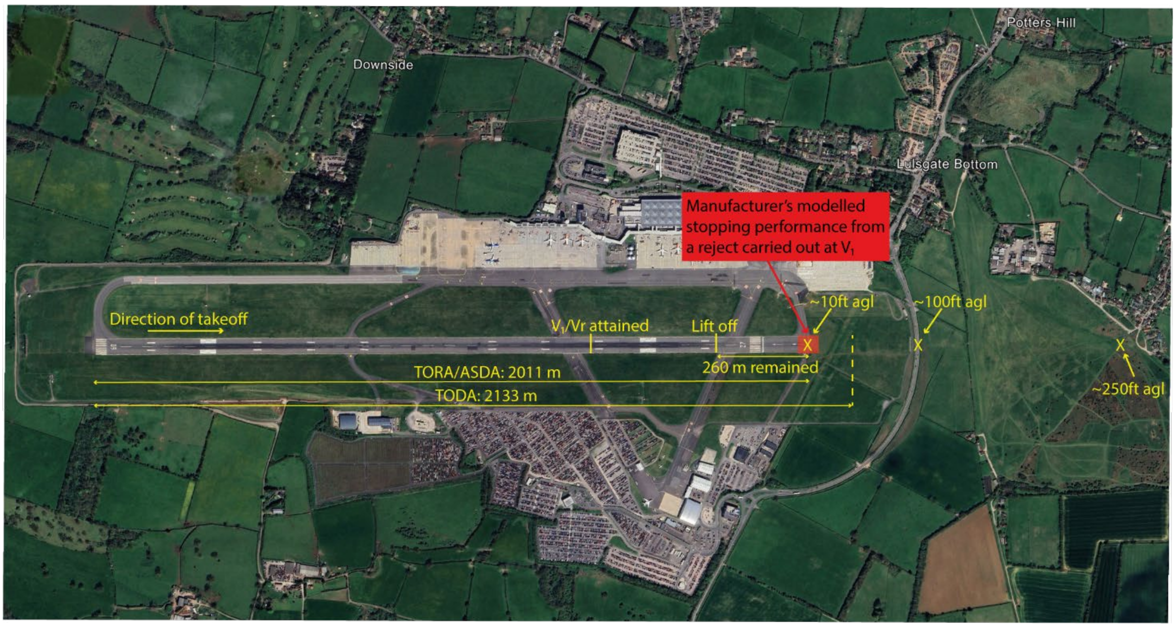


Figure 7

Graphic of G-FDZS's takeoff from Bristol Airport
© 2024 Google, Image © 2024 Airbus

Personnel

Both pilots had significant experience on the B737-800. The pilot in the left seat was a new commander under training for whom this was the eleventh flight sitting in that seat. He had completed a number of simulator sessions in the left seat as part of his command training course before beginning his training in the aircraft. The pilot in the right seat was a training captain and was the aircraft commander. He was qualified to operate in either seat and his recent flying had been split evenly between the two seats.

Changing seats can be challenging as the location of items shifts in the pilot's field of view and a pilot's mental scan pattern can be disturbed, with it requiring more mental effort to locate and read instruments and gauges. For the new captain sitting in the left seat this is also compounded by the unfamiliarity of a new role especially on departure with the added responsibilities including the need to taxi the aircraft.

The B737-Max displays are subtly different from those in the B737-800 with the engine gauges remaining identical but in a different position. The B737-Max has four large LCD screens in a row across the flight deck with the operators practise to have the engine instruments displayed on the inboard screen of the PM. Whilst this may seem a small movement, it requires an adaption in the visual scan for both pilots as they move from one type to the other.

B737-Max also requires a lower thrust setting on takeoff than the B737-800 with N_1 figures often in the eighties. A calculation using the actual passenger and baggage load for the incident flight, using a representative fuel figure for the B737-Max showed that an N_1 of 85% would have been required for a takeoff in the conditions of the day. This figure is close to that on the actual takeoff. Both pilots recent experience had been almost exclusively flying the B737-Max rather than the B737-800.

The takeoff is a dynamic part of the flight with both the PF and PM engaged in multiple tasks as the aircraft accelerates and gets airborne. Combined with the limitations in the human detection and processing systems, the crew are unlikely to detect that the aircraft is not accelerating as calculated until the visual picture alerts them to the rapidly approaching runway end. At this point evidence from many previous incidents also indicates that they are unlikely to select full thrust to improve their predicament.

Both crew members would have been expecting the A/T to function when it was re-engaged after the initial drop out and did not notice that it was not in an active mode. They did not fully appreciate that the A/T would only be in arm mode with the servo motors unpowered. Neither crew noted that the displayed N_1 did not match the reference N_1. The PF commented that he was busy with trying to align the aircraft with the centreline and probably did not glance at the gauges at the 80 kt check. It is likely that the PM glanced at the gauges and noted the green number without processing that the white number did not match it. Both crew members would have been expecting to see the thrust at the reference N_1 as that is the expected behaviour of the A/T.

Procedures

Before start procedures

As part of the before start procedures both pilots must complete independent calculations of the aircraft performance using the computer programme provided and the actual takeoff weight from the loadsheet. When both pilots have completed the calculation the left seat pilot calls out the data which is verified by the right seat pilot as identical to his calculation. The left seat pilot then enters the required acceleration altitudes (all engines and single engine) into the FMC before the right seat pilot enters the results of the performance calculation including any derate and/or assumed temperature. The left seat pilot then calls out the figures from the FMC (including the N_1 figure) which the right seat pilot verifies against his calculation. The left seat pilot then sets the A/T arm switch to ARM.

Takeoff procedures

G-FDZS has nosewheel steering only on the left side of the flightdeck and therefore must be taxied by the left seat pilot. Having taxied the aircraft onto the runway and lined up with the centreline, should the right seat pilot be PF, then control must be handed over at this point. The duties are then separated by PF/PM roles as in Table 1 once takeoff clearance is obtained:

Pilot Flying (PF)	Pilot Monitoring (PM)
Advance the thrust levers to approximately 40% N_1. Allow the engines to stabilize.	
Push the TO/GA switch.	
Verify that the correct takeoff thrust is set.	
	Monitor the engine instruments during the takeoff. Call out any abnormal indications. Adjust takeoff thrust before 60 knots as needed. * During strong headwinds, if the thrust levers do not advance to the planned takeoff thrust, manually advance the thrust levers before 60 knots. Call “THRUST SET”
After takeoff thrust is set, the captain’s hand must be on the thrust levers until N_1	
Monitor airspeed. Maintain light forward pressure on the control column.	Monitor airspeed and call out any abnormal indications.
Verify 80 knots and call “CHECK.”	Call “80 KNOTS.” **

Table 1

Takeoff procedures

* The manufacturers Flight Crew Training Manual (FCTM) states the PM should:

> *‘Ensure the target N_1 is set by 60 knots. Minor increases in thrust may be made immediately after 60 knots to reach the target N_1.’*

** The FCTM states the PM should:

> *'verify that takeoff thrust has been set and the throttle hold mode (THR HLD) is engaged. A momentary autothrottle overshoot of 4% N1 may occur but thrust should stabilize at +/- 2% N1, after THR HLD. Thrust should be adjusted by the PM, if required, to - 0% + 1% target N1. Once THR HLD annunciates, the autothrottle cannot change thrust lever position, but thrust levers can be positioned manually.'*

The FCTM also states that

> 'with any autothrottle malfunction, the autothrottle should then be disconnected and desired thrust set manually'.

Displayed thrust

The reference N_1 was set in the FMC at 92.8% as per the performance calculation completed before departure from the stand. This reference N_1 was displayed on the N_1 gauges as previously described. During the takeoff run, after the A/T had disengaged, the selected N_1 was 84.5%. A demonstration of what the N_1 gauges should have looked like compared to the actual N_1 used for takeoff is shown at Figure 8.

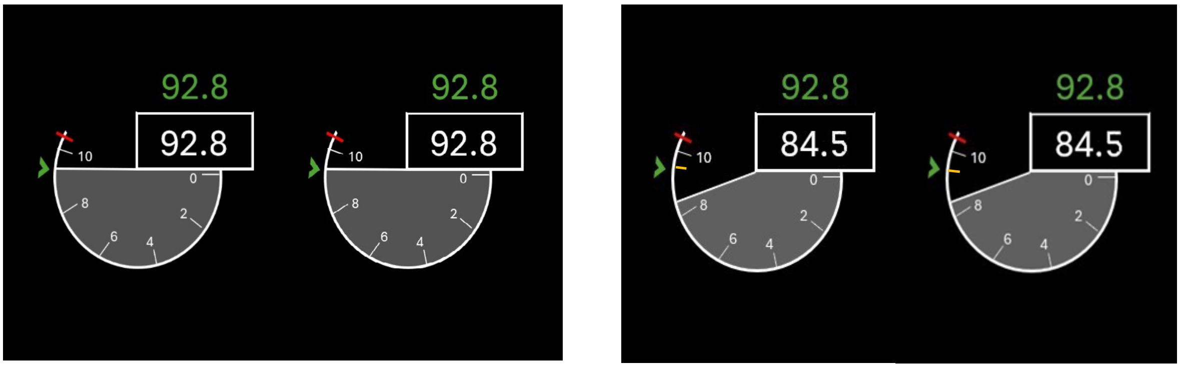


Figure 8

N_1 display as should have been (left) and with the N_1 used for takeoff showing (right)

Malfunction and emergency procedures

The manufacture produces a Quick Reference Handbook (QRH) which details the actions the crew need to take in the event of a malfunction or emergency. The QRH details the rejected takeoff manoeuvre and states that '*The captain has the sole responsibility for the decision to reject the takeoff.*' It goes on to list the reasons to reject the takeoff before 80 kt which includes '*system failure(s)*'. The manufacturer considered that the failure of the A/T to stay engaged in TOGA is a systems failure and should therefore resulted in a rejected takeoff.

The commander of G-FDZS was not sitting in the left seat and the left seat trainee captain was new to the role. In this configuration whilst the captain in the left seat could make the decision and carry out the reject actions, the training captain in the right seat, as aircraft commander, also had authority to decide and action a rejected takeoff. The training captain had received additional training for this scenario.

Other information

The manufacturer described the A/T system on the B737NG 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 as was the case with G-FDZS.

As a result of these reported uncommanded A/T disconnects the aircraft manufacturer together with the servo motor manufacturer analysed the possible cause. This analysis determined that it was likely that the voltage supplied to the servo motor dropped below that required and the motor remained stationary as a result. On occasion, such as occurred with G-FDZS, the voltage did not recover to a sufficient level for the servo motor logic electronics to start up again and so the A/T remained disconnected despite the crew attempting to re-engage it.

The original servo motor type had required remodelling due to an obsolescence issue, and this allowed adjustments to the characteristics of the new model during its development. These adjustments meant that the circuits in the ASM could restart at a lower voltage than the original model. These adjustments proved successful in significantly reducing the occurrence of uncommanded A/T disconnects. The newer model of ASM was introduced into the manufacturing line in 2017, but there was no requirement to retrofit the newer part to previously manufactured aircraft.

The manufacturer recommends that any operators of the B737NG who are affected by these disconnects should retrofit their aircraft with the newer model of ASM and associated FCC software. The manufacturer released a Fleet Team Digest in October 2021 detailing the issue and the available Service Bulletin (SB) for replacement. The Fleet Team Digest was revised in August 2022. At the time of this event G-FDZS was fitted with the earlier model of ASMs.

Analysis

During the takeoff at Bristol, the A/T disconnected uncommanded by the crew when the TOGA switch was pressed. Despite an attempt by the crew to select the A/T ON again, it did not engage in an active mode and therefore did not move the thrust levers to the takeoff N_1 setting as the crew expected. Despite the SOPs requiring both crew to check the N_1 setting at 80 kt, the thrust was not set as calculated and the takeoff was performed with a significantly reduced N_1. This resulted in the aircraft rotating close to the end of the runway and climbing at a very low rate until the crew started to increase the thrust at 450 ft aal.

Recognition of the issue

Previous investigations completed by the AAIB into takeoff performance errors have shown that the crews are very unlikely to notice any reduction in acceleration rates until the end of the runway becomes increasingly close to their position. Their actions at this point also rarely include the selection of full thrust in order to improve the acceleration and rate of climb of their aircraft. The performance of the crew of G-FDZS in this respect was therefore as expected from previous event analysis.

The crew also had some additional challenges in their performance in their familiarity with the seats in which they were sat as well as the change in position of the N_1 gauges from the aircraft they flew more regularly (B737-Max) to G-FDZS (B737-800). They were also more used to flying the B737-Max where the N_1 setting for takeoff was often close to that used on this takeoff. The SOPs for the aircraft type required both crews to check that the white digital readout of the N_1 set at 80 kts was the calculated N_1 for takeoff as shown as the green digital readout on the N_1 gauges. Both pilots missed the check, the PF as he was busy trying to straighten the aircraft on the takeoff roll, and the PM as he likely read only the green numbers without checking them against the white numbers below. The takeoff roll is a busy and dynamic phase of flight.

Response to the disconnect

The PM attempted to re-engage the A/T immediately but it had disconnected and although it seemed to have been successful, the A/T remained in an inactive mode with no control over the thrust lever servos and therefore no ability to move the thrust levers towards the target N_1. The manufacturer stated that such an uncommanded disconnect should be considered by the crews to be a systems failure and therefore fall into the reasons for a rejected takeoff. The reason for this is that it allows for the crews to consider the overall effect of a failure when the aircraft is stopped rather than during such a dynamic phase of flight. Such a rejection would have ensured that both crew members were fully aware of the fault, allowed them to consider a manual thrust takeoff and flight as well as consult with the operator and engineers as required.

Cause of the uncommanded disconnect

It is likely that the uncommanded disconnect of the A/T was caused by low voltage to the ASM when TOGA was selected. This issue is one widely known to the manufacturer. The aircraft manufacturer and ASM manufacturer investigated the nuisance disconnects on the 737NG and produced a new design of ASM which was more resistant to the problem and therefore less likely to have uncommanded disconnects. Whilst the fitment of the new design of ASM is not mandatory, the manufacturer does recommend that operators should retrofit their aircraft when they experience problems. G-FDZS was fitted with the original model of ASM on both throttles.

Conclusion

Having selected the TOGA switch to begin the takeoff roll at Bristol, the A/T disconnected. The crew reselected the A/T, but it did not re-engage in an active mode and did not control the throttles as the crew expected. Neither crew realised that the thrust was not set as required for takeoff but was significantly less than had been calculated during the pre-flight preparation. As a result, the aircraft performance was significantly compromised. The uncommanded disconnection was likely caused by low voltage being supplied to the ASM which caused it to disconnect from the throttles. The issue is a well known one for which a new model of ASM, and updated FCC Software incorporating changes to reduce the incidence of uncommanded disconnects.

