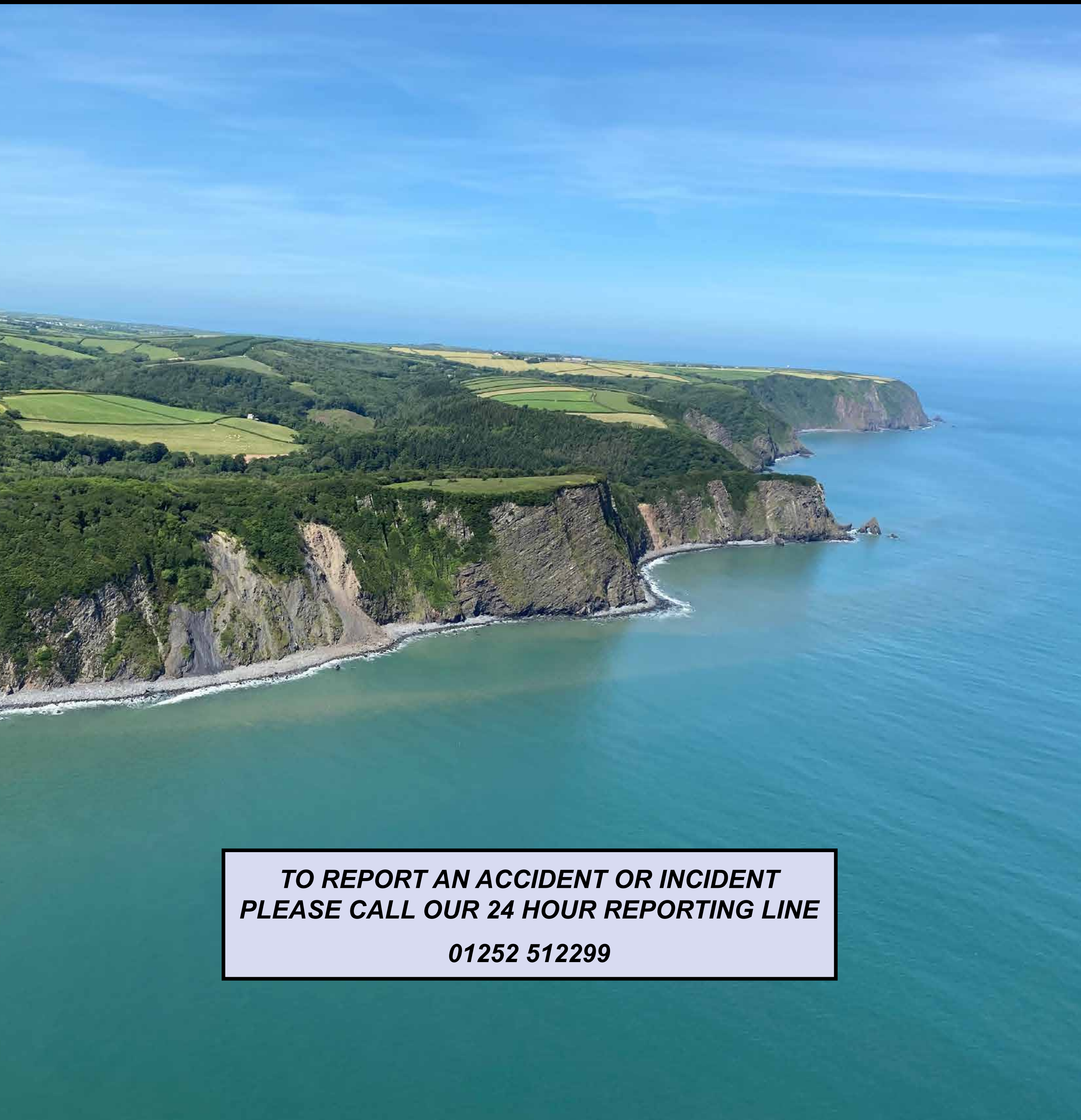
AAIB
Air Accidents Investigation Branch

AAIB Bulletin 11/2022



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AAIB
Air Accidents Investigation Branch

AAIB Bulletin S2/2022 *SPECIAL*

SERIOUS INCIDENT

Aircraft Type and Registration:	Bombardier CL-600-2B16 (604 variant), D-AAAY
No & Type of Engines:	2 General Electric CF34-3B turbofan engines
Year of Manufacture:	2004 (Serial no: 5602)
Date & Time (UTC):	10 August 2022 at 1640 hrs
Location:	In the climb after departing from Farnborough Airport, Hampshire
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 7
Injuries:	Crew - None Passengers - None
Nature of Damage:	Still under assessment
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	13,091 hours (of which 5,655 were on type) Last 90 days – 102 hours Last 28 days – 41 hours
Information Source:	AAIB Field Investigation

Introduction

At 1733 hours on 14 August 2022, the AAIB was informed that a Bombardier Challenger 604, registration D-AAAY, had an uncommanded flap extension, above the maximum flaps-extended speed. The event occurred at 1640 hours on 10 August 2022, while the aircraft was in the climb after departing Farnborough Airport. The aircraft returned to Farnborough where it landed without further incident.

On 15 August 2022, the AAIB commenced a safety investigation in accordance with Retained Regulation (EU) 996/2010 and the UK Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018. In accordance with established international arrangements, the National Transportation Safety Board (US), Transportation Safety Board (TSB) of Canada and the German Federal Bureau of Aircraft Accident Investigation appointed Accredited Representatives to the investigation. The TSB was assisted by Advisers from Transport Canada and the aircraft manufacturer.

This Special Bulletin contains preliminary information from the investigation. One Safety Recommendation has been made and four Safety Actions have been taken by the regulator and aircraft manufacturer.

History of the flight

On the day of the occurrence, the crew arrived at Farnborough Airport at 1300 hrs to operate a private charter flight to Málaga – Costa Del Sol Airport, Spain. There were three crew and seven passengers on board. The aircraft took off at 1618 hrs from Runway 06 using flap 20, after which the crew selected flap 0 to fully retract the flaps. Following a standard instrument departure to the south-west, the flight was cleared to climb to FL350. As the aircraft passed through FL190 at approximately 300 KIAS, with the autopilot engaged, the crew saw a FLAPS FAIL caution message on the EICAS[1] display primary page. The co-pilot, who was the PF, reported that the aircraft pitched nose-up slightly and started to decelerate. The EICAS primary page also displays flap position information which indicated to the crew that the flaps were extending (Figure 1)[2]. The crew reported that the flap overspeed audio warning did not operate as they expected. The flap control lever was still in the flap 0 position selected by the crew after take-off.

The commander switched on the seatbelt sign and took control of the aircraft. He disengaged the autopilot, reduced thrust to slow down, and initiated a descent. The crew informed ATC of the situation, requesting a descent to FL100 and radar vectors to Gatwick Airport. Subsequently, they decided to divert to Farnborough as it was closer than Gatwick and avoided extending the flight longer than necessary.

The crew established that the aircraft was responding normally to control inputs and decided to maintain FL150 at approximately 180 KIAS, which was below the VFE of 189 KIAS for flap 45. They reported that it required nearly full power to maintain this condition. The autopilot was re-engaged. The cabin crewmember made a visual inspection of the flaps from the cabin and reported that they appeared to be fully extended and symmetrical. The crew consulted the *'FLAPS FAIL'* procedure in the *'Non-normal Procedures'* section of the Quick Reference Handbook and found that no further actions were required. They established that they would land approximately 1,000 lb over the maximum landing weight of 38,000 lb and planned to increase the landing reference speed (V_{REF}) accordingly.

Footnote

1 The function of the EICAS is to display the engine instruments and to provide visual and aural crew-alert messages and real-time interpretation of aircraft system operation.

2 The maximum speeds at which the flaps may be extended (VFE) are: flaps to 20 degrees - 231 KIAS; flaps to 30 degrees - 197 KIAS; flaps to 45 degrees - 189 KIAS.

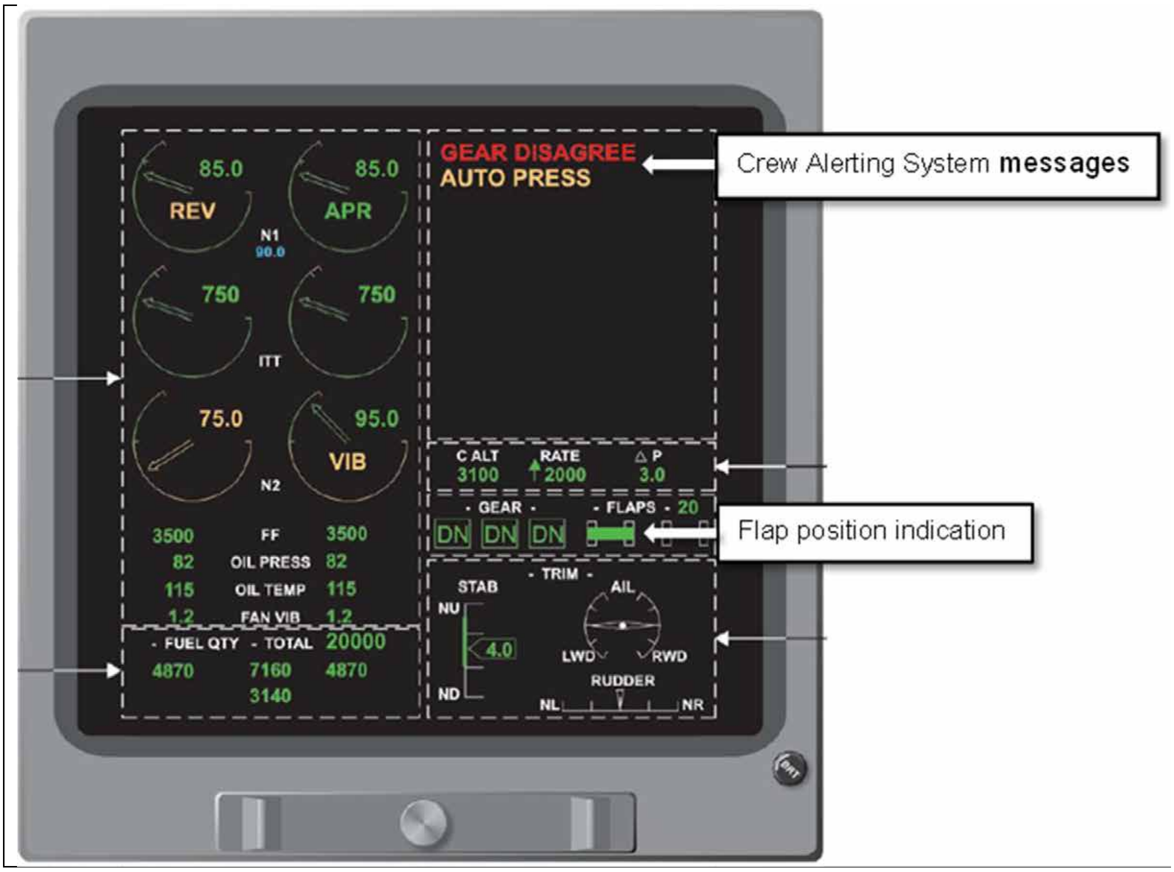


Figure 1

Illustration of EICAS primary page information

The aircraft was positioned for an ILS approach to Runway 06 at Farnborough and the crew configured the aircraft for landing, selecting the flap control lever to the flap 45 position to match the observed flap position. The aircraft landed without further incident at 1651 hrs, at an airspeed of 135 KIAS.

Recorded information

Data for the occurrence flight was available from the aircraft's FDR, which provided a recording of the last 154 hours of operation and the aircraft's previous 64 flights. The FDR parameters included the aircraft's indicated airspeed, and the position of the flap control lever in the cockpit and the right-wing flaps. The CVR recording of the incident flight had been overwritten during maintenance activity, which had taken place prior to the AAIB being informed of the occurrence. The aircraft's track during the flight was captured by radar and recordings of RTF communications with the flight crew were also available.

Interpretation

The flaps prior to takeoff had extended normally to 20° at a rate of about 2.4°/sec, but during their retraction after takeoff had moved at half their normal speed, at about 1.2°/sec. As the aircraft climbed through FL190 at a recorded airspeed of 305 KIAS, the flaps started to extend whilst the flap control lever remained in the flap 0 position (Figure 2, Point A). The rate at which the flaps extended was about 1.1°/sec, which was about half the normal extension speed. The autopilot remained engaged, and the aircraft's speed started to progressively reduce whilst also pitching down from 4° nose up. Shortly after, a flap failure message was recorded, which occurred when the flaps had extended by about 3°.

As the flaps reached 20°, the airspeed was 296 KIAS, which was 65 kt above flap 20 VFE. This coincided with the flight crew disconnecting the autopilot and reducing engine thrust from 91% to 47% N1 (Figure 2, Point B). The flaps continued to extend over the next 21 seconds until reaching 45° where they stopped, at which point the airspeed was 234 KIAS, 45 kt above flap 45 VFE (Figure 2, Point C).

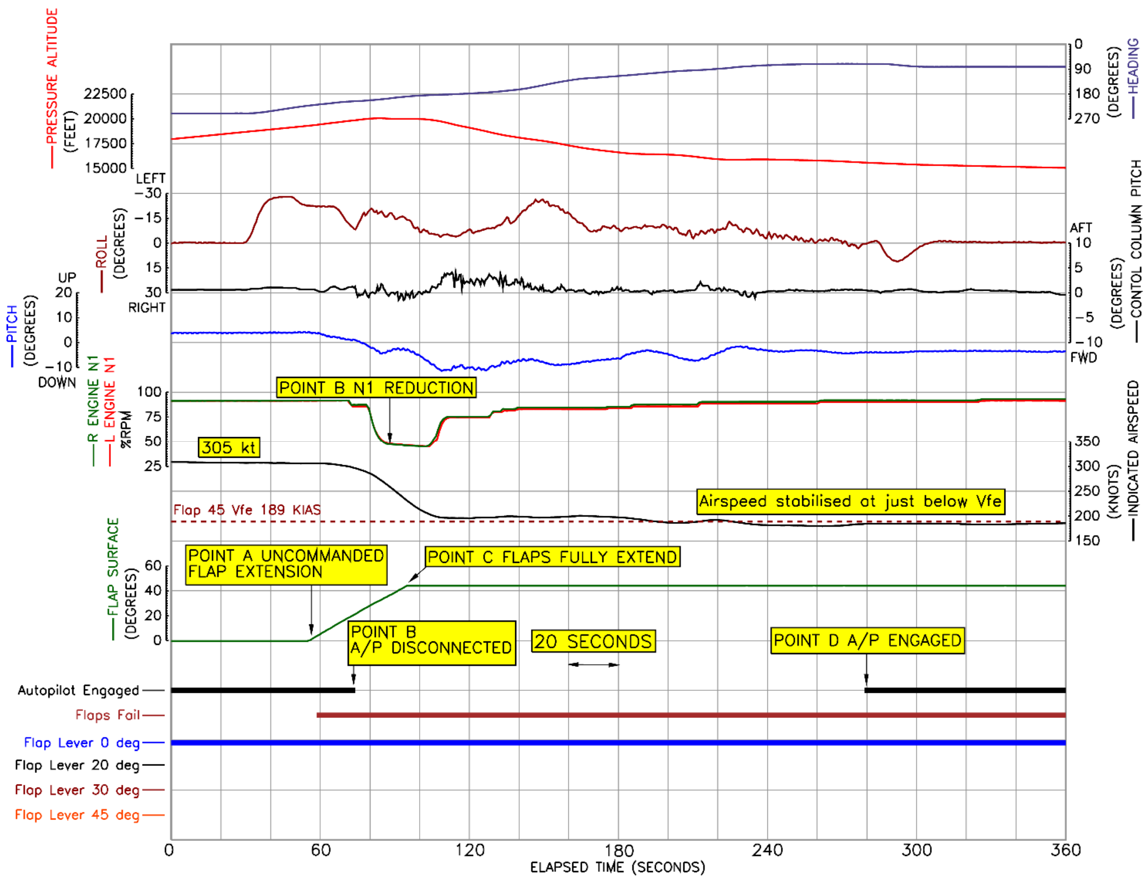


Figure 2

FDR data of uncommanded flap extension

The aircraft's speed continued to progressively reduce over the next 10 seconds, and as it approached 200 KIAS the crew started to progressively increase engine thrust. This coincided with the aircraft also starting to descend, having briefly climbed to FL200. The crew subsequently stabilised the aircraft's speed at about 183 KIAS with engine thrust set at 92% N1. The autopilot was then engaged (Figure 2, Point D), and the aircraft subsequently levelled off at FL150. The flaps had experienced an overspeed for a period of about

170 seconds, which was the time between the flaps starting to extend from 0°, and the airspeed having been stabilised at just below 189 KIAS with the flaps at 45°. During this period, the maximum flap overspeed was about 103 KIAS.

During the 64 previous flights recorded on the FDR, flap extension had occurred at normal speed, but retraction was at half normal speed. The oldest flight on the FDR was on 4 July 2022.

Aircraft description

General

The CL600-2B16 Challenger 604 is a swept-wing aircraft with a T-tail and is powered by two turbofan engines mounted one either side on the rear fuselage. The aircraft type is predominantly used for private business operations. The total Challenger 600 series fleet, which includes the Challenger 600, 601, 604, 605 and 650, is approximately 1,000 aircraft. D-AAAY was configured to carry up to 12 passengers and is operated by two pilots and one cabin crew.

Flap system

Two double-slotted flap panels (inboard and outboard) are externally hinged on the trailing edge of each wing. A flap lever, located on the cockpit centre pedestal, sends an electric signal to the Flap Control Unit (FCU) to initiate flap movement. When the FCU commands a change in flap position, the flap brakes are released, and two 200V 3-phase AC-powered motors mounted on a flap gearbox are energized by relays located in junction boxes. The motors and gearbox, which are part of the Power Drive Unit (PDU), rotate flexible shafts to move the flap ball-screw actuators, extending or retracting the flaps. When the desired setting is reached, measured by a flap position potentiometer on the PDU, the motors are de-energized, and the flap brakes are applied. The flaps are mechanically interconnected for simultaneous movement of the inboard and outboard flap sections. A schematic diagram of the flap system is shown in Figure 3.