The operator took action to raise awareness of the issue and what actions are expected as well as strengthening their FDM programme to better monitor the occurrences. The manufacturer encourages any operators who experience nuisance disconnects to replace the ASM with the newer model and ensure a later standard of FCC Software loaded.

Safety actions/Recommendations

The operator took the following safety actions:

Flight data Monitoring

- Event trigger created for A/T disconnection during takeoff. The event allows an understanding the historical and current level of nuisance A/T disconnects being experienced.
- Further refinement of the slow acceleration trigger using the statistical analysis.
- Event trigger created for a N_1 Reference and actual takeoff thrust delta. This is part of a layered approach to give visibility of potential events which do not meet the required takeoff thrust. This event compliments the slow acceleration FDM trigger.

Flight Ops

- A safety alert was published immediately after the event to raise awareness. The alert has been reissued to give clear guidance that A/T disconnect is a system failure and meets the definition for RTO.

Further work

- Recommendation for any further training to be considered.
- Reliability of ASM will be recommended for review.

Published: 5 December 2024.

Accident

Aircraft Type and Registration:	Eurofox 912(S), G-CIEF
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2014 (Serial no: LAA 376-15218)
Date & Time (UTC):	26 July 2023 at 1115 hrs
Location:	Approx 1 mile to the east of Darlton Airfield, near Retford, Nottinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft Destroyed
Commander's Licence:	Light Aircraft Pilot's Licence
Commander's Age:	75 years
Commander's Flying Experience:	719 hours Last 90 days - 12 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

Following the successful tow and release of a glider at 3,000 ft, the accident aircraft G-CIEF began a descent to return to the departure airfield. The initial descent, during which the aircraft was in a right turn, appeared normal and consistent with previous flights. However, passing through 1,000 ft, the aircraft entered a left turn away from the final approach path for the airfield. The aircraft remained in a descending left turn until it struck a field approximately 1 nm from the airfield. The pilot was fatally injured.

There was no evidence of a technical malfunction. Although the postmortem report did not indicate that a medical event had occurred, on consideration of all the evidence available, including the pilot's previous medical history, the investigation determined that the pilot may have experienced a partial or full medical incapacitation which rendered him incapable of controlling the aircraft.

History of the flight

The pilot was both a powered aircraft and glider pilot. He was the trustee of a syndicate of five owners of G-CIEF, which was kept at the gliding club from which the accident flight departed. The aircraft was used regularly to conduct aerotow launches for the gliding club and was also flown for their own purposes by the syndicate members.

On the day of the accident flight, the pilot arrived at the gliding club and flew a short solo flight in the local area, departing just after 0800 hrs. He subsequently flew two aerotow launches, the first of which was released at 3,000 ft and the second at 2,000 ft.

The accident flight was an aerotow glider launch, with the glider being successfully released at about 3,000 ft to facilitate the training objective of the glider pilots who intended to conduct spin recovery training. The glider pilot reported that the tow and release were normal.

After the glider released from the aerotow rope, the pilot of G-CIEF began two right descending turns away from the glider, which was described by club pilots as the normal release procedure. The aircraft reached a maximum rate of descent of 3,000 ft/min before reducing to 2,000 ft/min. The descent was flown at approximately 90 kt and reached a maximum angle of bank of 45°. When the aircraft passed through the runway extended centreline, the rate of descent was approximately 1,800 ft/min. The aircraft altitude was 1,000 ft at a range of approximately one nautical mile from the runway threshold.

The aircraft then entered a left descending turn until it struck a field about 30 seconds after the turn commenced. The pilot was fatally injured. There was no radio call made by the pilot.

Accident site

The accident site was in a crop field (Figure 1). There was an initial witness mark on the ground which was made by the left wing then a small debris trail which led to the main accident site. Due to the high energy involved, the aircraft suffered structural break up as it hit the ground before finally coming to rest inverted approximately 33 metres from the initial impact point. There was no fire at the scene and fuel was recovered from both wing tanks.

Figure 1

Accident site

Recorded information

Recorded data

Data transmissions from a Flight Alarm (FLARM)[1] electronic conspicuity (EC) device fitted to the aircraft was recorded by two ground-based systems[2]. This provided the aircraft's GNSS derived position, groundspeed, and altitude during the accident flight. FLARM data was also available for flights flown earlier the same day. GNSS position and altitude data was also recorded by a software navigation application[3] that was operating on a tablet computer recovered from the wreckage.

The final seconds of the accident flight were also captured by a video camera (dashcam) fitted to a vehicle that was being driven westbound along the A57.

Accident flight

The aircraft and aerotow glider took off from Runway 23 at 1107 hrs and flew to the east of the airfield where they climbed to 3,200 ft amsl, at which point the glider released (Figure 2 and Figure 3, Point A). G-CIEF then made a descending right turn. Its descent rate initially reached about 3,000 ft/min but then gradually reduced to 2,200 ft/min as it completed a turn through 360°. The right turn continued for a further 270° at which point the aircraft started to roll out of the turn at an altitude of about 1,400 ft amsl. The bank angle during the right turns reached about 45°.

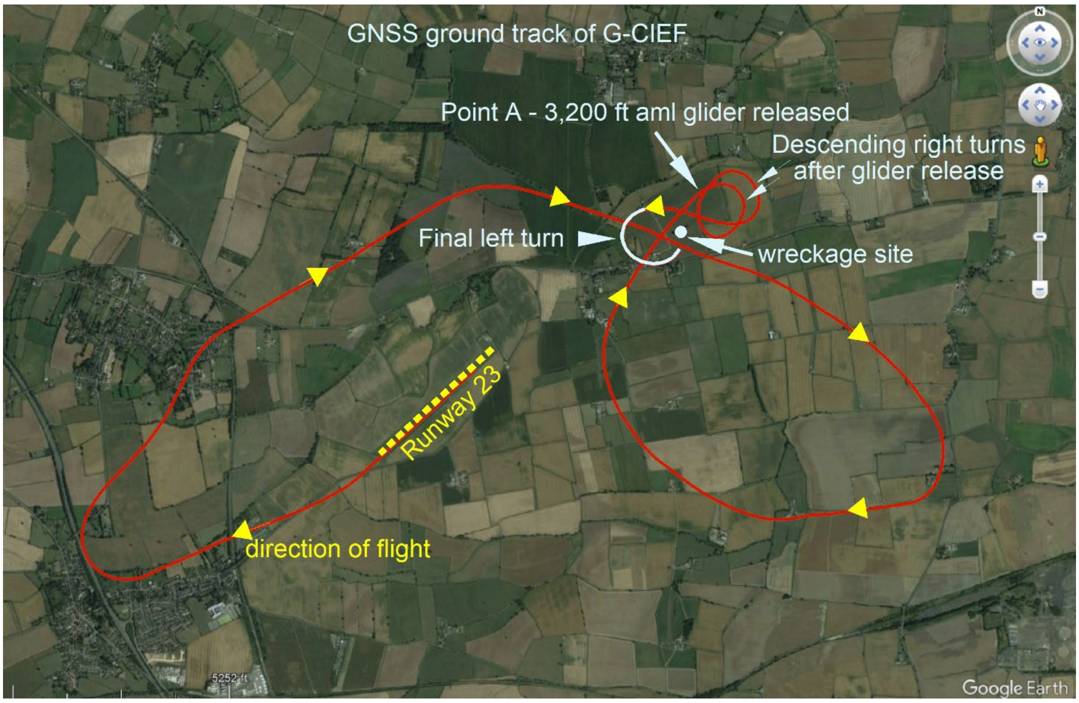


Figure 2

GNSS ground track of C-CIEF
(© 2023 Google, Image © landsat/copernicus)

Footnote

1 FLARM [accessed November 2024].
2 PilotAware Air Traffic Observation and Management (ATOM) grid and Open Glider Network (OGN).
3 SkyDemon [accessed November 2024].

The aircraft continued to descend and at about 1,100 ft amsl (~1,050 ft agl) it entered a left turn (Figure 2 Point B, Figure 3 and 4). Its groundspeed was 75 kt (an estimated airspeed of about 80 kt based on a wind from 230° at 11 kt) and the descent rate was approximately 1,800 ft/min. As the turn continued, the estimated bank angle of the aircraft increased progressively at an average rate of about 2°/s.

When the aircraft was at about 850 ft amsl (~800 ft agl) the data indicates that the descent rate had briefly reduced to about 1,000 fpm (Figure 4 and 5) but shortly thereafter started to increase again. The aircraft's bank angle at this point was estimated to have been about 30° and the normal load was approximately 1.15 g. The aircraft continued to descend, during which its rate of descent, calculated airspeed, bank angle and load factor continued to progressively increase.

The final recorded GNSS data point was recorded at 1118:12 hrs, which was shortly before the aircraft struck the ground. It was estimated that the aircraft's descent rate was about 3,000 ft/min, its airspeed was approximately 100 kt, the bank angle was about 55° left wing down and the normal load was nearly 2 g.

The dashcam footage of the final seconds of the flight was consistent with the GNSS data and showed the aircraft remaining in the descending left turn until it struck the ground, after which it could be seen to tumble several times before coming to rest.

The time between the aircraft starting the final left turn and striking the ground was about 30 seconds.