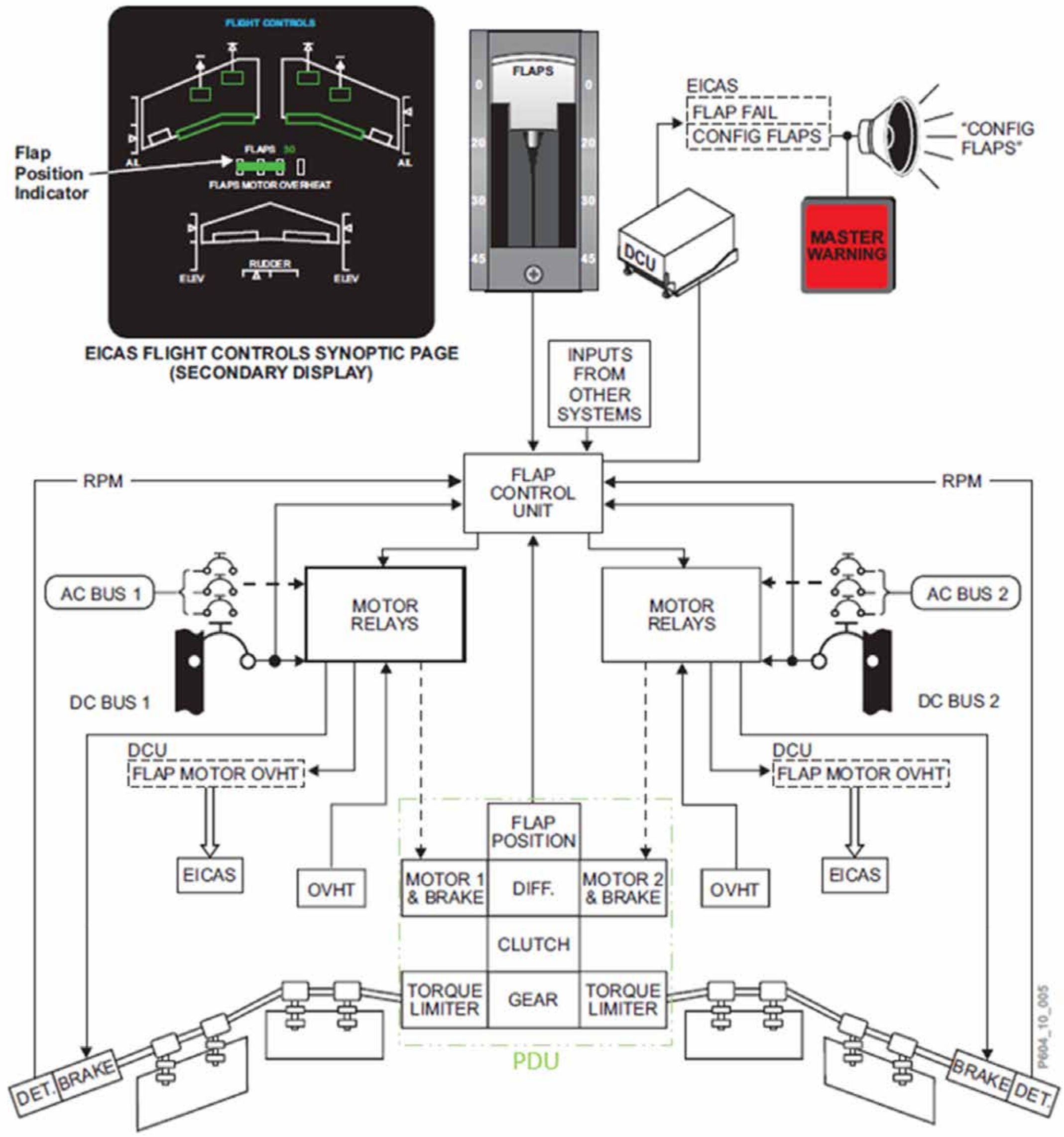


Figure 3

Schematic diagram of flap system

The flaps may be set to one of four positions: 0, 20, 30, and 45 degrees. Flap position is displayed on the EICAS primary page and the Flight Controls Synoptic Page in both analogue (coloured bar) and digital formats. This EICAS indication comes from a separate flap position sensor attached to the right inboard flap. The indications on the EICAS primary page are in view only if the flaps are extended, or if the landing gear is not up and locked.

When both motors are operational, the flaps operate at normal speed. If one motor fails or is not commanded to operate due to a failure in its control system, the remaining motor will continue to drive the flaps, but the system will operate at half speed due to the gearbox arrangement in the PDU. If a motor fails due to overheat, a 'FLAPS MOTOR OVHT' status EICAS message will be displayed.

If a complete failure of the flap system occurs, such as both motors failing to operate, an asymmetry of greater than 2.75°, or a flap uncommanded movement, a 'FLAPS FAIL' caution message will be displayed on EICAS.

Uncommanded flap movement protection

The FCU has an uncommanded movement protection system. If an uncommanded movement of the flaps occur and the actual flap position exceeds the commanded position by greater than three degrees, the system is activated to arrest further flap movement. Activation of the uncommanded motion monitor powers both the extend and retract commands to the motor relays to activate the protection. This engages the wing tip brakes, by de-energizing them, and removes power from both flap drive motors, arresting the movement, and a 'FLAP FAIL' EICAS message is displayed.

Maximum flap speeds

Flap setting (degrees)	Maximum airspeed (KIAS)
20	231
30	197
45	189

Overspeed warning for flap extension is provided by a second set of contacts in the flap lever. If the flap lever is set to a flap position other than flap 0, and the aircraft's speed is above the limit speed for that position, an aural 'clacker' warning will sound in the cockpit. There is no warning linked directly to the actual flap position.

Relevant maintenance history

Scheduled check of the operation of the flaps

A check of the flap extension and retraction time is included in a regular inspection of the flap system. This is carried out every 600 flight hours on the Challenger 600 and 601 aircraft and every 1,200 flight hours on the Challenger 604, 605 and 650 aircraft.

A functional check of the uncommanded movement protection system of the flaps is carried out every 4,800 flying hours on the Challenger 604, 605 and 650 aircraft. At the time of this occurrence the aircraft had flown 8,151 hours and the last check was carried out in December 2018, approximately 1,696 flight hours prior to this occurrence, as part of a functional test of the FCU. The operation of the protection system was satisfactory.

Recent maintenance on the flap operating system

The aircraft had recently undergone a 96-month 'major' check, which was completed in June 2022. The only work carried out on the flap system at this time was the replacement of one flap ball-screw actuator.

In August 2021, approximately 500 flight hours before this occurrence, the PDU position sensor was replaced. As part of the maintenance task, an operational test of the flaps was carried out which included measuring flap extension and retraction time, they were both normal.

Examination of the aircraft

After the aircraft had landed, engineers from a maintenance company began fault finding the defect reported by the flight crew. The aircraft was left parked with electrical power applied and the aircraft powered up. After approximately two hours, the flaps extended fully without command. The flap selector lever in the cockpit was in the flap 0 position.

The manufacturer was contacted for technical and fault finding advice and provided detailed testing and inspection procedures designed to identify any anomalies with the flap system. This work included detailed wiring and insulation checks as well as functional tests of the flap system. On 15 August 2022, the AAIB commenced its investigation.

In parallel with the fault isolation work, a preliminary structural inspection was carried out. The results were passed to the manufacturer for review in conjunction with the flight data to understand the loads experienced by the aircraft during the occurrence. The results of this review will be used to determine the extent of the remedial actions required.

No 1 retract relay

The testing and inspection identified that the No 1 motor retract relay was not working as expected.

All four of the flap extend / retract relays were taken to a specialist facility and were scanned using a computerised tomography (CT) scanner. Figure 4 is an image of the No 1 motor retract relay from the scan showing a contact anomaly. This anomaly is being investigated further, along with discrepancies in the operation of the relay.

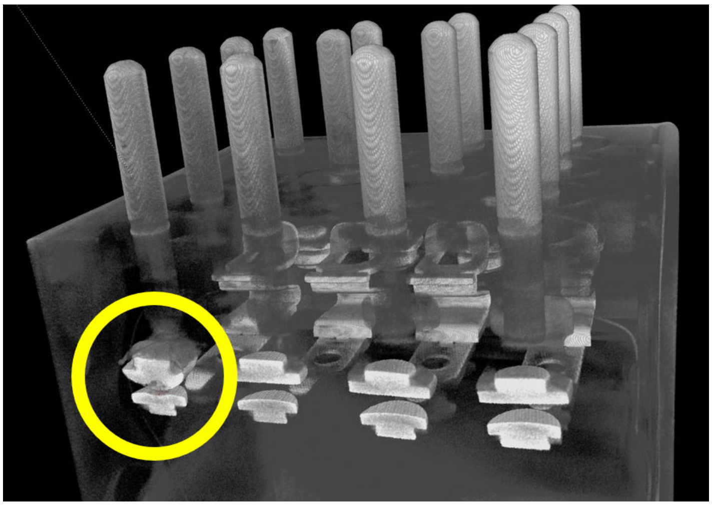


Figure 4

CT scan image of a contact anomaly in No1 motor retract relay

Flight safety risk

As part of the certification process for the aircraft, a safety analysis was conducted by the aircraft manufacturer. For the flap system a Fault Tree Analysis was conducted considering multiple failures. An uncommanded flap extension in cruise was identified as a potentially catastrophic event[1]. The analysis concluded that two concurrent failures would be required, and the probability of this occurring was calculated as being extremely improbable[2].

Analysis

At least two faults are required for an uncommanded flap movement beyond three degrees of the commanded position. One to cause the flaps to move, and a second to prevent the movement from being arrested.

Uncommanded extension of flaps

The reason for the uncommanded extension of the flaps has not yet been determined and is subject to further investigation.