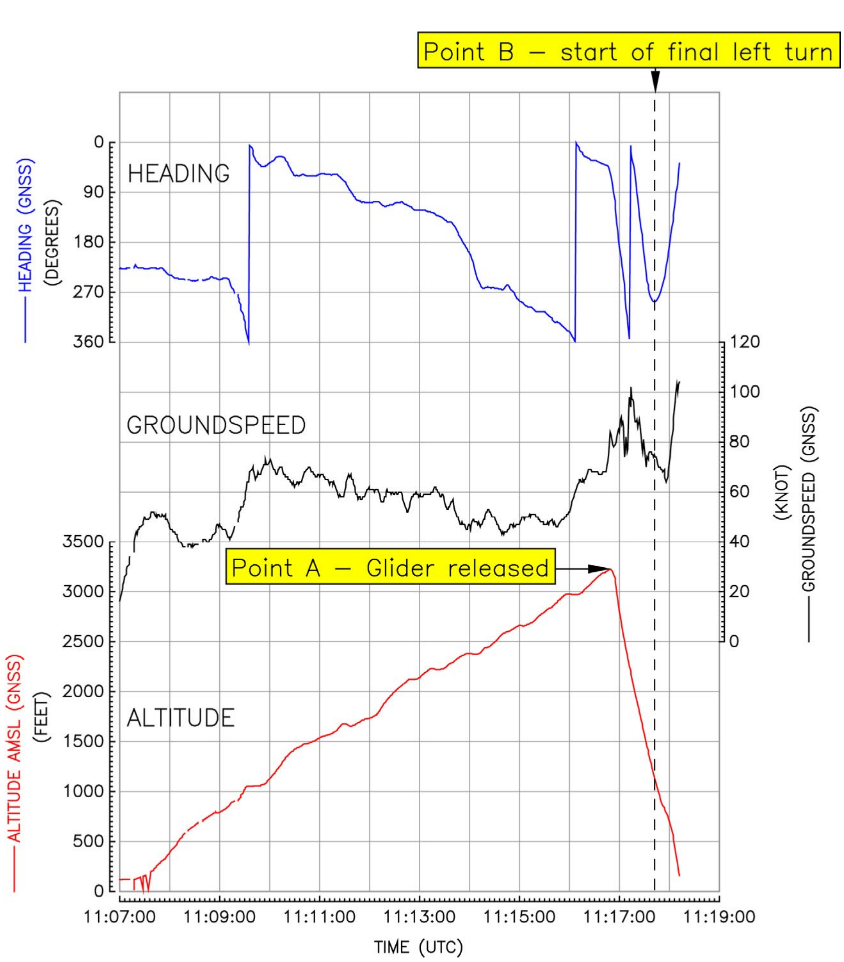


Figure 3

G-CIEF climb and descent

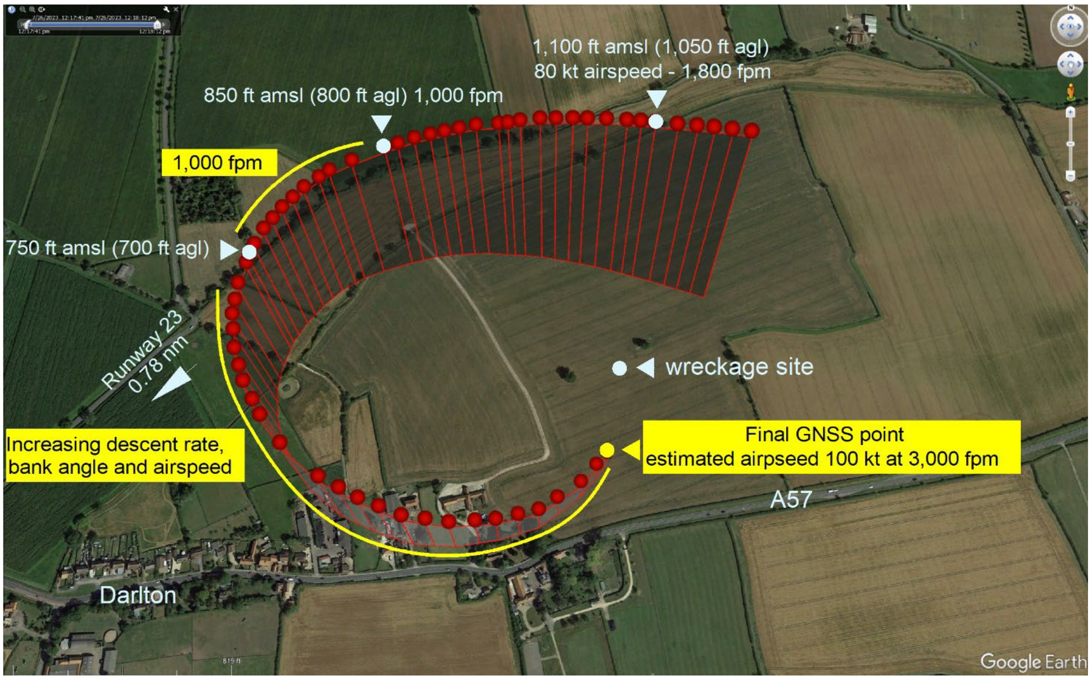


Figure 4

Final descending turn

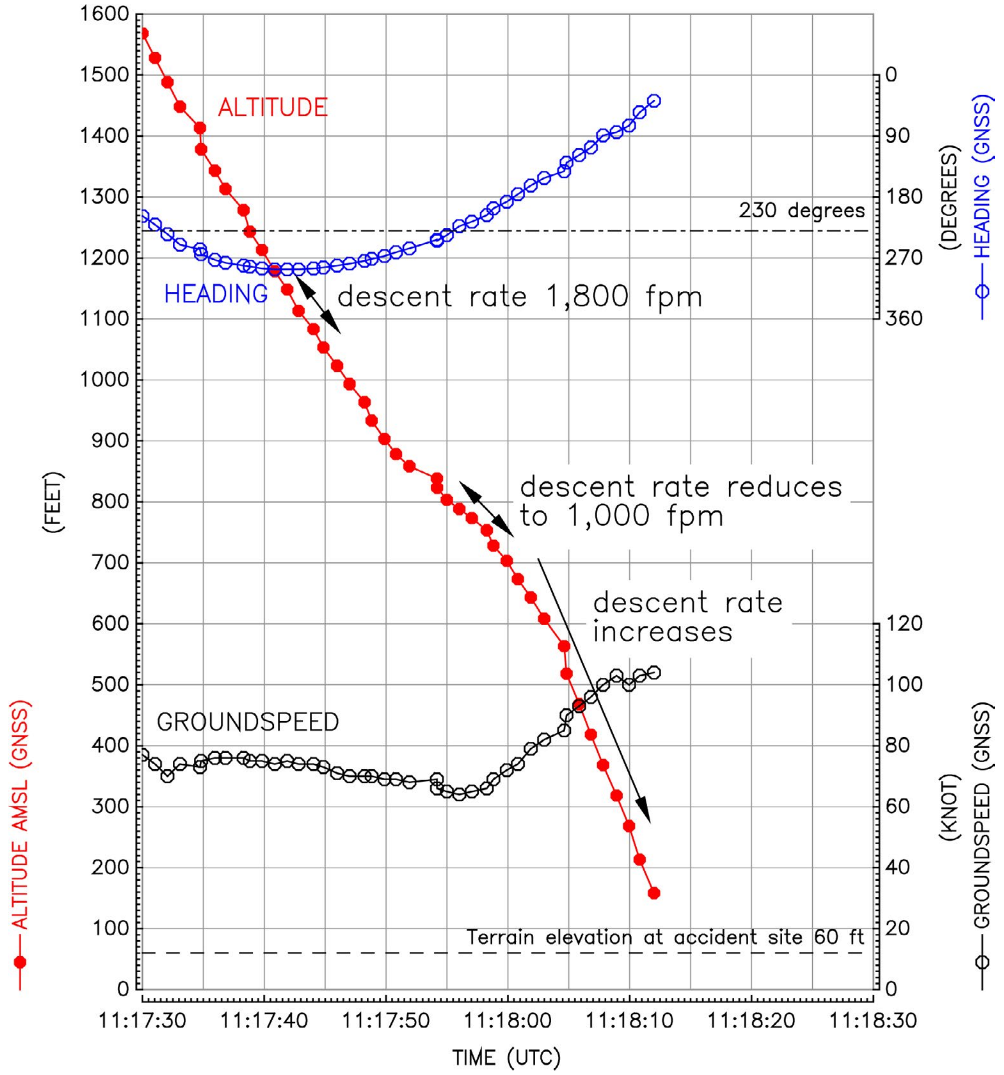


Figure 5

Plot of final descending turn

Aircraft position relative to Runway 23 final approach

Shortly after the aircraft commenced the final left turn it then flew through the extended centre line of Runway 23. At this point it was 0.78 nm from the runway threshold and at 780 ft amsl (655 ft above the runway threshold). From this position, the approach slope to have touched down at the runway threshold was just less than 8°, which would have required an average descent rate of 980 fpm if flown at a ground speed of 75 kt (estimated airspeed of about 86 kt based on a wind from 230° at 11 kt).

The standard approach slope to land is typically about 3°. At a distance 0.78 nm from the runway and on a 3° approach, an aircraft would be at an altitude of about 375 ft amsl (250 ft above Runway 23 threshold), and at a groundspeed of 75 kt the required rate of descent would be about 400 ft/min.

Previous flights

The pilot's first flight on the day of the accident lasted a total of 24 minutes (0807 hrs to 0831 hrs). This consisted of a local 20-minute flight followed by a touch-and-go landing on Runway 23. The aircraft then made a right turn, reaching a maximum height of 300 ft agl before landing back on the runway. Without coming to a complete stop, it then made a 180° turn and took off from Runway 05. A short distance from the end of the runway it completed a 180° right turn to land back on Runway 23 before coming to a stop. The subsequent two aerotows were from 0933 hrs to 0940 hrs and 1015 hrs to 1024 hrs.

Table 1 provides the relative distance, height and approach slope when G-CIEF was established onto the final approach to land during the previous three flights. For Flight 2 and 3, the aircraft's distance and height when at 0.8 nm from the runway threshold are also included for comparison with the accident flight when it turned through the runway extended centre line at about 0.8 nm.

Flight	Distance, height and approach slope relative to Runway 23 threshold
1 (solo) [4]	0.5 nm 570 ft 10.6°
2 (aerotow)	1.3 nm 1,780 ft 12.7° 0.8 nm 870 ft 10.1°
3 (aerotow)	2 nm 1,500 ft 7° 0.8 nm 650 ft 7.6°
Accident	0.8 nm 655 ft 7.8°

Table 1

Distance, height and approach slope

Aircraft description

The Eurofox kit is manufactured by Aeropro s.r.o. in Nitra, Western Slovakia. The Eurofox is a conventional, two-seat, high-wing, tractor monoplane, which with appropriate modifications is capable and widely used as a tug aircraft for gliders up to 750 kg.

Structure and systems

The cockpit is enclosed with side-by-side seating and the doors are top hinged gull wing type. The fuselage structure is welded steel tube and the wing structure is tubular aluminium spars with sheet aluminium ribs. The wings are braced with external lift struts and jury struts and the wings are easily foldable by one person. Control is through rudder, elevator and manually operated flaperons.

Each of the two wing tanks is of 40 litres capacity and mounted in the wing root supported by the front and rear spars. The wing tanks feed into a 6-litre collector tank (5 litres useable) mounted behind the cockpit seat. With a maximum gross weight of 560 kg for most examples, any combination of fuel loading, baggage loading and occupant weight, up to the placard maximum, is highly unlikely to place the aircraft outside of its C of G range.

Powerplant

The Eurofox 912(S) model is powered by a Rotax 912-ULS engine, rated at 100BHP at 5,800 rpm, mounted on a conventional welded steel tube mount. There are three types of propeller which may be fitted, either a DUC Windspoon or a Woodcomp SR200 or a DUC SWIRL-3-L, all being three-bladed ground-adjustable pitch types with moulded composite blades. However, the LAA require that for aerotow operations that the DUC Windspoon is fitted, this being a fine pitch three bladed propeller of 1,727 mm diameter.

Aircraft build and maintenance

The aircraft was sold as an amateur build kit under the 51% rule[4] and was assembled by the syndicate operating the aircraft with guidance and advice from the manufacturer and an LAA inspector. The build, which included LAA approved modifications required for tug flying, commenced in July 2013. The aircraft was registered with the CAA on 14 May 2014 and following successful build inspections and test flights was issued with a Permit to Fly on 14 November 2014. There had been no LAA approved modifications made to the aircraft since the initial Permit to Fly certification.

The maintenance required to ensure that the airworthiness of the aircraft is maintained is specified in the Aeropro Checklist B Service/Maintenance. Whilst the technical logbook for the aircraft could not be located during the investigation, inspection of the aircraft maintenance records showed that the aircraft had been maintained in accordance with the schedule with the last 50 hour check (carried out at 1,300 flying hours) undertaken two weeks before the accident flight. Service Bulletin SB 01/2014, which was issued in response to a rudder jam incident caused by a rotating adjustable centring spring attachment nodule on this aircraft type, was incorporated on G-CIEF in 2014.

Aircraft examination

The damage observed to the structure of the aircraft was consistent with an accident sequence that commenced with the left wing striking the ground first, and this correlated with the dashcam footage. All other damage observed was assessed to be due to the impact forces. There was no evidence of fatigue failure of primary or secondary structures that would have affected the integrity of the aircraft structure in flight.

Because of the severe damage sustained to the aircraft it was not possible to perform a full and free control continuity and freedom of movement check. Inspection of the flying control system showed damage to some of the control rods and cables, but this was all assessed to be due to impact forces. All fractures demonstrating typical overload failure characteristics associated with a high energy impact with the ground. There was no evidence found of control restriction in the flying control system. The rudder centring mechanism was inspected and whilst there was distortion to the frame around the mechanism from the impact forces, the adjustable centring spring attachment nodule remained in the correct orientation. The evidence indicated that the integrity of the flying control system was not compromised prior to the initial contact with the ground.

Footnote

[4] This rule provides the parameters under which a kit-based aircraft can be considered eligible for a Permit to Fly certificate.

The damage to the propeller and nose of the aircraft was consistent with the nose and cockpit striking the ground as part of the accident sequence. The Rotax 912 (ULS) has a gearbox, so if the engine stopped, the propeller would have likely stopped instantly and it would have been more likely that the carbon fibre propeller would have sustained unequal damage. The equal damage to the propeller blades suggests that the engine was turning when it hit the ground.

The engine was removed from the aircraft and disassembled and inspected at a specialist Rotax maintenance facility. Whilst it had sustained some post-impact damage, there were no mechanical or electrical issues discovered with the engine.

Survivability

The cockpit structure had sustained damage, but the steel lattice had not encroached into the cockpit area. The safety harnesses were intact, however the high energy initial impact and subsequent tumbling of the aircraft which resulted in the aircraft coming to rest upside down meant that this was not considered a survivable accident.

Weight and balance

With only the pilot on board and minimal baggage the aircraft would have comfortably been within its weight and balance limits for towing of gliders[5].

Meteorology

The weather conditions reported at Waddington Airfield, approximately 13 nm from the accident site, were good. The temperature was 20°C with a light wind from the south-west, few clouds at 3,900 ft.

Airfield information

Darlton Gliding Site has one Runway 05/23 which is 1,170 m long. The club owned four gliders which are operated by club members. Gliders are launched from the site by both winch launches and aerotows.

Personnel

Licence

The pilot had a total powered flight time of 719 hours. He first obtained his PPL(A) in 1989, which he converted to LAPL (A) in 2016. A LAPL (A) has a lifetime validity and does not contain ratings that need to be revalidated or renewed. However, in order to exercise the privileges of the licence, a pilot must meet the LAPL recency requirements[6]. The pilot's logbook showed that he met these recency requirements at the time of the accident.

The pilot had more than 30 years of gliding experience and had logged a total of 922 hours. He was a gliding instructor until 2017, when his FI(S) lapsed.

Footnote

5 Light Aircraft Association Airworthiness Approval Note: LAA 376-874 Issue 11, Aircraft Type: Eurofox 912(S).
6 Retained EU Regulation 1178/2011 Part-FCL.140.A LAPL(A) – Recency requirements.

Medical

The pilot had a LAPL medical certificate issued in September 2019 (expired October 2021) following an examination by an aeromedical examiner (AME). He subsequently completed a Pilot Medical Declaration (PMD) in October 2021, which was valid for three years.

The pilot had a stroke in February 2022. He experienced limited physical symptoms, however his cognitive function was affected and he was restricted from driving. Following an occupational therapy driving assessment, he was cleared to drive by a consultant medical doctor in March 2022, five weeks after his stroke occurred. There were multiple witness reports that after his stroke, the pilot was 'never quite the same'. He had no lasting physical effects, however, he was reported to have experienced verbal challenges for over a year after his stroke occurred, only reaching a full recovery in the three months preceding the accident.

The pilot's logbook and witness reports indicate that he flew in April 2022, six weeks after his stroke and four weeks after being cleared to drive.

Pilot Medical Declaration

If a private pilot intends to only fly UK registered aircraft in UK airspace, they can apply for a PMD by self-declaring their medical fitness using an online application. A medical declaration is an affirmation of a pilots medical 'fitness to fly' and may be used to exercise the privileges of a qualifying pilot's licence, with certain conditions and limitations which are outlined on the CAA website[7].

The pilot met the conditions and limitations to apply for a PMD at the time of his self-declaration in April 2020.

The CAA offers the following guidance with regards to a pilots decrease in medical fitness:

> *"The essential requirement of pilot medical fitness remains. Licence holders are reminded of their responsibility not to fly in the event of a decrease in their fitness with respect to an illness, medical condition, medical surgery or treatment that may affect the safe operation of an aircraft. Consultation with a medical practitioner and/or AME may be needed to advise the pilot as to whether the fitness conditions of the PMD are met."*

With regard to the validity of a pilot's licence, in the context of PMD's, the CAA guidance states:

> *"Your licence is invalid without a current medical certificate or having made a medical declaration. It is your responsibility to renew the declaration if it has expired.*

Footnote

7 https://www.caa.co.uk/general-aviation/pilot-licences/applications/medical/medical-requirements-for-private-pilots/ [accessed 23 April 2024].

If you have reason to believe you no longer meet the DVLA Group 1 ODL standard, or suffer from any of the specified medical conditions, you must not fly and must withdraw the declaration by ticking the appropriate box and re-submitting the form."

The CAA confirmed that the pilot's declaration should have been withdrawn during the time when he did not hold a valid driving licence, but that once the pilot was cleared to drive by a doctor, he met the criteria required to make a PMD. Official Record Series (OFS) 4 No. 1597[8] General Exemption 6131 to the ANO means that pilots, operating aircraft less than 2,000 kgs MTOW, are required to meet the medical requirements to hold a Group 1 driver's licence, and not be taking psychiatric medication in order to make a PMD. There are no additional medical requirements and there are no circumstances under which AME advice must be sought. Therefore, the pilot's PMD and pilot's licence were valid at the time of the accident.

Other information

Post-mortem examination

The post-mortem examination concluded that the pilot sustained fatal injuries to his head and chest at the point of impact. It stated although there was no evidence the pilot experienced a medical event prior to the accident, such events may not be apparent in post-mortem examination. Therefore, impaired cognitive function or medical incapacitation could not be excluded.

Analysis

Final flight path

Evidence from the pilots in the glider under tow during the accident flight, suggests the pilot was operating the aircraft as expected at least up until and at the point of tug release. The subsequent descending right turn was largely consistent with previous flights, and although the aircraft passed through the extended centreline relatively high for a nominal 3° descent profile, data from his previous flights indicate he routinely flew steep approaches.

Control input would have been required to stop the right turn and enter a left turn but, as there was no radio call made, it is not possible to know the pilot's intention. There was a brief reduction in the rate of descent during the left turn, which may have been an indication of pilot input. Thereafter, the aircraft rate of descent, angle of bank and speed remained consistent with how the aircraft would likely fly without further pilot input.

Medical fitness

Following his stroke, the pilot had undergone medical examinations to regain his driving licence and he met the criteria to hold a valid PMD. The post-mortem report stated the cause of death was severe head and chest injuries sustained at the point of impact. There was

Footnote

8 Official Record Series 4 No. 1597 General Exemption E 6131 available at https://www.caa.co.uk/publication/download/21806 [accessed 11 October 2024].

no evidence of a medical event identified during the postmortem which would conclusively indicate the pilot was incapacitated prior to the accident. However, it further stated that the absence of such evidence was not sufficient to rule out a medical episode (such as a stroke or cardiac event) having occurred prior to the accident. Incapacitation of the pilot could have been a partial impairment or full medical incapacitation.

Aircraft serviceability

Inspection of the aircraft build history, available maintenance documents and examination of the wreckage and engine could not identify technical causal or contributory factors to this accident.

Conclusion

There was insufficient evidence for the investigation to determine the cause of the accident with certainty. Taking into account the absence of any identified technical defects, the final flight path, postmortem report and the pilot's medical history, the investigation determined that the pilot most likely experienced a partial or full medical incapacitation which resulted in his inability to continue to fly the aircraft.

Published: 21 November 2024.

AAIB Correspondence Reports

These are reports on accidents and incidents which were not subject to a Field Investigation.

They are wholly, or largely, based on information provided by the aircraft commander in an Aircraft Accident Report Form (AARF) and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

Accident

Aircraft Type and Registration:	AW189, G-FSAR
No & Type of Engines:	2 General Electric Co CT7-2E1 turboshaft engines
Year of Manufacture:	2015 (Serial no: 89004)
Date & Time (UTC):	22 July 2024 at 2050 hrs
Location:	Approx 190 nm East of Stanley Airfield, Falkland Islands
Type of Flight:	Search and Rescue
Persons on Board:	Crew - 4 Passengers - 1
Injuries:	Crew - 1 minor Passengers - 1 missing
Nature of Damage:	None reported
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	45 years
Commander's Flying Experience:	4,257 hours (of which 1,260 were on type) Last 90 days - 28 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During a Search and Rescue operation a casualty was being recovered to the aircraft by rescue hoist. As the crew attempted to bring the casualty aboard, he slipped from the rescue strop and the crew could not hold him. The casualty fell into the sea and due to fuel limitations for the aircraft no further rescue was attempted.

History of flight

The AW 189 Search and Rescue (SAR) aircraft in the Falkland Islands (Figure 1) are contracted to the Ministry of Defence (MOD) and their operations are directed by the military Joint Operations Centre (JOC) at Mount Pleasant Airport (MPA). At the SAR shift handover briefing on 22 July, the commander was informed that a fishing vessel was in distress 213 nm east of MPA. With the option of a refuel at Stanley Airfield the commander considered that it may be possible to operate to that range with sufficient time on scene to recover at least some of the crew. Non-essential equipment was offloaded from the aircraft to allow it to pick up eight casualties without exceeding its maximum permitted mass. The vessel was 187 nm from Stanley. The commander calculated that with a forecast wind of 270° at 40 to 50 kt the aircraft could achieve 190 nm max range with 20 minutes on task. The commander asked the off going duty pilot to confirm his calculations before offering the capability to the JOC. Shortly after receiving the information the JOC tasked the crew to respond and informed them that the engine room of the vessel was taking on water and that the ship's crew were preparing to abandon the vessel.

Figure 1
AW 189 SAR Aircraft

The aircraft departed MPA at 1600 hrs and flew to Stanley for a rotors-running refuel to maximum capacity of 2,000 kg. Once this was complete the aircraft departed Stanley at 1629 hrs and routed to the position of the fishing vessel. An A400 Atlas fixed wing aircraft had also been launched from Mount Pleasant to provide “top cover” for the operation. The A400 crew passed initial information to the helicopter that the vessel was listing 45° to starboard and that there were two fully inflated life rafts, one partially inflated life raft and one floating lifejacket. The crew planned to prioritise the life jacket once on scene, anticipating that it would be on a person in the water. The A400 later confirmed that the lifejacket was empty, so the crew priority became the personnel still aboard the vessel.

Upon arriving at the scene of the incident, the crew faced challenging operating conditions, at night and in severe weather. The crew assessed the mean height of the waves to be approximately 8 m and the wind on scene was 270° at 40 gusting 50 kt.

The aircraft was positioned into a hover alongside the vessel for an initial reconnaissance. The vessel was estimated to be listing to starboard by 50°, with the front end submerged, which caused the aft port quarter to lift out of the water. The vessel’s orientation and the prevailing wind conditions caused concerns about potential loss of visual references for the commander while manoeuvring over the vessel. The vessel was experiencing significant and irregular movement due to swell.

To reduce risk, the crew discussed the possibility of deploying empty rescue strops. There were concerns that these could become entangled on the vessel or that survivors could make attempts to grab the strops and compromise their own security. The crew identified four casualties, all in precarious positions on the vessel: three at the highest point of the stern and one just beneath them. Given the challenging nature of the winch operation, the crew agreed to conduct an overhead check to assess the feasibility of a rescue. This check was flown manually with the aircraft moving laterally to the right over the vessel's stern. However, the winchman assessed that, due to the position of the casualties and excessive deck movement, attempting a rescue was unduly hazardous for both the casualties and the aircraft's crew.

With limited time on scene, the crew moved to the closest life raft to attempt a rescue. The radar height hold (RHT) was engaged at 80 ft, but the actual height fluctuated between 50 and 80 ft due to the swell. Despite these fluctuations, the mean vertical position was maintained, and the co-pilot closely monitored the radar altimeter. The commander controlled the horizontal position of the aircraft manually. The winchman was deployed, but a large wave submerged him, causing pain to his neck and shoulder. He was recovered to the aircraft. With only five minutes of fuel left on scene and 190 nm to Stanley, the crew decided that another attempt on the life raft was not feasible.

As they prepared to depart, a person was spotted floating in the water near the aircraft's nose. The casualty was face-up with arms and legs outstretched in a star shape, showing no movement other than that caused by the swell. The crew decided to attempt a recovery. The winchman was lowered by hoist again, quickly gaining contact with the casualty. He planned to place two rescue strops around the casualty but stated that due to the severe conditions and the casualty's "oversized suit because of water ingress, I could not get the second strop into position." The winchman also stated that the casualty's suit had been contaminated with fuel and was very slippery.

As the casualty was lifted clear of the water his left arm slipped out of the rescue strop. The winchman maintained the strop in place with physical force and the casualty was brought to the aircraft door. While trying to bring the casualty onboard, the winchman and winch operator had significant difficulties due to the casualty's low position and his greater than normal weight. Despite their efforts, the casualty slipped out of the strop and fell back into the sea. With their time on scene exceeded by two minutes, the crew had no choice but to depart for Stanley.

The route back to Stanley was challenging, with heavy rain and low temperatures necessitating the activation of the anti-ice system, increasing fuel consumption. The significant headwind of up to 50 kt increased the transit time to over two hours. The crew discussed their intentions upon arrival, with a desire to refuel and relaunch to attempt another rescue, as they expected the vessel to have sunk. However, concerns about the injured winchman, increased fuel consumption, survivor drift, and crew fatigue were also considered.

During the transit, a message was received to contact JOC upon arrival at Stanley. Due to water ingress, the winchman's helmet communications had failed, but his worsening neck and shoulder symptoms were relayed by the winch operator. On arrival at Stanley, the co-pilot remained in the cockpit with the aircraft rotors running while the commander assessed the winchman's condition and contacted the JOC to update the Air Commander/Tasking Authority on the crew's status, conditions on the scene, and time constraints.

The commander requested an update on the survivors' position from the top cover aircraft, noting a drift of one nautical mile east since the incident. Considering all factors, it was decided with the Air Commander that the crew should return to base. The aircraft recovered to Mount Pleasant at 2116 hrs after a total flight time of 4 hours and 22 minutes, with rotors running for 5 hours and 24 minutes.

A further meteorological update was arranged for 0530 hrs the following morning to assess the potential for a relaunch, aiming to arrive back on scene at daybreak. However, the forecast included a frontal system moving from west to east, bringing freezing rain, a freezing level at sea level, and full cloud cover from the surface to above FL100. The adverse weather conditions prevented a second rescue attempt. The first vessel on the scene the following morning reported winds from the south-west at 75 kt and swell heights of 7-8 m, further complicating rescue efforts.

Recorded information

The aircraft was fitted with a CVR which could record for 2 hours. The CVR was recovered but the information from the time of the incident had been overwritten due to the long transit back to Stanley. Information was recovered from the cctv cameras on board and the aircraft's sensor system.

Aircraft information

The AW 189 aircraft on the Falkland SAR contract are fitted with a Limited Ice Protection System (LIPS) to allow limited operation in icing conditions. The limitations of the LIPS system require a minimum 500 ft deep layer of positive air temperature above the surface into which the aircraft can always descend to de-ice naturally. With the LIPS system fitted, flight in freezing rain, freezing drizzle or super cooled liquid droplet conditions remains prohibited. While the LIPS system itself has no effect on fuel consumption, conditions which require it will also require use of engine anti-icing which does increase fuel consumption.

Aircraft performance

The commander used the following method to determine the aircrafts radius of action (ROA). The calculation was based on maximum useable fuel of 2,000 kg and allowed for 180 kg reserve fuel and 153 kg to permit 20 minutes on scene. Due to the severe conditions, the commander purposely used a pessimistic figure for the calculation, ie a lower than anticipated groundspeed for both outbound and inbound legs. Fuel burn figures are taken from the operator's operations manual (OMB). A contingency of 10% was included to allow for unanticipated changes in the weather or technical issues. No diversion airfield was available and Stanley also represented the closest point of land.

> *'Fuel Burn + 10% / GS Out = Fuel required per nm Outbound*
>
> *Fuel Burn + 10% / GS Home = Fuel required per nm Inbound*
>
> *Combined these give the fuel required per nm for a return journey. Total useable is fuel divided by that number to provide ROA.*

Using 460 kg/hr (cruise below 5000' - OMB 5.1.2) and 460 kg/hr hover consumption (estimated with additional Auxiliary Power Unit burn but high winds reducing power required). The commander's calculations in this instance were:

460+46 = 506 / 170 kt =2.98 kg/nm (pessimistic – 40 kt tailwind)

460+46 = 506 / 85 = 5.95 kg/nm (pessimistic – 45 kt headwind)

Fuel required per nm on return journey = 2.98+5.95 = 8.93 kg/nm

Total useable fuel 2,000 kg (only able to achieve 1,970 kg pressure fuelling at SFAL)

-180 (IFR FRF OMB 5.1.1) = 1,820 kg

-153 (Time in hover 460 / 60 x 20 min) = 1,667 kg Useable Fuel

1,667 / 8.93 = 186 nm ROA.'

As the aircraft was only able to refuel to 1,970 kg, the ROA was reduced to 183 nm.

The actual distance from Stanley to the reported position of the vessel was 189 nm.

Meteorology

The weather situation in the South Atlantic was reviewed after the event by the Met Office. The forecast low level weather chart, which was available to the crew, is shown at Figure 2.

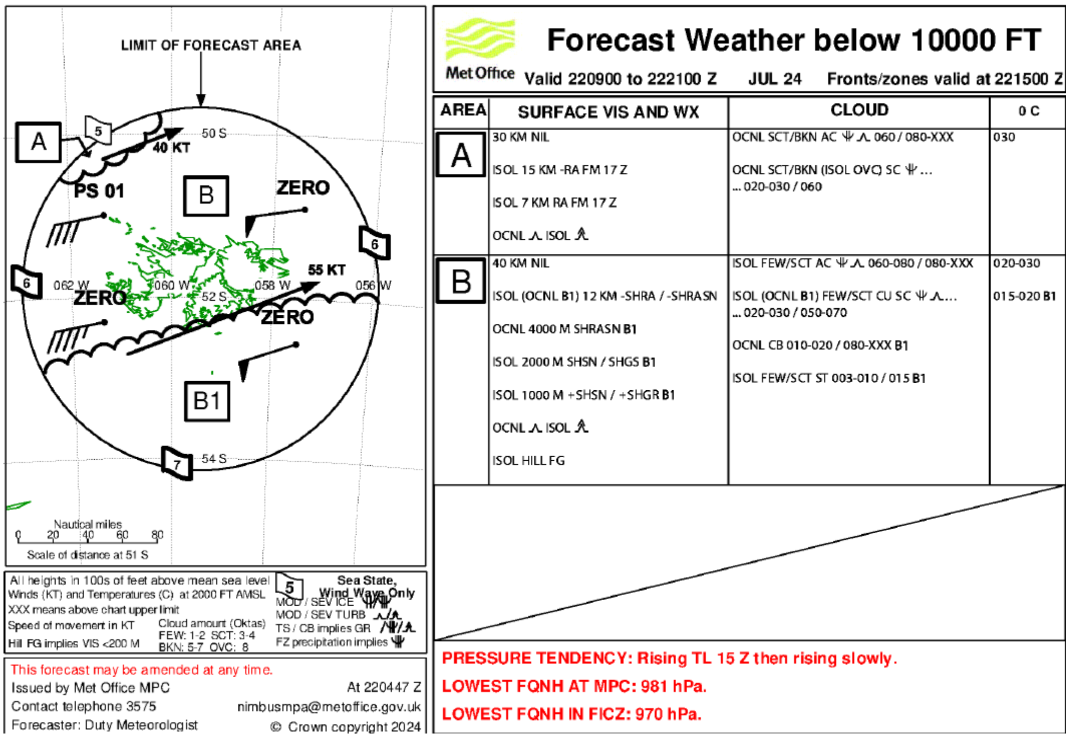


Figure 2

Forecast Low level weather chart 0900 to 2100 22 Jul 2024

On the chart the route flown would be within Zone B. The general forecast conditions were for good visibility with Few or Scattered (FEW/SCT) cloud between 2,000 and 3,000 ft. Isolated light showers or showers of rain and snow (ISOL -SHRA / -SHRASN) were forecast reducing visibility to 12 km at times. Occasional (OCNL) moderate showers of rain and snow (SHRASN) were also forecast reducing visibility to 4,000 m. There was also a risk of isolated (ISOL) showers of snow or small hail (SHSN / SHGS) or even heavy showers of snow or hail (+SHSN / +SHGR) reducing visibility to as low as 1,500 m. Associated with this was a risk of occasional cumulonimbus cloud (OCNL CB) between 1,000 and 2,000 ft with isolated (ISOL) lower cloud between 300 and 1,000 ft. The risk of the showers of rain or snow continued overnight, although visibility values were expected to be lower.