Uncommanded flap movement protection

When uncommanded flap movement is detected by the protection system, it provides electrical power to the No 1 and No 2 extend and retract relays. This engages the wing tip brakes, by de-energizing them, and removes power from both flap drive motors thereby arresting the movement of the flaps.

The fault with the No 1 retract relay meant the No 1 motor continued to operate and the wing tip brakes did not engage. The No 2 relays worked as expected and the No 2 motor was unpowered. Consequently, the flaps continued to extend uncommanded at half speed, driven by the No 1 motor, until they reached the limit stop.

Failure of the No 1 retract relay meant that the uncommanded movement protection system was disabled and only an uncommanded extend signal was required to extend the flaps. The safety case for an uncommanded flap movement was calculated assuming two concurrent failures, but this event shows that it is possible for one failure to exist undetected for some time, thereby increasing the risk of this potentially catastrophic event occurring. The following Safety Action is being taken by Transport Canada and the aircraft manufacturer to review the safety case for the Challenger 600 series of aircraft:

Safety Action

Transport Canada have advised that they and Bombardier are reviewing the safety case for the flap operating system of the Challenger 600 series of aircraft to ensure that the safety risk probability of an uncommanded flap movement is correct.

Footnote

1 Catastrophic – Aircraft destroyed and/or multiple deaths. (ICAO Doc 5863, Safety Management Manual).
2 Extremely improbable – Almost inconceivable that the event will occur. (ICAO Doc 5863, Safety Management Manual).

On this occasion the crew, who were actively monitoring the aircraft during climb, quickly noticed the uncommanded flap extension and were able to respond appropriately to control the aircraft and reduce its speed to below the flap limit speed. Even so, the flap overspeed reached up to about 103 kts and the speed was not reduced below the flaps 45 limit speed for some 170 seconds.

Had the aircraft been in the cruise, the crew may not have been able to recognise the uncommanded flap extension so promptly and take corrective action within the time required for the flaps to fully extend.

As the outcome of an uncommanded flap extension could potentially be catastrophic, the aircraft manufacturer has taken the following Safety Action to advise operators of this event:

Safety Action

By 20 October 2022, Bombardier will advise operators of the Challenger 600 series of aircraft, through an Advisory Wire, of the circumstances of the occurrence to D-AAAY.

To ensure that operators are aware of the actions to take in the event of an uncommanded flap operation, which may occur without warning, the following Safety Recommendation is made:

Safety Recommendation 2022-017

It is recommended that Bombardier inform operators of the Challenger 600 series of aircraft of the actions to take in the event of uncommanded flap operation in flight.

A failed relay, or the flaps operating at half speed, is not annunciated and it is possible that other aircraft in the fleet may be operating with a similar latent failure that could render the uncommanded flap movement protection system ineffective. Therefore, the following Safety Actions have been taken to advise operators of the instructions available to check the speed of movement of the flaps, and ensure that appropriate mandatory inspections are carried out to ensure the continued safe operation of the fleet:

Safety Action

By 20 October 2022, Bombardier will advise operators, through an Advisory Wire, of the existing maintenance tasks that will identify if the flaps are operating at half speed.

Safety Action

Transport Canada have advised that Bombardier and Transport Canada will determine any appropriate actions to ensure that the protection system on the Challenger 600 series of aircraft will stop an uncommanded flap extension and the system operates as intended. Transport Canada will mandate such actions as necessary for the continued safe operation of the aircraft.

Initial findings

1. Whilst the aircraft was climbing, an uncommanded flap extension occurred which was not arrested by the uncommanded movement protection system.

2. The flap overspeed warning did not sound, as the flap lever remained at the flap 0 position. This warning is triggered by flap lever movement, not the actual flap position.

3. The flap uncommanded movement protection system detected the uncommanded movement and the 'FLAP FAIL' EICAS message was displayed.

4. The flap position indicator showed the flaps extending.

5. Fault finding identified an anomaly with the operation of the electrical contacts inside the No1 retract relay. The result of this anomaly was that as the flaps were only being driven by one of the two motors, they retracted at half-speed.

6. There is no annunciation or warning to indicate the incorrect operation of the relay or to indicate the flaps are operating on one motor at half speed.

7. A further effect of the defective No 1 retract relay was that the uncommanded flap movement protection system did not work on D-AAAY.

8. The flaps on D-AAAY had been retracting at half speed since at least the 4 July 2022. Since this date the aircraft had operated for 154 hours and 64 flights.

Further work

The investigation continues to focus on identifying the cause of the uncommanded flap extend signal.

The four flap extend and retract relays, along with other flap system components removed from the aircraft, will be sent for more detailed examination and testing.

The structural analysis of the event by the manufacturer is continuing and initial inspections and checks for damage to the aircraft are ongoing.

Published: 22 September 2022.

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:	Boeing 737-800, G-JZHL
No & Type of Engines:	2 CFM CFM56-7B26E turbofan engines
Year of Manufacture:	2016 (Serial no: 63568)
Date & Time (UTC):	1 December 2021 at 1452 hrs
Location:	Kuusamo Airport, Finland
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	7,459 hours (of which 3,344 were on type) Last 90 days - 204 hours Last 28 days - 47 hours
Information Source:	AAIB Field Investigation

Synopsis

This investigation was delegated to the AAIB by the Safety Investigation Authority of Finland.

During takeoff from Kuusamo Airport in Finland the flight crew inadvertently left the thrust set at the 70% engine run-up setting rather than the 89% required for takeoff. The aircraft became airborne with 400 m of runway remaining and climbed away slowly. At 250 ft agl the flight crew realised they had insufficient thrust and applied the correct power. The flight continued without further incident.

The thrust was not set correctly because the TOGA button was not pressed. It was not pressed because the co-pilot was startled by the aircraft starting to move when he set 70% power against the brakes. The aircraft started to move because the co-pilot applied insufficient brake pressure. The commander was distracted by a radio call and neither he, nor the co-pilot, checked the thrust was correctly set.

The AAIB has investigated several takeoff performance incidents across the industry. This incident is further evidence that the current barriers designed to prevent these events are not fully effective, and improved reliability is likely only through the introduction of a technical barrier. A Safety Recommendation is therefore made to develop technical specifications and, ultimately, certification standards for a technical solution.

A Safety Recommendation is also made to improve the detection of takeoffs with compromised performance, to support the prompt reporting of occurrences.

History of the flight

The crew were scheduled to operate return flights from London Stansted Airport to Kuusamo Airport (Kuusamo) in Finland. Neither pilot was working on the day prior to the flights but each took time to revise the cold weather and contaminated runway procedures and read the briefing material for Kuusamo. On the day of the incident the crew reported at Stansted at 0915 hrs.

The outbound flight was uneventful. The flight crew used some quiet time during the cruise to discuss the departure from Kuusamo. The weather in Kuusamo was a light wind from the north-east, light snow and a temperature of -8°C. The runway was covered with 3 mm of dry snow and the airfield was reporting a Runway Condition Code (RWYCC) of 4[1]. The aircraft landed on Runway 30, arriving on stand a few minutes ahead of schedule.

Once the passengers had disembarked the crew prepared for the return sector. There were no passengers for the return flight leaving just the two pilots and four cabin crew onboard. As the wind was still across the runway, they planned to depart from Runway 12 using intersection A (Figure 1). The takeoff weight was 52,100 kg with 9,600 kg of fuel. The airfield conditions were unchanged so the crew completed a takeoff performance calculation using medium to good braking action and derated takeoff thrust. The calculation gave Flap 5, an N_1 of 89.0%, a V_1 of 93 kt, a V_R of 122 kt and a V_2 of 131 kt which was loaded into the FMC and Mode Control Panel (MCP). The crew obtained their clearance and briefed for the takeoff whilst the aircraft was de-iced. The clearance was, after departure, to route via waypoint IBEVU and climb to FL400. The co-pilot was to be the pilot flying. As the ramp was contaminated with snow the crew planned to taxi with the flaps up, selecting them before lining-up on the runway. The conditions required a pre-takeoff engine run-up to clear any ice from the engines. This required the engines to be accelerated to 70% N_1 on the runway for 30 seconds whilst the aircraft was held on the brakes.

Kuusamo Airport either provides an Air Traffic Control service (ATC) or a Flight Information Service (FIS) depending on the expected volume of traffic. During the initial arrival an ATC service was provided but this switched to a FIS shortly before the aircraft landed. A FIS was still being provided when the aircraft departed.

The crew started the engines on stand and, once all the checks were completed, requested taxi instructions. They were instructed to taxi onto the runway and asked to report ready for departure. The commander taxied the aircraft the short distance from the parking position to the runway whilst the co-pilot completed the before takeoff procedure and checklist including selecting the flaps to 5. Once lined-up on the runway the commander handed control to the co-pilot. The crew reported they were ready for departure and the Flight Information Service Officer (FISO) replied the runway was clear and reported the surface

Footnote

[1] Runway Condition Code is part of the new Global Reporting Format for assessing and reporting runway surface conditions. RWYCC 4 means that braking deceleration or directional control is between Good and Medium; and pilot reports of runway braking action are Good to Medium. For further information, see: https://www.caa.co.uk/commercial-industry/airports/safety/runways/new-contaminated-runway-reporting-system/ [accessed July 2022].

wind. The co-pilot then advanced the thrust levers to 70% N_1 whilst holding the toe brakes. However, as he did this, he felt the aircraft start to slide and yaw. The crew had briefed that this might happen and had agreed that if it did, they would release the brakes and continue the takeoff. The co-pilot recalled saying something like "it's sliding" and the commander replied with words like "let it go". The co-pilot recalled that he was startled by how readily the aircraft had slid and yawed and by the proximity of the snowbanks to the side of the runway. He released the brakes and focused on steering the aircraft down the runway. He remembered working quite hard with the rudder pedals to keep the aircraft straight.

Figure 1

Kuusamo Airport

As the co-pilot was advancing the thrust levers to 70% the commander had selected the secondary engine instruments to be displayed on the lower centre screen (with his right hand). He held his finger over the button ready to clear the display after the run-up was complete. At the same time, he was ready to start his timer with his left hand to time the 30 second run-up.

To set the takeoff thrust, the operator's Standard Operating Procedures (SOPs) require the co-pilot to press the TOGA button then immediately remove their hand from the thrust levers. The commander is then required to place their hand on the thrust levers until V_1. On this occasion, due to the startle of the aircraft sliding, the co-pilot omitted to press the TOGA button and removed his hand from the thrust levers leaving the thrust set at 70% N_1.

Whilst this was happening and as the aircraft was starting to move, the FISO made a transmission to the aircraft asking for them to confirm they would be turning right after departure. The commander replied to confirm they would, but this exchange distracted him and he omitted to check that the thrust was correctly set and did not make the "thrust set" standard call. The co-pilot was focussing on steering the aircraft along the runway and, similarly, did not confirm the thrust was set.

By this stage the aircraft was approaching 80 kt. The commander reported that he was aware that something was not right but could not resolve what was wrong. He felt the acceleration was slightly low but thought that might be due to the contamination on the runway. The crew made the normal calls at 80 kt and this was shortly followed by V_1 at 93 kt. The takeoff continued and both pilots reported being aware that something was not right. The co-pilot initiated the rotation at V_R but recalled the aircraft was "very heavy" in pitch. As he looked down to the Primary Flight Display (PFD), he realised there was no vertical flight director so he focused on flying a pitch attitude to maintain airspeed. He recalled the aircraft was not climbing normally and the airspeed was hovering around V_2, he described that "it felt like flying an engine failure on takeoff in the simulator". The co-pilot remembered saying "we need more power". At this stage the commander realised they did not have takeoff power set and manually advanced the thrust levers to 89% N_1. On reaching 2,400 ft amsl they selected N1 on the MCP to reduce to climb power then, as the aircraft passed 3,900 ft amsl, started to accelerate and retract the flaps. Once clean they selected LVL CHG[2] which restored the vertical flight director. The remainder of the flight to Stansted continued without further incident.

Recorded information

G-JZHL was fitted with a CVR capable of recording the last two hours of the flight but, due to the length of the return flight, the recording would have been overwritten before the aircraft landed at Stansted. However, data was available from both the FDR and Quick Access Recorder, which were downloaded. The data showed that the crew had correctly loaded the FMC for the derated takeoff, resulting in a target engine N_1 of 89%.

Figure 2 shows salient data from the FDR for the takeoff and second segment climb. It shows that, although the maximum system braking pressure is 3,000 psi, a brake pressure of only 600-700 psi was applied before the thrust levers were slowly advanced for the pre-takeoff engine run-up. Twelve seconds later, as the engines were spooling up towards 70% N_1, and with 600-700 psi brake pressure still applied, the recorded longitudinal acceleration shows that G-JZHL began to move. The brakes were then released, and the engines stabilised at 70% N_1. G-JZHL accelerated and, on passing 6 kt groundspeed, a radio transmission was made from the aircraft, followed by another transmission at 53 kt airspeed. At 80 kt airspeed, G-JZHL was accelerating at approximately 0.12g, or 2.25 kt/second, and attained $V_{1,}$ with the engines still at 70% $N_{1,}$ 32 seconds after brake release. At V_R, the aircraft was rotated for takeoff, leaving the ground six seconds later and establishing a 600 ft/min rate of climb in which the airspeed settled around V_2. However, G-JZHL did not accelerate any further, despite the pitch attitude of the aircraft being reduced and the retraction of the landing gear, until 250ft agl when the thrust levers were advanced to 89% N_1, the correct power setting for the takeoff.

Footnote

2 Level Change: an autopilot flight director mode for changing altitude or Flight Level.

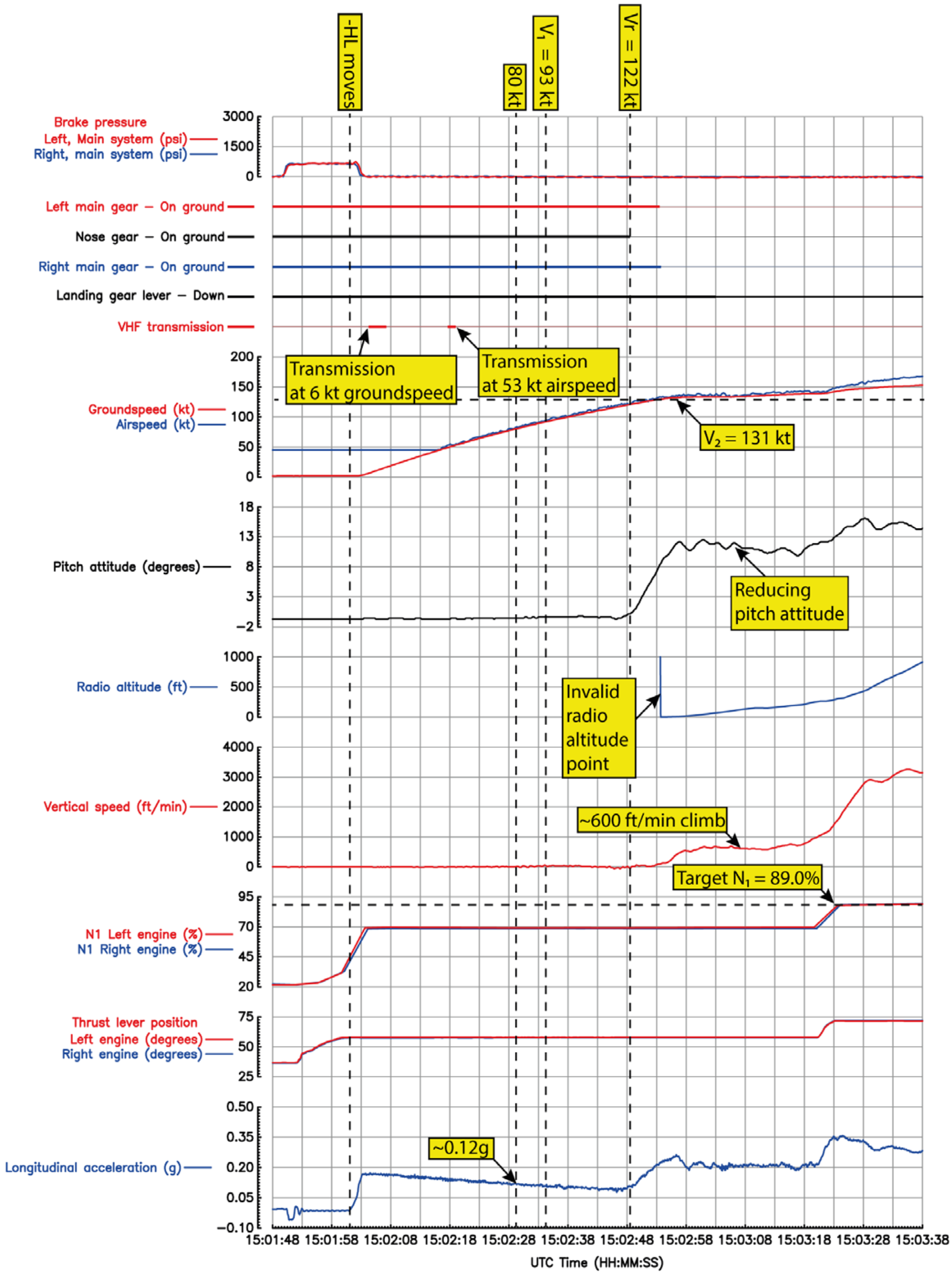


Figure 2

FDR data for G-JZHL's takeoff and second segment climb

Figure 3 shows the takeoff and second segment climb in plan view. The distance from where G-JZHL performed the pre-takeoff engine run-up until the end of the runway is 2,330 m. G-JZHL passed 80 kt with 1,790 m of runway remaining ahead of the aircraft and, at V_1, 1,510 m remained ahead of the aircraft. G-JZHL became airborne 400 m from the end of the runway, and the thrust was restored to 89% N_1 approximately 1,800 m after G-JZHL lifted off.

The FDR data also showed that no EGPWS cautions or warnings were triggered.