The Met Office in the Falklands produced a bespoke forecast for the operational area and this is shown at Figure 3.

Please see forecast details as requested for 52, 20.26 S 052, 52.00 W

Sunset: 1952 Z
ECT: 2030 Z
2000 FT Wind: 250 60 KT
Surface Wind: 250 40 G 55 KT isolated gusts to 60 KT possible in showers.
Cloud Base: Main base SCT/BKN 3000 FT, with occasional CBs from 19 Z BASE 300-800 FT TOP 180000 FT (sev icing and turb likely in CBs)
Weather: Trough moving eastwards across the area. Occasional showers of snow from 19 Z, potentially heavy at times reducing visibility to 500-1000 M at times. Becoming more isolated by 24 Z, staying slightly further south.
Sea State: Total Sea and Wind Wave both 7-8 M, High seas.

Figure 3
Bespoke operational forecast

The bespoke forecast refers to sea state High with wave heights of 7 to 8 m. The sea state chart is at Figure 4.

In their review the Met Office stated:

> *'The area of interest is a very data sparse area, with little or no observation data available. All of the forecast information available was indicating Gale Force Southwesterly winds with very high sea conditions. There was also a risk of very, low cloud and visibility in the area due to the presence of Heavy Snow Showers. Satellite derived surface winds were obtained from the NOAA ASCAT system. This is indicating a large area of 30 to 35 knot winds between the Falkland Islands and South Georgia, with an area of 40 to 45 knots winds near 54S'.*

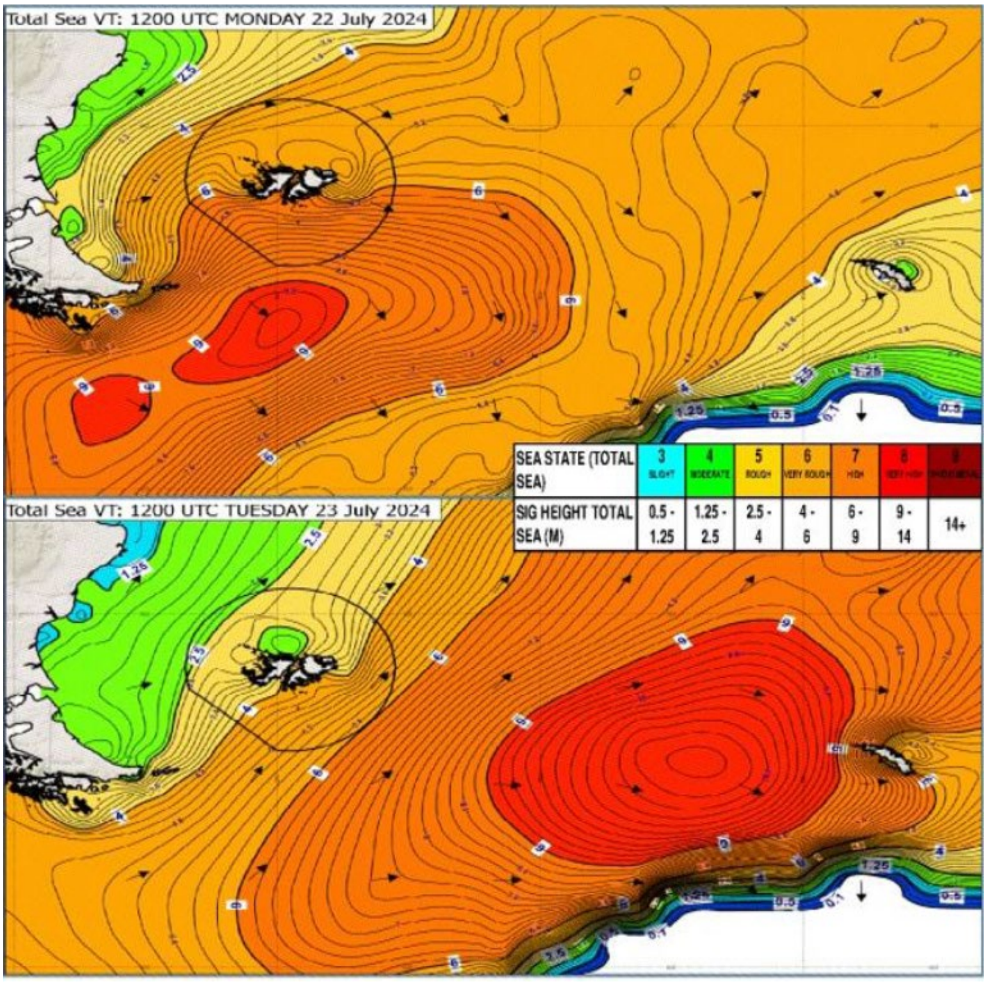


Figure 4
Sea state chart

Organisational information

The SAR helicopters in the Falkland Islands are contracted by the MOD and operate as assets of the British Forces South Atlantic Islands (BFSAI). BFSAI exercises control of the aircraft via the Air Commander at the JOC. Requests for use of the SAR aircraft for civilian rescue must be made by the Falkland Island Government. The Stanley Harbour Master was appointed as the Incident Commander by the Falkland Islands Government and it was they who made the request for SAR assistance to BFSAI. The first information of a vessel in difficulties was provided to the JOC at 1400 hrs. At 1535 hrs the Stanley Harbour Master informed the JOC that the crew of the vessel were preparing to abandon ship and formally requested SAR support. At 1536 hrs the JOC tasked the SAR helicopter and an A400 Atlas aircraft to the operation. The A400 Atlas remained on scene until 2048 hrs when it was replaced by an A330 Voyager aircraft also from MPA. The A400 refuelled at MPA and then returned to relieve the Voyager at 0830 hrs on 23 July 2024, remaining on scene until the limit of its endurance. Severe weather at MPA on 23 July 2024 led to unacceptable conditions for the A400 to land and the aircraft diverted to the South American mainland.

Further rescue efforts

At 0915 hrs on 23 July 2024 surface vessels tasked by the Falkland Islands Government reached the scene with guidance provided by the fixed wing aircraft. Those vessels rescued 14 survivors and recovered the bodies of nine deceased members of the vessel's crew. Four casualties remained missing. Search and Recovery operations continued until 0730 hrs on 24 July 2024 at which time all vessels departed the scene.

Analysis

When informed of the incident the commander recognised the operation would be close to limit of the aircraft's operating range. He was aware of the severe weather conditions for the transit and at the scene of the incident. Having confirmed the position of the vessel he calculated that 20 minutes on scene would be achievable and that if able to maximise effectiveness on scene it may be possible to rescue eight casualties. He informed the tasking authority of the available capability. A short while later the crew were tasked to respond to the incident and were informed that the vessel's crew were preparing to abandon ship. It was therefore clear that the situation was grave, with 27 lives in imminent peril. Although aware that their response was limited in scale, given the situation for the vessel, the decision to launch was made.

The aircraft flew from Mount Pleasant to Stanley, which was closer to the vessel, in order to refuel and maximise its endurance for the operation. During the refuel the aircraft was only able to take on 1,970 kg of fuel rather than the planned maximum of 2,000 kg. This reduction in fuel would have reduced the ROA by approximately 3 nm. As the track to the vessel was downwind the aircraft was at relatively high groundspeed and so reached the vessel in a little over an hour. It therefore had burned approximately 660 kg of fuel when arriving on scene. Aware of the relatively low fuel burn on the outbound leg the commander had offloaded non-essential equipment prior to departure to ensure that on scene the aircraft had the capacity to lift eight casualties without exceeding the maximum weight limit.

With the information supplied by the fixed wing top cover the crew's priority once on scene was to attempt a rescue of those still aboard the vessel. The crew conducted a reconnaissance and then the commander flew the aircraft to a hover above the vessel. However, once in the overhead the winchman assessed that due to the motion of the vessel and the precarious position of the casualties it was not safe to attempt the rescue.

Due to the short time now available on scene the crew shifted their focus to the closest life raft. The winchman was deployed to try and make contact with the life raft, but he sustained injuries to his neck and shoulders and signalled to be brought back aboard the helicopter. As the crew were assessing the situation the co-pilot informed them that fuel remained for only five more minutes on scene. Given the conditions and the injuries to the winchman the crew decided that another attempt on a rescue from the life raft was not feasible and they prepared to depart the scene. While doing so the commander spotted the person in the water. Given the risks to a person in the water, an attempt was made to affect the rescue of this individual despite the winchman's injuries. The winchman planned to use two rescue strops as would be usual for a casualty in the water. However, he was unable to place the second strop due to the severe sea conditions, so the casualty was lifted in one. The casualty was unresponsive and so lacked any muscle tone. Additionally, his survival suit had been contaminated with fuel and inundated with water. He was therefore much heavier than anticipated. As the casualty was brought toward the aircraft door, due to the slippery suit and lack of muscle tone his left arm slipped from the rescue strop. While he remained held, the casualty's position in the strop became lower than usual. This meant the crew was faced with a significant physical lift rather than just swinging the casualty through the door. With the excess weight of the casualty this proved impossible and after a struggle the casualty slipped from the strop and fell into the sea. The aircraft was already beyond the calculated time for departure to Stanley and departed the scene.

Conclusion

A casualty fell from the rescue hoist of a SAR AW189 during a rescue operation near the limit of the aircraft range in severe weather. The casualty was unresponsive throughout and his survival suit had been inundated with water and contaminated with fuel making him slippery and much heavier than expected. The crew was unable to recover him into the aircraft and he fell into the sea. Having exceeded its calculated time on scene the aircraft was forced to depart without further attempts at a rescue.

Serious Incident

Aircraft Type and Registration:	Boeing 747-433, G-UNET	
No & Type of Engines:	4 Pratt & Whitney PW4056-3 turbofan engines	
Year of Manufacture:	1991 (Serial no: 25075)	
Date & Time (UTC):	6 January 2024 at 1800 hrs	
Location:	London Heathrow Airport	
Type of Flight:	Commercial Air Transport (Cargo)	
Persons on Board:	Crew - 4	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Left upper wing panel detached	
Commander's Licence:	N/A	
Commander's Age:	N/A	
Commander's Flying Experience:	N/A	
Information Source:	Enquiries by the AAIB	

Synopsis

After landing, an upper left wing panel detached from the aircraft and came to rest in the grass area to the side of the runway. The panel was found two months later and the AAIB was notified. The wing panel most likely detached due to fatigue cracking of its supporting rib. This rib was known to suffer from cracks and the aircraft manufacturer had published a Service Letter with actions to help mitigate cracking, although the actions have not always prevented it. Analysis by the aircraft manufacturer indicated that there was low probability of a detached wing panel causing damage that would result in either an injury or prevent continued safe flight. The main hazard was considered to be runway foreign object debris (FOD) which could cause damage to a landing or departing aircraft.

History of the flight

On 7 March 2024 the AAIB received a report from the operator of Heathrow Airport that a large metal panel had been found in the grass area to the south of Runway 27L, about 600 m west of the runway threshold (Figure 1). The panel was sent to the AAIB for examination where it was identified as an upper wing panel from a Boeing 747 aircraft. Subsequent enquiries revealed that a Boeing 747 cargo aircraft (G-UNET) had arrived on stand at Heathrow Airport two months earlier, on 6 January 2024, with this panel missing from its left wing. The flight crew had been unaware that a panel had detached from the aircraft, but it was identified as missing during the subsequent turnaround. The aircraft operator had filed a Mandatory Occurrence Report to the CAA but did not report it to the AAIB as they had not considered it to meet the threshold for an accident or serious incident[1].

Footnote

[1] The operator stated that this was because Boeing SL 747-SL-57-101-B (discussed later in the report) stated that the separation of such a panel was not considered safety-related.

Figure 1
Location of metal panel (circled in red) relative to Runway 27

Examination of the panel

The panel (Figure 2) had maximum dimensions of 1.1 m by 0.9 m. It was identified as having detached from the upper left wing, adjacent to the outboard edge of spoiler 5 (Figure 3). The panel had a structural failure at its forward edge, revealing the internal honeycomb, and a structural failure at its inboard rib. The outboard edge of the panel had detached from a line of rivets. The rib along the inboard edge exhibited evidence of previous repairs.

The panel part number was identified as 65B11629 and the rib part number as 65B10865.