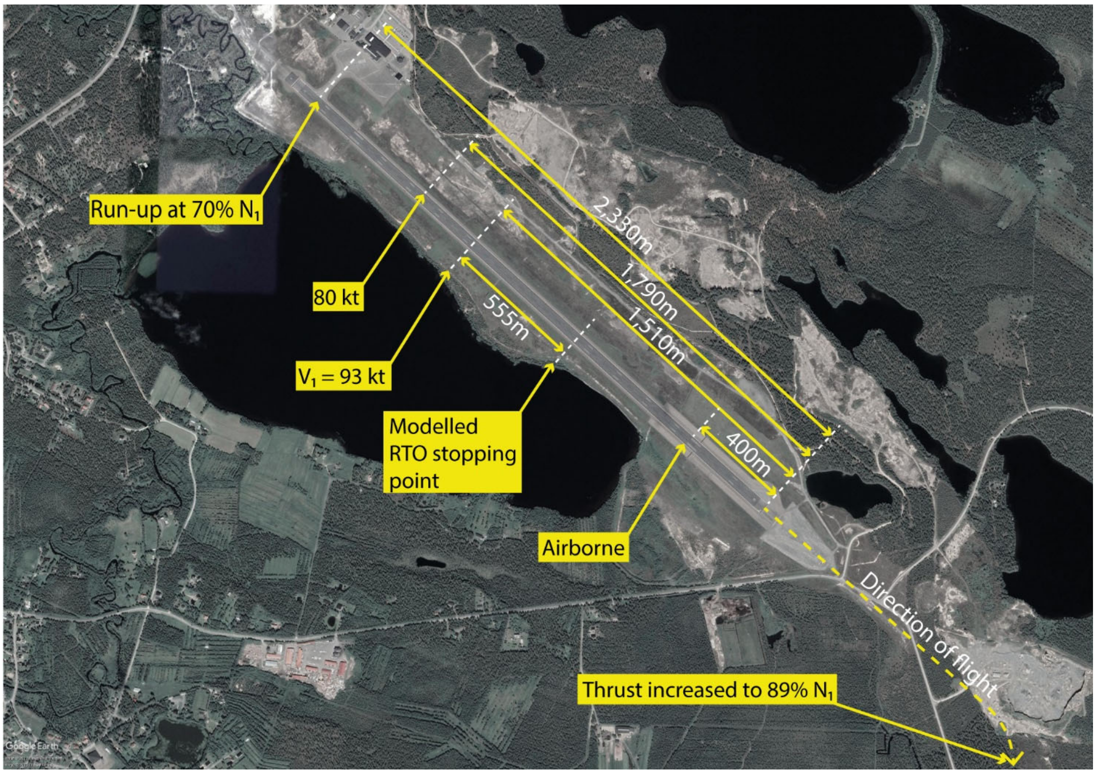


Figure 3

Plan view of G-JZHL's takeoff and second segment climb

No radar or RTF recordings were available for G-JZHL's departure, as Kuusamo Airport is not equipped with a local radar installation and their RTF recording equipment had not been working since 23 September 2021. The RTF recording equipment was subsequently repaired on 9 December 2021, and the maintainer introduced weekly serviceability checks.

Manufacturer's performance modelling

Wheel speed is not a parameter recorded by the FDR, so the aircraft's manufacturer was asked to estimate the brake pressure needed, given a RWYCC of 4, to stop the wheels from rotating against an engine power setting of 70% N_1, the power setting used for the pre-takeoff engine run-up. The manufacturer responded that for G-JZHL, which was equipped with carbon rather than steel brakes, 1,000-2,000 psi would be required dependent on the brake temperature and, to a lesser extent, the humidity of the air. This range of values is substantially higher than the braking pressure observed during G-JZHL's run-up. Furthermore, the manufacturer commented that given the aircraft's weight and centre of gravity and the runway condition, it is unlikely that the tyres would have slipped on the runway's surface.

The manufacturer also carried out several performance studies and these confirmed that in the event of a rejected takeoff (RTO), commenced at V_1 and using maximum braking effort, the aircraft would have been able to stop within 555 m, leaving 955 m of remaining runway ahead of the aircraft.

However, if G-JZHL had suffered an engine failure close to V_1 and continued the takeoff without any further adjustment to the engine power setting, the aircraft would have left the end of runway, having not attained the scheduled rotation speed, at a groundspeed of 115 kt.

The manufacturer's studies also showed that using 70% N_1 resulted in a total engine thrust at the start of G-JHZL's takeoff roll of approximately 22,800 lbf, or 53% of the 42,800 lbf expected if 89% N_1 had been used – little more than the thrust of a single operative engine.

Airfield and air traffic service information

Kuusamo Airport has a single runway, which is orientated 12/30 and is 2,500m long. The parking apron is at the north-western end of the runway and is accessed via intersection A. The airport elevation is 868 ft amsl.

The insert in Figure 1 shows the location of the airport, which is approximately 10 nm from the boundary between Helsinki and St Petersburg Flight Information Regions (FIR). Figure 4 is an extract from the IFR plates used by the operator. The chart shows the proximity of the border (in green) and the waypoint IBEVU which the crew were cleared to route via after departure. There is a restricted area (R100) along the border and a danger area to the north (D200). These are depicted on the IFR chart (Figure 4) but are shown more clearly in Figure 5 (this was not available to the flight crew in flight). The danger area exists from the surface to 1,000 ft agl, but the restricted area covers all altitudes.

During the incident departure the airport was providing a FIS. The service provided changes between ATC and FIS depending on the expected volume of traffic. NOTAMs are issued to inform flight crews which service to expect.

Generally, a FISO can only provide advice and information useful for the safe and efficient conduct of a flight. A FISO is not permitted to issue instructions or clearances to an aircraft in flight of their own volition (they can pass on clearances issued by other agencies). However, they can issue instructions to aircraft on the apron. At Kuusamo Airport, the FISO could instruct the aircraft to taxi to the runway but could not issue a takeoff clearance. Instead, they report the runway is clear, the commander can then takeoff at their discretion.

On the incident flight, when the flight crew advised they were ready for departure, the FISO told them the runway was clear and the flight crew replied that they were taking off. The FISO expected the flight crew to confirm their intended routing after takeoff, but as they did not do this, she asked the flight crew to confirm they would turn right.

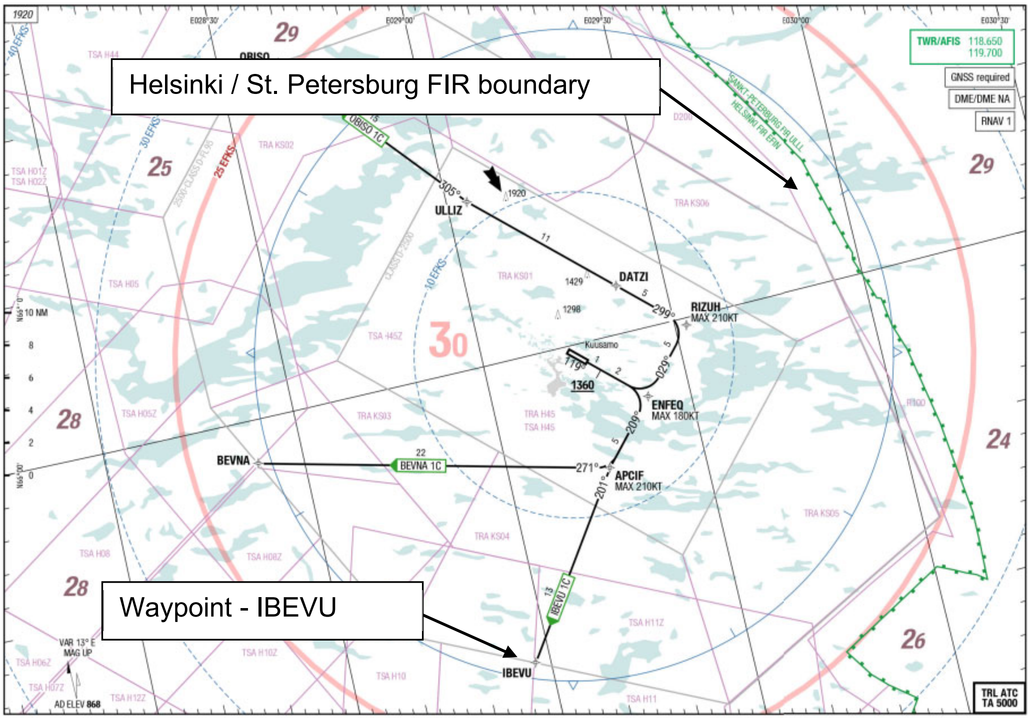


Figure 4

IFR Departure Chart for Kuusamo Airport

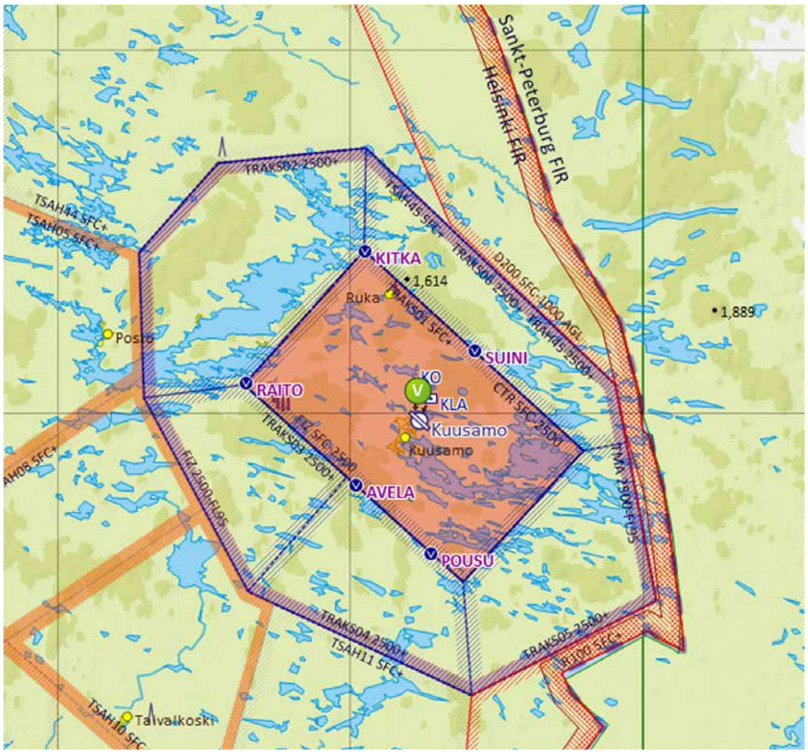


Figure 5

Airspace surrounding Kuusamo Airport

The Airport Operational Information section of the operator's IFR charts for Kuusamo contains the note '*aircraft with a MTOW exceeding 2000kg: after TKOF from RWY 12 turn right'* (the note is extracted from the Finnish Aeronautical Information Publication (AIP)). The flight crew had also been cleared via a waypoint to the south of the airport. They, therefore, intended to turn right but were not aware of any obligation or requirement for them to report this to the FISO.

The Standardised European Rules of the Air (SERA)[3] Section 3, *General rules and collision avoidance*, (SERA.3225) states:

> *'An aircraft operated on or in the vicinity of an aerodrome shall:* […] *(c) except for balloons, make all turns to the left, when approaching for a landing and after taking off, unless otherwise indicated, or instructed by ATC.'*

The Finnish AIP[4] Part GEN 3.3 contains information about air traffic services. Section 3.1 describes operations at Finnish airport where Aerodrome Flight Information Services (AFIS) are provided. Section 3.1.4.1 stated that:

> *'Departing aircraft shall report* […] *the planned route or the flight track and a possible intention to make a right turn.'*

This is followed by a note which states:

> *'According to The Rules of the Air, an aircraft may make turns to the right after takeoff* […] *where Aerodrome Flight Information is available providing that this can be done without hazard to other air traffic and the intention to turn right is reported to the AFIS unit.'*

The FISO reported that local flight crew who regularly fly to Kuusamo always confirm they will turn right when they report they are taking off. The FISO's understanding was that, because the SERA rules states that aircraft should normally turn left after takeoff and the Finnish AIP states that aircraft must report their intentions if they plan to turn right, the commander would report that he intended to turn right. When the commander did not report this, the FISO felt she was required to clarify his intentions, in part due to the proximity of the restricted and danger area ahead and to the left.

Once the aircraft is airborne, the FISO is not allowed to issue any instruction to the aircraft and, as there is no radar at Kuusamo and it was dark, there is no way for them to confirm the aircraft's routing. When an ATC service is being provided the controller can clear an aircraft to fly a particular standard instrument departure (SID). This removes any ambiguity about the aircraft's routing after departure. However, a FISO is not able to issue a SID clearance.

The FISO reported that they could see that the aircraft had commenced its takeoff roll (view from the tower at a similar time of day is shown in Figure 6).

Footnote

3 SERA regulations are available at https://www.easa.europa.eu/document-library/easy-access-rules/easy-access-rules-standardised-european-rules-air-sera [accessed September 2022]

4 Finnish AIP is available at https://ais.fi/ais/eaip/en/ [accessed August 2022].

Figure 6
View from the ATC Tower

The ICAO Aeronautical Telecommunication Procedures manual (ICAO Annex 10 Volume 2) contains the following rule:

> *'5.2.1.7.3.1.1 Except for reasons of safety, no transmission shall be directed to an aircraft during takeoff, during the last part of the final approach, or during the landing roll.'*

When interviewed after the incident the FISO clearly understood the rule and the importance of avoiding distracting the flight crew at a critical stage of flight. However, at the time she considered it was necessary to confirm the aircraft would turn right after takeoff.

The FISO held a valid licence and had 10 years' experience providing a FIS. She had participated in virtual classroom refresher training in 2020 and simulator refresher training in autumn 2021.

Meteorology

At the time of the incident the airfield was reporting a surface wind from 040° at 5 kt, visibility of 6 km, it was snowing, cloud was scattered at 3,100 ft agl, temperature was -8°C, dewpoint was -10°C and sea level pressure was 983 hPa. The surface wind gave a 5 kt crosswind on Runway 12 with no head or tail wind.

The runway conditions were reported as a 100% covering of 3 mm dry snow with a RWYCC of 4 for all sections of the runway.

Takeoff performance calculation

Using the operator's runway condition assessment matrix with 3 mm of dry snow gave a RWYCC of 5. However, as the airfield was reporting a RWYCC of 4 the crew used this as the worst case. The flight crew used the operator's approved iPad app to calculate the takeoff performance.

After the incident, the calculation was verified with the assistance of the operator. The FDR data also confirmed the data was correctly loaded into the FMC and MCP.

Flight crew

Both flight crew held valid licences and medicals to operate the B737-800. Their total flight hours and recent experience is shown in Table 1.

	Commander	Co-pilot
Age	44	41
Total Time	7,459 hrs	4,582 hrs
On Type	3,344 hrs	2,399 hrs
Last 90 days	203 hrs	139 hrs
Last 28 days	47 hrs	32 hrs

Table 1

Flight crew age and experience

Both pilots felt they were current and did not think that recency was a factor in the incident. They both reported they were well rested prior to the flight.

Neither pilot had operated to Kuusamo before. They both reported they had limited experience of cold weather operations. The commander had some experience from a previous operator and the co-pilot's only experience was from simulator training. However, they both felt well prepared for the flight from the training they had received and from their pre-flight revision of the operator's manuals.

Takeoff procedure

Figure 7 shows the takeoff procedure as detailed in the operator's Flight Crew Operations Manual (FCOM).

The procedures require the commander's hand to be on the thrust levers during the takeoff roll so that they can rapidly initiate a rejected takeoff if required. The operator has added an additional note to the takeoff procedure specified by the manufacturer (marked as note 1 in Figure 7) to clarify the exact point at which the co-pilot must remove their hand. The note states that the co-pilot must remove their hand immediately after pressing TOGA. The commander will then place their hand on the thrust levers as they advance.

Captain	First Officer	
Verify that the brakes are released. Align the airplane with the runway.		
Verify that the airplane heading agrees with the assigned runway heading.		
	When cleared for takeoff, set the FIXED LANDING/LANDING (as installed) light switches to ON.	
Select Chronograph to Start and Elapsed Time to RUN.		
Pilot Flying	**Pilot Monitoring**	
Advanced the thrust levers to approximately 40% N1. Allow the engines to stabilise.		
Push the TO/GA switch. Note: If the F/O is PF their hand should be removed from the thrust levers immediately after the TO/GA switch is pushed. The Capt should then keep one hand on the thrust levers as they advance.		1
Verify that the correct takeoff thrust is set		2
	Monitor the engine instruments during the takeoff. Call out any abnormal indications. Adjust takeoff thrust before 60kts 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"	2
After takeoff thrust is set, the Captain's hand must be on the thrust levers until V1.		
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".	
Note: If the "80 KNOTS" call is delayed, the PM calls the speed passing, e.g. "90 KNOTS".		
Verify V1 speed	Call "V1".	
At VR, rotate toward 15° pitch attitude. After lift-off, follow F/D commands.	At VR, call "ROTATE" Monitor airspeed and vertical speed	

Figure 7

Takeoff procedure extracted from the operator's FCOM
(blue numbers added to link to the discussion in the following narrative)

The operator advised that this note was added to provide clarity about when the co-pilot's hand should be removed and to ensure the commander was holding the thrust levers as the power increased so that they could always abort the takeoff if required.

Engine run-up

When operating in icing conditions (visible moisture, ice, snow, slush or standing water) and the temperature is 3°C or less a pre-takeoff engine run-up is required. The procedure states (described in the FCOM supplementary procedures):

> *'Run-up to a minimum of 70% N1 and confirm stable engine operation before the start of the takeoff roll. A 30-second run-up is highly recommended whenever possible.'*

The commander reported that he usually displayed the secondary engine instruments during the 30 seconds so that he could monitor the engine indications. He would then clear the secondary display prior to starting the takeoff. Displaying secondary engine instruments requires a single press of the ENG button in the centre of the instrument panel, they are cleared by pressing the button a further two times. During the 30 seconds the captain would hold his finger over the button ready to clear the display.

There is no requirement to display the secondary engine instruments during a run-up but similarly there is no guidance not to display them. However, if any engine parameter is out of limits the display will automatically pop-up.

Following this incident, the operator sought further guidance from the aircraft manufacturer about conducting a take-off with an engine run-up. The operator has incorporated this guidance in their FCOM, highlighting the importance of applying sufficient brake pressure and clarifying actions to be taken should the aircraft start to move during the run-up.

Thrust set check

During the takeoff roll, prior to 80 kt, both pilots are required to verify the correct takeoff thrust is set (marked as note 2 in Figure 7). This requires the pilots to verify the actual N_1 display on the upper centre display matches the target N_1 (Figure 8). The actual N_1 and the target N_1 are shown in digits and on a rotary dial. The lower images in Figure 8 show the indications with the correct thrust set (left image) and with approximately 70% N_1 set (right image).

PFD indication

The top section of the PFD contains the Flight Mode Annunciator (FMA). The FMA tells the pilot which autothrottle, flight director and autopilot modes are armed or active. Figure 9 shows the PFD prior to the takeoff as it was set up on the incident flight. The autothrottle is armed (ARM in white in the left column of the FMA), the flight director roll mode has LNAV (lateral navigation system) armed (LNAV in white in the centre column) and the pitch mode (right column) is blank.