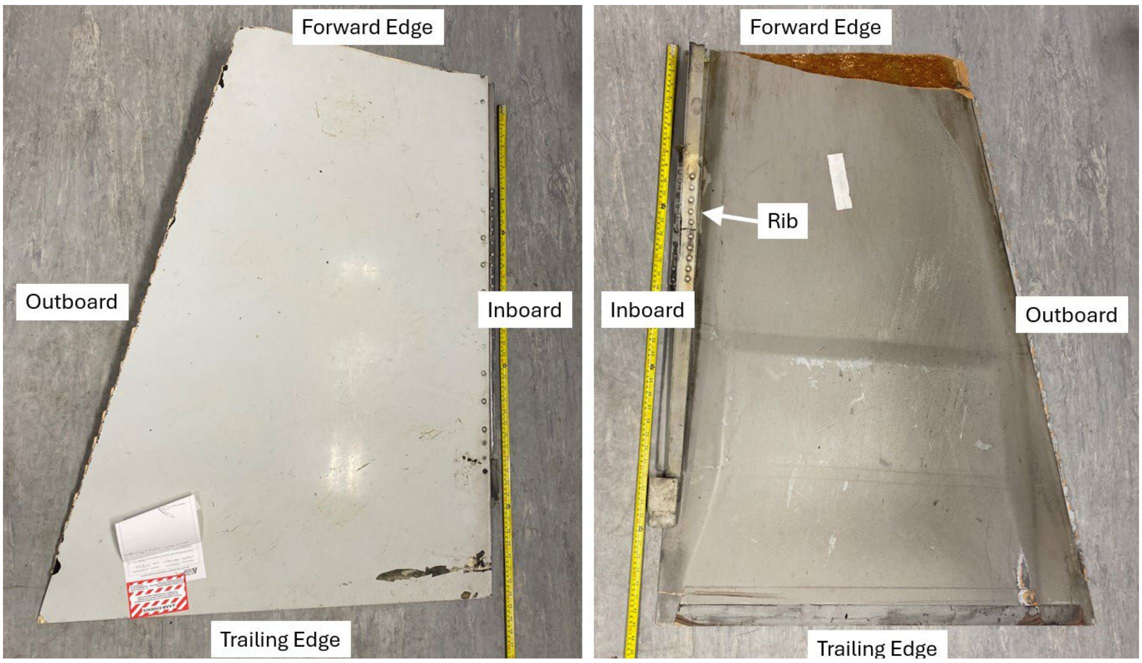


Figure 2
Photos of detached wing panel

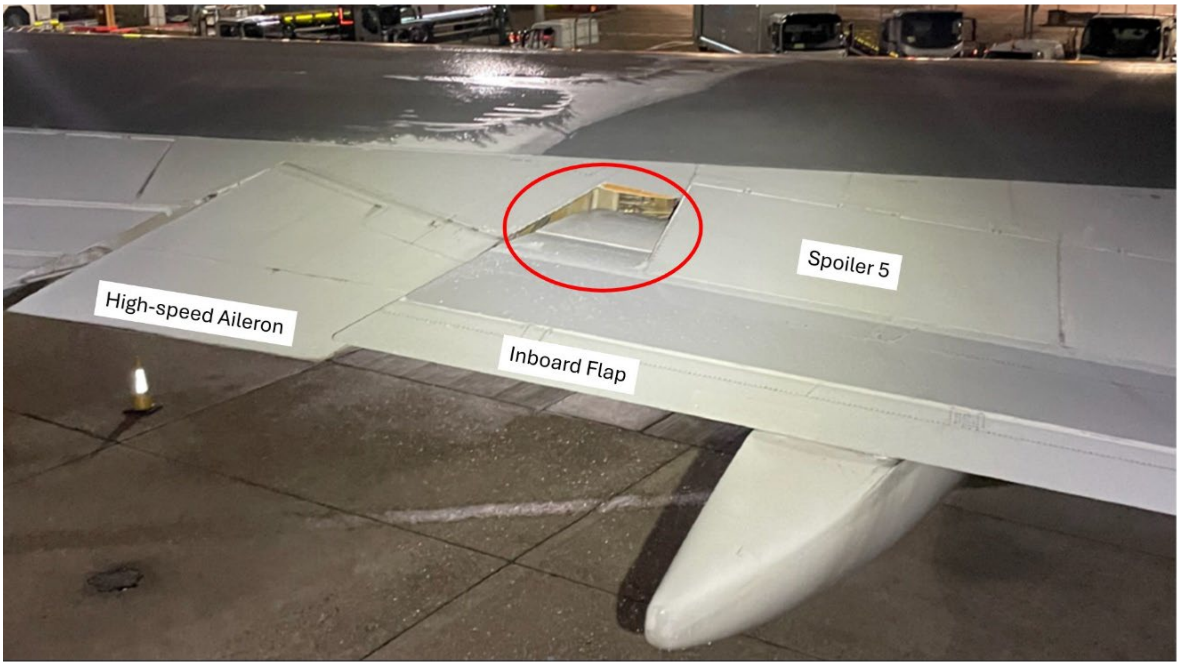


Figure 3
Location of missing wing panel (circled in red)

Service Letter to address wing panel detachments

On 30 November 2010 the aircraft manufacturer published Service Letter (SL) 747-SL-57-101-B 'Fixed Trailing Edge – Spoiler Support Revision at WBL 255.692 and WBL 432.6504'. It stated that:

> *'Operators have reported cracks in the reference e) P/N 65B11544 fixed trailing edge rib located at WBL255.69, and at the reference f) P/N 65B10865 fixed trailing edge rib located at WBL432.65. Cracks typically originate from the rib lower chord just aft of the diagonal tie rod fitting and propagate upwards through the web as shown in the attached illustration. Continued crack growth can cause complete fracture of the rib. In cases of complete rib fracture the reference g) upper fixed TE panel common to the rib at WBL432.65 can also become damaged.*
>
> *Some operators have reported in-flight departure of a portion of the reference g) panel and reference f) rib.*
>
> *Damage to the ribs and panel, including the partial departure of the panel during flight, is not considered safety-related and does not significantly affect the controllability of the airplane. No regulatory action is anticipated regarding this issue.'*

The illustration from the SL is shown in Figure 4 with the crack location on G-UNET superimposed in red.

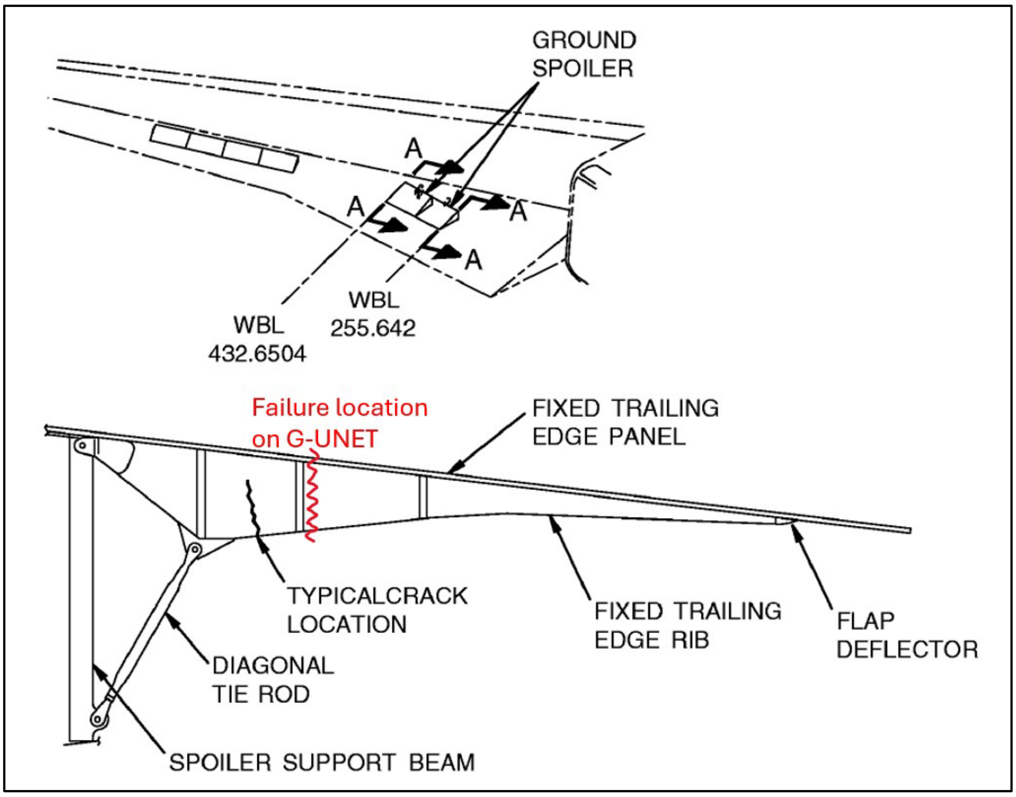


Figure 4

Illustration from Service Letter 747-SL-57-101-B with location of rib failure on G-UNET shown in red.
Image Copyright © Boeing. Reproduced with permission

The SL explains the following cause:

> *'For improved aerodynamic performance the 747-400 wing was designed to flex more than the 747-Classic wing. Greater wing flex of the 747-400 increases the upward movement of the TE flap which may in turn impose higher than expected loads to the reference e) and f) ribs. The magnitude of upward loads imposed by the flap is sensitive to adjustment of the ribs relative to the flap. Investigation of cracked ribs submitted to Boeing by operators show indications of fatigue cracking due to cyclical upward loads acting on the rib over an extended period of time.*
>
> *The original release of this service letter discussed the implementation of spoiler downrigging for improved range performance. To address the spoiler support rib cracking issue, Boeing recommended operators determine if an airplane had downrigged spoilers, and if so, to check that that the spoilers were correctly adjusted. However, additional operator reports indicate that airplanes with correctly adjusted spoilers may still develop spoiler support rib cracks. The current revision to this service letter therefore discusses the fixed TE panel rigging change. Spoiler downrig is still accomplished, if applicable, when performing the Suggested Operator Action.'*

The suggested operator action specified in the SL is to adjust the spoiler support rib clearance between the fixed trailing edge (TE) upper panels and the upper surface of the inboard TE flap as specified in the SL. The SL was originally issued in 2005 but at that time it did not include information about parts departing the aircraft.

Aircraft operator action

The aircraft operator stated that it was not aware of any specific task having been carried out on G-UNET concerning SL 747-SL-57-101-B. Following the left wing panel failure, the operator tasked their maintenance organization to check the spoiler support rib clearances on G-UNET's right wing against SL 747-SL-57-101-B; they were found to be within limits with no adjustments required. They also stated that the rib that failed would have been inspected during wing zonal inspections which are carried out during A-checks at 1,000 flight hour intervals.

Information from the aircraft manufacturer

The aircraft manufacturer was asked for information on previous wing panel detachments. They were able to find the following information on ten panels of the same part number that had detached:

- 8 panel detachments were found during walkaround inspections after landing with no detail as to the phase of flight.
- 1 was listed as 'panel departed on approach'. This panel detachment was spotted by the control tower during approach.
- 1 was during departure. The crew felt a shudder on departure and noted missing wing material during the flight.

The manufacturer's database search also included an entry where this panel was found cracked during a D-check.

The aircraft manufacturer provided details of an analysis of the effects of a fixed trailing edge upper wing panel departing the aircraft. They had considered the following four failure modes:

Potential for the fixed trailing edge upper wing panel to:

1. Depart and impact the aircraft such that the damage results in loss of continued safe flight and/or landing.
2. Depart and penetrate the fuselage such that the damage results in injury to an occupant or aircraft depressurisation.
3. Depart the aircraft and impact a person on the ground.
4. Depart the aircraft and create runway FOD (foreign object debris).

The potential for loss of continued safe flight and/or landing, and the potential for an occupant injury or depressurisation, were both assessed by the aircraft manufacturer '*not to be a safety concern*'. The risk to a person on the ground was, based on the manufacturer's service history studies, also assessed as '*not to be a safety concern'*.

The most likely hazard from a separated wing panel was considered to be runway FOD, which could damage another aircraft. However, the aircraft manufacturer considered that the FOD hazard was '*not to be a safety concern*' as it is mitigated by existing airport initiatives intended to control and minimise exposure to runway FOD, and by aircraft design standards which address protection from damage caused by runway FOD.

The aircraft manufacturer was asked if they had data on the number of airports equipped with automatic FOD radar detection systems. They stated that data from an FAA briefing in 2018 indicated that 21 airports worldwide had such FOD detection systems installed, of which 19 were capable of taking a Boeing 747. They expected that the number of airports with such systems has increased over the past six years.

Foreign object detection at Heathrow Airport

Heathrow Airport was equipped with a FOD radar detection system. The airport operator stated that the system was sensitive enough to detect small objects the size of a screw or part of a bird carcass, so it would have easily detected a part the size of the detached wing panel. However, the system only scans the hard surfaces of the runways, so it would not have detected the wing panel in the grass area to the side of the runway. The airport was also equipped with Surface Movement Radar designed to track aircraft, but this was not sufficiently sensitive to detect a part the size of the wing panel.

The wing panel had detached from the aircraft on 6 January and was found two months later, on 7 March. The airport operator stated that because it was winter the grass was mown less frequently, otherwise the part would have been found sooner.

Analysis

The left wing panel was found 600 m beyond the threshold for Runway 27L indicating that it probably detached from the aircraft after touchdown when the spoilers were deployed. The panel most likely cracked and then failed at its supporting rib first, before failing at the leading edge honeycomb structure. The aircraft manufacturer's Service Letter 747-SL-57-101-B indicated that this rib was known to suffer from fatigue cracks and failures, and recommended mitigating action involving adjusting spoiler support rib clearances. There was no documentary evidence that the actions in the SL had been carried out on the incident aircraft; however, when the opposite right wing was checked the clearances were within the limits of the SL.

The aircraft manufacturer's analysis indicated that the loss of such a wing panel in-flight had an acceptably low probability of causing damage that would result in either an injury or continued safe flight.

The most likely hazard from a separated wing panel was considered to be runway FOD, which could cause damage to a landing or departing aircraft. It was runway FOD that caused the catastrophic accident to Concorde (F-BTSC) during takeoff from Charles de Gaulle Airport in July 2000[2]. Heathrow Airport had a FOD radar detection system that would have detected the wing panel had it ended up on the runway surface. However, not all major airports worldwide are equipped with FOD radar detection systems. Mitigation therefore relies on runway inspections and aircraft design standards which address protection from damage caused by runway FOD.

Conclusion

The left wing panel detached from the aircraft after touchdown, most likely due to fatigue cracking of its supporting rib. This rib was known to suffer from cracks and the aircraft manufacturer had published a Service Letter with actions to help mitigate it, although the actions did not always prevent it. Analysis by the aircraft manufacturer indicated that there was low probability of a detached wing panel causing damage that would result in either an injury or prevent continued safe flight. The main hazard was considered to be runway FOD which could cause damage to a landing or departing aircraft. FOD radar detection systems are an effective mitigation, but not all major airports are equipped with them.

Footnote

2 https://bea.aero/uploads/tx_elydbrapports/f-sc000725a.pdf [accessed 15 July 2024].

Accident

Aircraft Type and Registration:	EMB-145EP, G-SAJK
No & Type of Engines:	2 Allison Ae 3007/A1/1 turbofan engines
Year of Manufacture:	1999 (Serial no: 145153)
Date & Time (UTC):	10 October 2024 at 1800 hrs
Location:	Aberdeen Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	No damamge reported
Commander's Licence:	Airline Transport Pilot's License
Commander's Age:	33 years
Commander's Flying Experience:	1,831 hours (of which 1,371 were on type) Last 90 days - 100 hours Last 28 days - 48 hours
Information Source:	Enquiries made by the AAIB

During the aircraft turn-around, a member of cabin crew was removing the bin liner from the metal galley bin when they were distracted by a flight dispatcher handing them a document. The metal bin dropped onto their foot causing a bone fracture. The cabin crew member did not depart on the subsequent flight and received medical attention. To prevent reoccurrence, the operator is going to advise its cabin crew to use the galley trolley bins, instead of the galley fixed bin.

Accident

Aircraft Type and Registration:	Cessna T182, G-CIMM
No & Type of Engines:	1 Lycoming O-540-L3C5D piston engine
Year of Manufacture:	1982 (Serial no: 182-68092)
Date & Time (UTC):	30 July 2024 at 1804 hrs
Location:	Little Stretton, Leicestershire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - None Passengers - None
Nature of Damage:	The nose wheel collapsed on the landing roll causing prop and front fuselage underside damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	68 years
Commander's Flying Experience:	456 hours (of which 391 were on type) Last 90 days - 32 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB

Synopsis

The pilot was conducting an overhead join to Leicester Airport and was adjusting the throttle to reduce speed. As he did so, the engine speed disproportionately dropped to idle. There was no response to any further throttle inputs, which the pilot noted were "stiff and notchy". He carried out a force landing in a nearby field during which the nose landing gear collapsed. Subsequent examination of the aircraft found there was a throttle cable restriction which led to a power loss.

History of the flight

The pilot had completed a cross-country flight and was joining overhead Leicester Airport. As he adjusted the throttle to reduce speed, there was a disproportionate drop in engine speed to idle. He immediately set best glide speed, checked the fuel system settings and tank quantity, and found all were satisfactory. The pilot had no response from the engine to any throttle movements, and observed that the throttle handle felt "stiff and notchy". He declared a PAN to Leicester air to ground radio, selected a suitable field and carried out a forced landing. As a result of the forced landing, the nose landing gear collapsed and caused damage to the underside of the nose section of the aircraft. The pilot and passengers vacated the aircraft uninjured.

Engineering cause

An examination of the aircraft found a slight stiffness in the throttle mechanism which caused a restriction of the cable when advanced towards the half-throttle setting at the carburettor throttle arm. Its stiffness and effect on the throttle cable was therefore the most likely cause of the power loss.

Accident

Aircraft Type and Registration:	Falco F8L, G-HCBW	
No & Type of Engines:	1 Superior XP-IO-320-B2HC2 piston engine	
Year of Manufacture:	2018 (Serial no: PFA 100-12788)	
Date & Time (UTC):	27 August 2024 at 1259 hrs	
Location:	Headcorn Aerodrome, Kent	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Left landing gear mechanism damaged	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	61 years	
Commander's Flying Experience:	6,033 hours (of which 41 were on type) Last 90 days - 103 hours Last 28 days - 33 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

During takeoff the aircraft bounced and, as a result of a cross wind, came down on its left wheel before climbing away. Despite the pilot's attempts to retract the landing gear, using both the normal and emergency systems, the landing gear would not retract. The pilot reselected DOWN but although the green down light was illuminated, the pilot took additional steps to ensure the gear was down. However, on landing the left gear partially collapsed bending its retraction screwjack. It is likely the left landing gear mechanism was damaged after the bounce during which higher than normal side loads may have occurred.

History of the flight

The pilot, who was a qualified flying instructor sitting in the right seat, had planned to carry out a differences training flight for the benefit of the aircraft's new owner. The pre-flight checks and taxi out to the runway were all normal. The pilot was demonstrating the takeoff and as he did so, an undulation on the runway caused the aircraft to bounce and descend sideways on the left wheel before becoming airborne and climbing away.

When the pilot selected landing gear UP, the red UNLOCKED light illuminated, and the landing gear circuit breaker tripped. The airfield air to ground (A/G) radio operator confirmed that the gear had not been seen to retract. Manual landing gear retraction was attempted but the handle would not move. The pilot selected gear DOWN and the green DOWN lamp illuminated. The landing gear telltale pins on the wing appeared to confirm this.

The pilot was uncomfortable that he could not fully rely on the aircraft configuration and carried out a fly-by. The A/G radio operator visually confirmed the landing gear appeared to be down. The pilot then carried out a normal landing during which the landing gear indicator remained green throughout. However, as the aircraft encountered unevenness on the runway during the landing roll, the pilot sensed the left wing dropping. He realised the left landing gear leg had partially collapsed and folded under the aircraft as the aircraft left the runway and came to a stop. The pilot made the aircraft safe, and he and the owner vacated the aircraft uninjured.

Aircraft examination

An examination of the aircraft found the retraction screwjack was bent with damage to its drive linkages and tube (Figure 1). In his own analysis, the pilot considers that the bounce on takeoff with a 90°crosswind, albeit low, caused a side drift which overloaded the landing gear retraction linkages.

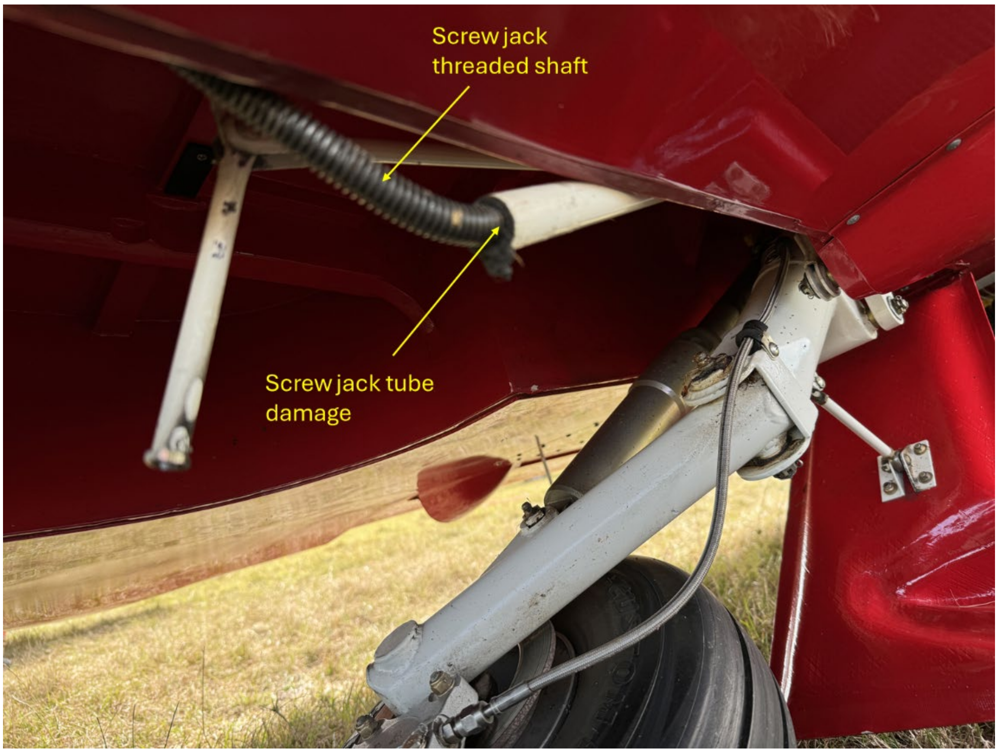


Figure 1

Damage to screwjack and tube
(picture courtesy of the pilot)

The damage may also have caused overloading of the screwjack motor resulting in the breaker tripping on UP selection. Despite indicating and outwardly appearing to be locked down, the geometric lock in the mechanism had probably been compromised. In this state it is possible that the landing and the loads imparted in the landing gear leg as it rolled along the runway, led to forces then being imparted into the screwjack bending it enough to cause the partial collapse of the left landing gear leg.

Accident

Aircraft Type and Registration:	1) Piper J3C-65, G-BBLH 2) Bombardier Global 6000, M-SFPL
No & Type of Engines:	1) 1 Continental Motors Corp A65-8F piston engine 2) 2 Rolls Royce BR700-710A2-20 turbofan engines
Year of Manufacture:	1) 1943 (Serial no: 10,549) 2) 1991 (Serial no: 9,692)
Date & Time (UTC):	26 June 2024 at 1230 hrs
Location:	London Biggin Hill Airport
Type of Flight:	1) Private 2) Private
Persons on Board:	1) Crew - 1 Passengers - 1 2) Crew - 2 Passengers - None
Injuries:	1) Crew - None Passengers - None 2) Crew - None Passengers - N/A
Nature of Damage:	1) Damage to left wingtip 2) None
Commander's Licence:	1) Airline Transport Pilot's Licence 2) Airline Transport Pilot's Licence
Commander's Age:	1) 40 years 2) 48 years
Commander's Flying Experience:	1) 11,000 hours (of which 100 were on type) Last 90 days - 240 hours Last 28 days - 80 hours 2) 8,500 hours (of which 4,000 were on type) Last 90 days - 75 hours Last 28 days - 25 hours
Information Source:	Aircraft Accident Report Forms submitted by the pilots and further investigations by the AAIB

Synopsis

G-BBLH, a Piper J3C-65 'Cub'[1], was being taxied behind M-SFPL, a Bombardier Global 6000 (G6000) that was parked on an adjacent apron with engines running. G-BBLH was caught in the G6000's jet efflux and "aggressively" spun round resulting in damage to the Cub's left wingtip. The G6000 had not been positioned in accordance with apron ground markings that had been aligned to direct engine efflux from parked aircraft away from Taxiway L, which ran south of the apron.

Footnote

1 Sometimes referred to as an L4 Grasshopper.

The maintenance organisation responsible for movements on the apron undertook safety action to remind their operations team of the requirement to align aircraft with the apron ground markings prior to engine start.

History of the flight

G-BBLH was proceeding along Taxiway L at London Biggin Hill Airport (Biggin Hill) when it got caught in the jet efflux from M-SFPL, a G6000 parked on a northerly heading with its engines running on an adjacent apron (Figure 1). The pilot of G-BBLH was not aware that the G6000 had started its engines before he taxied behind it.

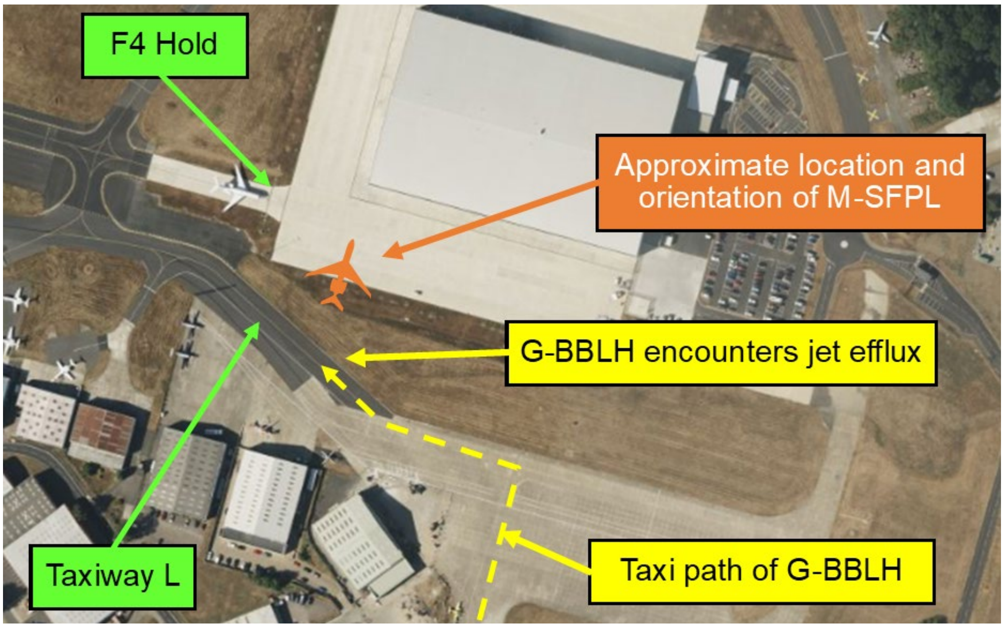


Figure 1

Incident location and respective positions of G-BBLH and M-SFPL
(image ©Vexcel Imaging ©2024 Microsoft)

G-BBLH's pilot reported that, when it got caught in the efflux, their aircraft "aggressively" ground looped and weather cocked "clockwise into the jet blast." For several seconds they experienced "total uncontrollability" which resulted in the aircraft's left wingtip striking the ground on at least two occasions. After declaring an emergency to ATC, they shut down their engine and vacated the aircraft so they could attempt to hold it down to prevent further damage. Onlookers from a nearby hangar assisted the pilot in manoeuvring G-BBLH away from the efflux zone.

At the time of the accident, the pilots of M-SFPL were not aware that G-BBLH was about to taxi behind them and had initiated a test of the wing anti-ice (WAI) system. On the G6000, activating WAI results in an increased engine idle thrust setting.

Aerodrome information

Control of aircraft on the apron east of the F4 Holding Point (F4 Hold), where M-SFPL was parked, is delegated to the maintenance organisation who operate from it.

The distance between the newly established apron and Taxiway L was limited so jet efflux attenuation barriers were not installed when it was constructed. Instead, the airport and maintenance organisation came to an agreement that apron line markings would be installed for the movement of aircraft. These lines were designed by the airport and subsequently installed by the maintenance organisation. The ground markings in the area close to Taxiway L are aligned on an approximate north-westerly heading rather than perpendicular to the apron edge (Figure 2). The airport operator explained these ground markings were positioned so efflux from aircraft parked there "would be diagonal to the L taxiway and towards the rising ground (grass) between the [maintenance apron] and the airport's South-East apron."

An internal investigation by the maintenance organisation found "a level of normative practise in the positioning of aircraft" where aircraft were parked "along the apron resulting in reduced area to park aircraft in what would be the appropriate positioning in line with the taxi markings" (Figure 2).

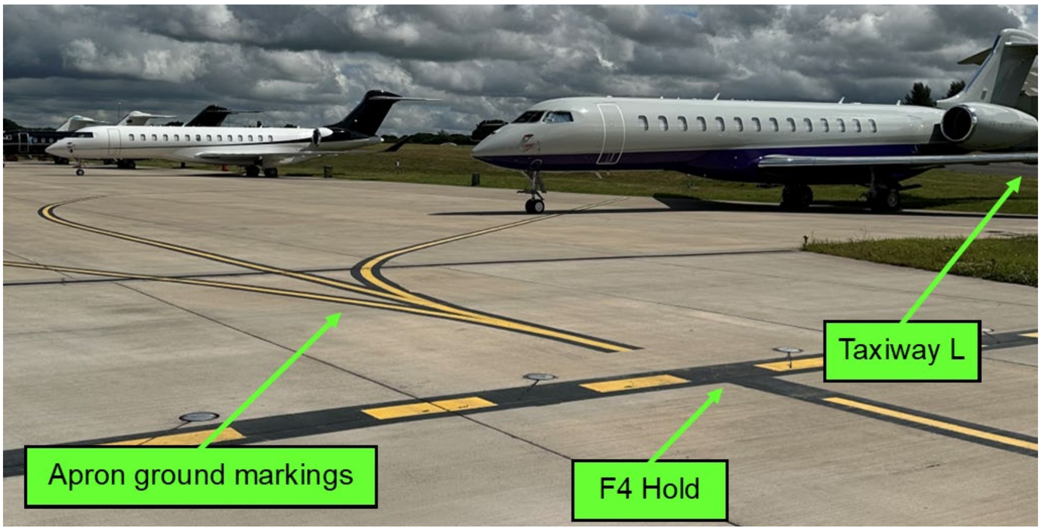


Figure 2

F4 Hold and aircraft parked on maintenance organisation's apron

Conclusion

The conditions for this accident were created when M-SFPL was parked perpendicular to the apron edge for engine start rather than in alignment with yellow ground markings. Had any of the pilots involved been aware of the risk posed at that time to G-BBLH by M-SFPL's jet efflux the confliction could likely have been avoided by mutual coordination over the radio.

The investigation did not have sufficient evidence to determine whether the increased engine idle thrust setting during M-SFPL's WAI test sequence was a significant contributory factor.

Safety action

The maintenance organisation publicised this event within its operations team to raise awareness of the circumstances and to highlight the importance of aligning parked aircraft with the apron ground markings before engine start.

Accident

Aircraft Type and Registration:	Piper PA-28-140, G-AWBS
No & Type of Engines:	1 Lycoming O-320-E2A piston engine
Year of Manufacture:	1968 (Serial no: 28-24331)
Date & Time (UTC):	18 June 2024 at 1955 hrs
Location:	Near Eddsfield Airfield, East Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - 1 (Minor) Passengers - 2 (Minor)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	1,475 hours (of which 16 were on type) Last 90 days - 8 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Shortly after takeoff the aircraft sank as it was climbing over trees at the end of the runway. The pilot adjusted the aircraft's attitude to maintain flying speed but it struck the trees. The aircraft came to rest on the driveway of a local residence with the pilot and passengers sustaining minor injuries.

It was considered whether carburettor icing might have resulted in a reduction in engine power and the pilot stated he would give more consideration to the effect of obstacles on the wind.

History of the flight

The pilot had flown to Eddsfield Airfield to pick up two passengers for a pleasure flight and the aircraft was parked for approximately 15 to 20 minutes prior to starting up again with the passengers on board. Power checks were completed at the parking area adjacent to the Runway 27 threshold followed by taxi checks as the aircraft was taxied along the 725 m grass runway for departure from Runway 09 at 1955 hrs. The wind was 12 kt, gusting 22 kt from 040° with the air temperature of 15°C and a dew point of 12°C.

The pilot applied full power at the runway threshold and held the aircraft on the brakes. Upon releasing the brakes, the aircraft accelerated normally and lifted off approximately three-quarters of the way along the runway. The pilot set the aircraft attitude for a maximum gradient (V_x) climb to clear the 80 ft trees at the far end of the airfield. Whilst overhead the trees the pilot adjusted the attitude to increase speed and gently turned onto a heading of 070°. Simultaneously he felt the aircraft sink by approximately 10 to 15 ft and it stopped climbing. The pilot then felt the aircraft clipping the foliage of the treetops, jolting slightly and then begin to descend. He did not recall hearing the stall warner or experiencing any symptoms of a stall. The aircraft banked further to the left and pilot directed it through the trees to the only piece of clear space that he could see.

The aircraft came to rest in the garden and on the driveway of a local residence and was destroyed (Figure 1). After completing emergency shutdown procedures, the pilot and passengers were able to exit the aircraft unaided with minor injuries.

Figure 1
G-AWBS at the accident site

AAIB Comment

The engine was tested with the carburettor by an independent engine maintenance organisation and found to perform normally. The weight and balance calculations were verified, along with the takeoff performance calculations and no anomalies could be found.

It is the opinion of the pilot that either a power issue or the gusty wind conditions over the trees were causal factors in the accident. Whilst no evidence was found to explain a loss of power it was noted that there was a possibility of carburettor icing. According to the CAA Safety Sense Leaflet 14 on Piston Engine Icing[1] the air temperature and dew point at the time indicated the risk of serious icing at any power setting. It is possible that the long taxi along the grass runway, late in the day resulted in a build-up of ice prior to take off. The pilot stated he will give more consideration to gusty wind conditions at low speed and the impact of obstacles such as trees, on the wind in the future.

Footnote

[1] caa9396-piston-engine-icing-v8.pdf – CAA Safety Sense Leaflet 14 "Piston Engine Icing" [accessed November 2024].

Accident

Aircraft Type and Registration:	Piper PA-28R-200 Cherokee Arrow II, N747MM
No & Type of Engines:	1 Lycoming IO-360 piston engine
Year of Manufacture:	1973
Date & Time (UTC):	19 September 2024 at 1500 hrs
Location:	Oxenhope Airfield, West Yorkshire, and Tatenhill Airfield, Staffordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left landing gear partially detached, wing and flap damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	1,132 hours (of which 500 were on type) Last 90 days - 11 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

On final approach to Runway 11 at Oxenhope Airfield the aircraft rapidly descended in a downdraught which resulted in the left main gear leg striking a stone wall. The gear leg partially detached, and as a result the wing and flap were also damaged. The pilot and passenger, both experienced GA pilots, flew the aircraft to an airfield they considered more suitable to carry out an abnormal landing.

History of the flight

The pilot along with a passenger, also a qualified pilot, were conducting a cross-country flight from Cumbernauld to Oxenhope and then planned to fly on to Denham. The aircraft approached Oxenhope, was configured for landing with the landing gear down and full flap, and was on final to Runway 11. To the west of the threshold there was a road and a dry stone wall, and as the aircraft neared these features a sink developed destabilising the approach. The pilot immediately commenced a go-around and increased power. As he did so, there was a loud "metallic" bang emanating from the left side of the aircraft. Soon afterwards it was noticed the left main gear status light had extinguished. The aircraft also appeared to require abnormal control inputs to maintain stable flight. The pilot continued with the go-around, retracted the flaps but did not select landing gear up. He flew a gentle climbing left hand circuit over the threshold before setting a southerly course and climb.

The pilot and passenger assessed the situation and observed that whilst the right flap was up and correctly in position, the left flap had over-travelled upwards. In addition, there was visible deformation of the upper skin of the left wing.

The aircraft was climbing very slowly and required full right rudder and at least two-thirds right aileron to maintain heading.

After some discussion it was decided to land at Tatenhill Airfield which was approximately 70 miles to the south. On arrival at Tatenhill, observers on the ground advised that the left landing gear was dangling freely beneath the wing. Despite the damage to the aircraft, a normal approach was made during which preparations were made for a forced landing and to facilitate an immediate exit from the aircraft.

The aircraft touched down on the right wheel, followed by the nose, and as the aircraft decelerated the left wing tip contacted the ground. The aircraft eventually slewed through 90° and came to a stop just off the edge of the runway. Both occupants were uninjured. On examination it was clear the left landing gear had hit the wall at Oxenhope causing significant damage to the gear leg and the surrounding wing and flap structure.

Discussion

The pilot and passenger were both experienced GA pilots and have conducted their own analysis of the incident at Oxenhope. Both felt that Oxenhope can be quite challenging due to the topography of its surroundings, and they knew that it is often affected by gusty winds. This was the first time the pilot had made an approach to this airfield. However, the passenger had operated similar aircraft types in and out of Oxenhope numerous times, so briefed the pilot on factors to take into consideration. He briefed that shallower and slower approaches with good speed control were required for the downhill Runway 29. However, the approach was made to Runway 11 for which the airfield plate and website warns that downdraughts are a hazard. Unfortunately, the passenger forgot to mention this to the pilot.

With hindsight, both pilot and passenger consider the causal factors to be the pilot's unfamiliarity with the airfield, and perhaps a loss of awareness of the changing perspective outside the aircraft due to the pilot concentrating on the approach speed. The sudden sink was probably due to a downdraught just as the aircraft was about to overfly the wall at the edge of the airfield which led to the unstable approach.

Both knew the aircraft had been damaged but were unable to determine to what extent. They decided it was unwise to re-attempt a landing at Oxenhope. Having spent some time considering their options, assessing the aircraft's response at various speeds, and preparing the aircraft for the abnormal landing, they felt that Tattenhill, 70 miles south of Oxenhope, was the nearest suitable airfield. It had a hard runway, emergency cover and the flight could be continued without having to gain permission to transit controlled airspace. The route was also over benign terrain with few obstacles. This enabled them to concentrate on flying the aircraft and prepare for the abnormal landing.

AAIB Record-Only Investigations

This section provides details of accidents and incidents which were not subject to a Field or full Correspondence Investigation.

They are wholly, or largely, based on information provided by the aircraft commander at the time of reporting and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

Record-only UAS investigations reviewed: October - November 2024

16 Jun 2024 **DJI Mavic 3 Cine** Newton-on-the-Moor, Northumberland

The UA was being used for filming inside a building. The UA began to wander off track, due to loss of GPS position, and struck a wall and then fell onto one of the film extras causing minor injury. The film company's Health and Safety team have reviewed the accident and put more robust controls in place for filming in similar environments.

1 Sep 2024 **DJI Mini 4 Pro** Portsmouth, Hampshire

The UAS was conducting a flight adjacent to Portsmouth Historic Dockyard to obtain imagery of HMS Warrior. As the UA flew along HMS Warrior's starboard side, the rotors made contact with the ship's rigging. The UA fell onto the deck, and the gimbal and two of the rotor arms were damaged.

4 Oct 2024 **Holybro X500 V2** Near Lode, Cambridgeshire

The UA, after 13 minutes of flight, commenced its critical low voltage emergency landing procedure at the moment that the remote pilot landed the aircraft; this procedure begins with a climb to 15 m. The remote pilot, saw the unexpected climb (which was uncommanded by him) and so cut all power to the motors; the UA fell to the ground from a height of about 6 m.

10 Oct 2024 **DJI Mavic 3** Diana's Peak National Park, St Helena

During a survey flight the UA lost signal at a height of about 100 m and did not respond to a return to home command. The UA was not recovered.

10 Oct 2024 **Skydio X10D** Near Stanton St Bernard, Wiltshire

The link was lost during a training flight and the UA did not execute the programmed return to home function. The UA was damaged and subsequently recovered in a field approximately 1,600 m from the launch point.

11 Oct 2024 **DJI M30T** Dunscroft, South Yorkshire

Shortly after taking off at night the UA became entangled in telephone wires, before falling to the ground.

14 Oct 2024 **Custom Puffin PC2** Aston Down Airfield, Gloucestershire

This was the UA's maiden flight. During a hop test the UA took off and pitched up, possibly due to a centre of gravity issue. The remote pilot tried to regain control but the UA stalled, and then struck the ground between the two runways.

Record-only UAS investigations reviewed: October - November 2024 cont

17 Oct 2024 **DJI Inspire 2** Edinburgh
The UA, at the maximum operating distance within visual line of sight, was reported to have descended to the ground in a spin.

17 Oct 2024 **DJI M300** Rotherhithe Pier, London
The UA was performing a survey at about 1 m above the River Thames. The remote pilot paused the mission to avoid a pier but unexpectedly the UA lost height and dropped into the water. The cause of the problem was not determined.

5 Nov 2024 **DJI Phantom 4 Pro** Near Lymington, Hampshire
During a training flight the remote pilot reported that the aircraft dropped out of the sky and struck the ground. The flight log showed that a drop in voltage had occurred. Following the accident the battery was found dislodged, but at the time of reporting it was not known if this occurred in-flight or as a result of striking the ground.

Miscellaneous

This section contains Addenda, Corrections and a list of the ten most recent Aircraft Accident ('Formal') Reports published by the AAIB.

The complete reports can be downloaded from the AAIB website (www.aaib.gov.uk).

TEN MOST RECENTLY PUBLISHED FORMAL REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

3/2015 Eurocopter (Deutschland) EC135 T2+, G-SPAO
Glasgow City Centre, Scotland
on 29 November 2013.

Published October 2015.

1/2016 AS332 L2 Super Puma, G-WNSB
on approach to Sumburgh Airport
on 23 August 2013.

Published March 2016.

2/2016 Saab 2000, G-LGNO
approximately 7 nm east of Sumburgh Airport, Shetland
on 15 December 2014.

Published September 2016.

1/2017 Hawker Hunter T7, G-BXFI
near Shoreham Airport
on 22 August 2015.

Published March 2017.

1/2018 Sikorsky S-92A, G-WNSR
West Franklin wellhead platform, North Sea
on 28 December 2016.

Published March 2018.

2/2018 Boeing 737-86J, C-FWGH
Belfast International Airport
on 21 July 2017.

Published November 2018.

1/2020 Piper PA-46-310P Malibu, N264DB
22 nm north-north-west of Guernsey
on 21 January 2019.

Published March 2020.

1/2021 Airbus A321-211, G-POWN
London Gatwick Airport
on 26 February 2020.

Published May 2021.

1/2023 Leonardo AW169, G-VSKP
King Power Stadium, Leicester
on 27 October 2018.

Published September 2023.

2/2023 Sikorsky S-92A, G-MCGY
Derriford Hospital, Plymouth, Devon
on 4 March 2022.

Published November 2023.

Unabridged versions of all AAIB Formal Reports, published back to and including 1971, are available in full on the AAIB Website

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

aal	above airfield level
ACAS	Airborne Collision Avoidance System
ACARS	Automatic Communications And Reporting System
ADF	Automatic Direction Finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
AOM	Aerodrome Operating Minima
APU	Auxiliary Power Unit
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European Union Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EGPWS	Enhanced GPWS
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FAA	Federal Aviation Administration (USA)
FDR	Flight Data Recorder
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth's gravity
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
mb	millibar(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
PM	Pilot Monitoring
POH	Pilot's Operating Handbook
PPL	Private Pilot's Licence
psi	pounds per square inch
QFE	altimeter pressure setting to indicate height above aerodrome
QNH	altimeter pressure setting to indicate elevation amsl
RA	Resolution Advisory
RFFS	Rescue and Fire Fighting Service
rpm	revolutions per minute
RTF	radiotelephony
RVR	Runway Visual Range
SAR	Search and Rescue
SB	Service Bulletin
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TAF	Terminal Aerodrome Forecast
TAS	true airspeed
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TODA	Takeoff Distance Available
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
USG	US gallons
UTC	Co-ordinated Universal Time (GMT)
V	Volt(s)
V_1	Takeoff decision speed
V_2	Takeoff safety speed
V_R	Rotation speed
V_{REF}	Reference airspeed (approach)
V_{NE}	Never Exceed airspeed
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional radio Range

AAIB Bulletin 1/2025

Air Accidents Investigation Branch