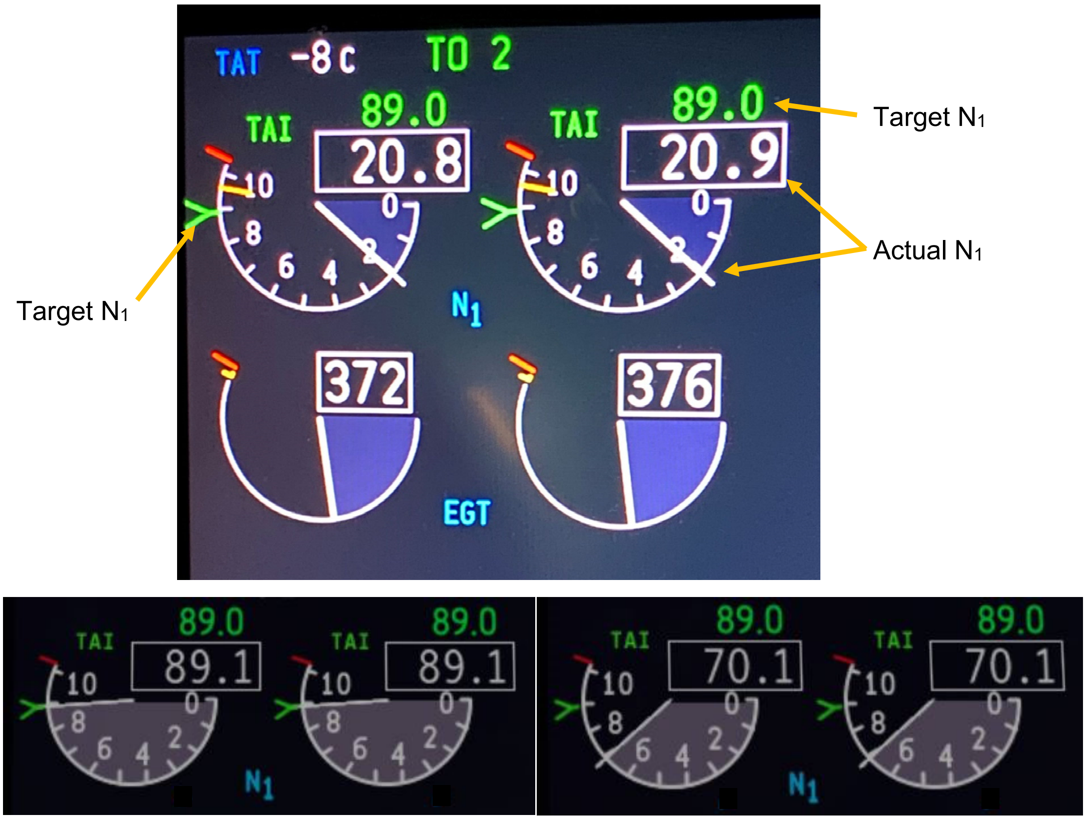


Figure 8

Primary engine instruments shown on the upper centre screen (images captured in a simulator)

Figure 9

PFD prior to starting the takeoff (image captured in a simulator)

During a normal takeoff FMA's would change as shown in Table 2

Prior to takeoff	ARM	LNAV	
When TOGA is pressed	N1	LNAV	TOGA
Passing 84 kt	THR HLD	LNAV	TOGA
Passing 50 ft aal	THR HLD	LNAV	TOGA

Table 2

FMA changes during a normal takeoff

In addition to the FMA changes the flight director command bars would appear on the PFD when the TOGA button is pressed.

Table 3 shows how the FMA behaves if the TOGA button is not pressed during the takeoff.

Prior to takeoff	ARM	LNAV	
TOGA press omitted	ARM	LNAV	
Passing 84 kt	THR HLD	LNAV	
Passing 50 ft aal	THR HLD	LNAV	

Table 3

FMA changes during takeoff when TOGA is not pressed

If TOGA is not pressed, the flight director command bars will not be displayed until the aircraft passes 50 ft agl and LNAV engages. At this stage the roll bar will appear but the pitch bar will remain off until a pitch mode is selected.

The PFD speed tape shows a trend arrow, and the top of the arrow predicts what the speed will be in 10 seconds at the current acceleration rate. Figure 10 shows the difference in the trend arrow with 89% N_1 set and 70% N_1 set.

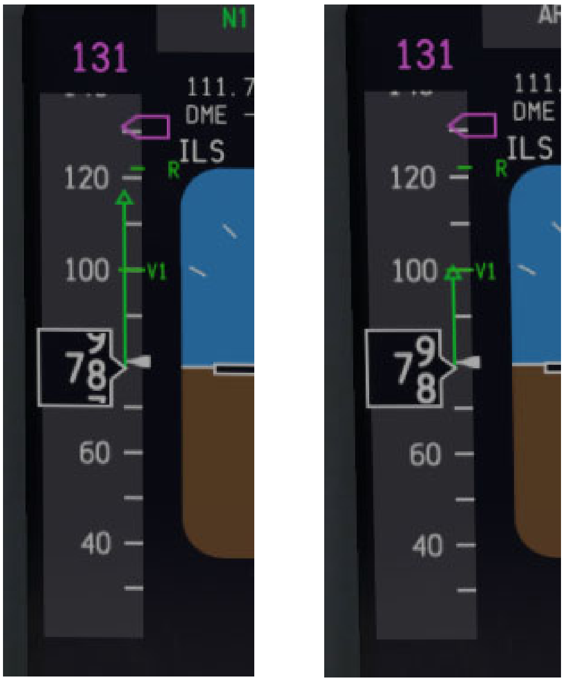


Figure 10

PFD Speed Tape trend arrow (left image with 89% N_1, right image with 70% N_1)
(images captured in a simulator)

Operator's investigation into brake pressure

After the incident, the co-pilot had the opportunity to experiment with the brakes in a simulator and found the brake pedals have significantly more travel than he had previously been using.

The operator reviewed their historic Flight Data Monitoring (FDM) data and found two previous events where it is likely that insufficient brake pressure was applied during static run-ups.

The operator issued a flight crew general notice to all their flight crew highlighting the issue and began monitoring FDM data to detect any future issues. A static run-up was also included in one of the line-orientated evaluation (LOE) sectors used in the operator's next simulator check. The LOE also included some distraction during the start of the takeoff roll.

Previous events

The AAIB has investigated several serious incidents where the takeoff performance of large commercial aircraft was severely compromised.

Most notably, in 2017, the AAIB investigated an event where Boeing 737-800, C-FWGH, carrying 179 passengers and six crew, took off from Belfast, Northern Ireland[5], with

Footnote

[5] AAIB Aircraft Accident Report AAR2/2018 – C-FWGH, 21 July 2017, available at: https://www.gov.uk/aaib-reports/aircraft-accident-report-aar-2-2018-c-fwgh-21july-2017 [Accessed 30 May 2022].

insufficient thrust for the environmental conditions. This led to the aircraft hitting a runway light, which was 36 cm high, 29 m beyond the end of the runway, before climbing away very slowly.

Frequency of occurrence

Following the 2017 event, the AAIB began compiling a list of subsequent takeoff performance incidents from operators' safety reports, MORs and validated occurrences from online aviation websites. This list, which should not be considered exhaustive, is attached at Appendix A in a de-identified form and shows that a total of 32 events have occurred in just under 5 years, including this incident to G-JZHL.

The most recent event occurred in April 2022 to an Airbus A330-900 departing from Luanda Airport in Angola. In this instance, the aircraft was carrying 148 passengers and 10 crew and departed from Intersection E of Runway 23 using performance data appropriate for a full-length departure. Consequently, the performance data that was used was appropriate for a runway approximately twice the length of that available for the aircraft's departure. Fortunately, the crew saw the end of the runway approaching and applied full power. Six seconds later the aircraft became airborne having reached the extreme end of the runway.

Events relevant to this investigation

The AAIB's list shows that on 15 July 2018, an A220 took off from Porto[6] with insufficient thrust, after the crew did not advance the thrust levers far enough for the autothrottle to engage. This was a similar incident to the event on G-JZHL although, in the Porto case, the crew advanced the thrust levers late in the takeoff roll. On 28 November 2009, an MD-11F was lost at Shanghai[7], with three fatalities, after the crew did not advance the thrust levers far enough for the autothrottle to transition into the correct mode and, as a result, provide the correct takeoff thrust.

Recognition of degraded aircraft performance and intervention

Of the 32 events recorded in Appendix A, 12 were investigated by the AAIB and, of these, 10 resulted in a significant shortfall in the acceleration of the aircraft. In nine of these events the crew did not recognise the reason for the lack of aircraft performance and either abort the takeoff or increase engine power before becoming airborne.

The histogram in Figure 11 shows the acceleration at 80 kt for a sample of 73,669 Boeing 737-800 takeoffs, gathered by a US avionics manufacturer to support development of a technological barrier to detect significant shortfalls in acceleration on takeoff[8].

Footnote

[6] STSB Final Report No. 2355, available at: https://www.sust.admin.ch/inhalte/AV-berichte/2355_e.pdf [Accessed 30 May 2022].

[7] Avient Aviation MD11 at Shanghai on 28 November 2009, overran runway on takeoff, available at: https://avherald.com/h?article=423638d8 [Accessed 30 May 2022].

[8] For more information on this data and analysis, see the AAIB report into C-FWGH's takeoff (Footnote 4).

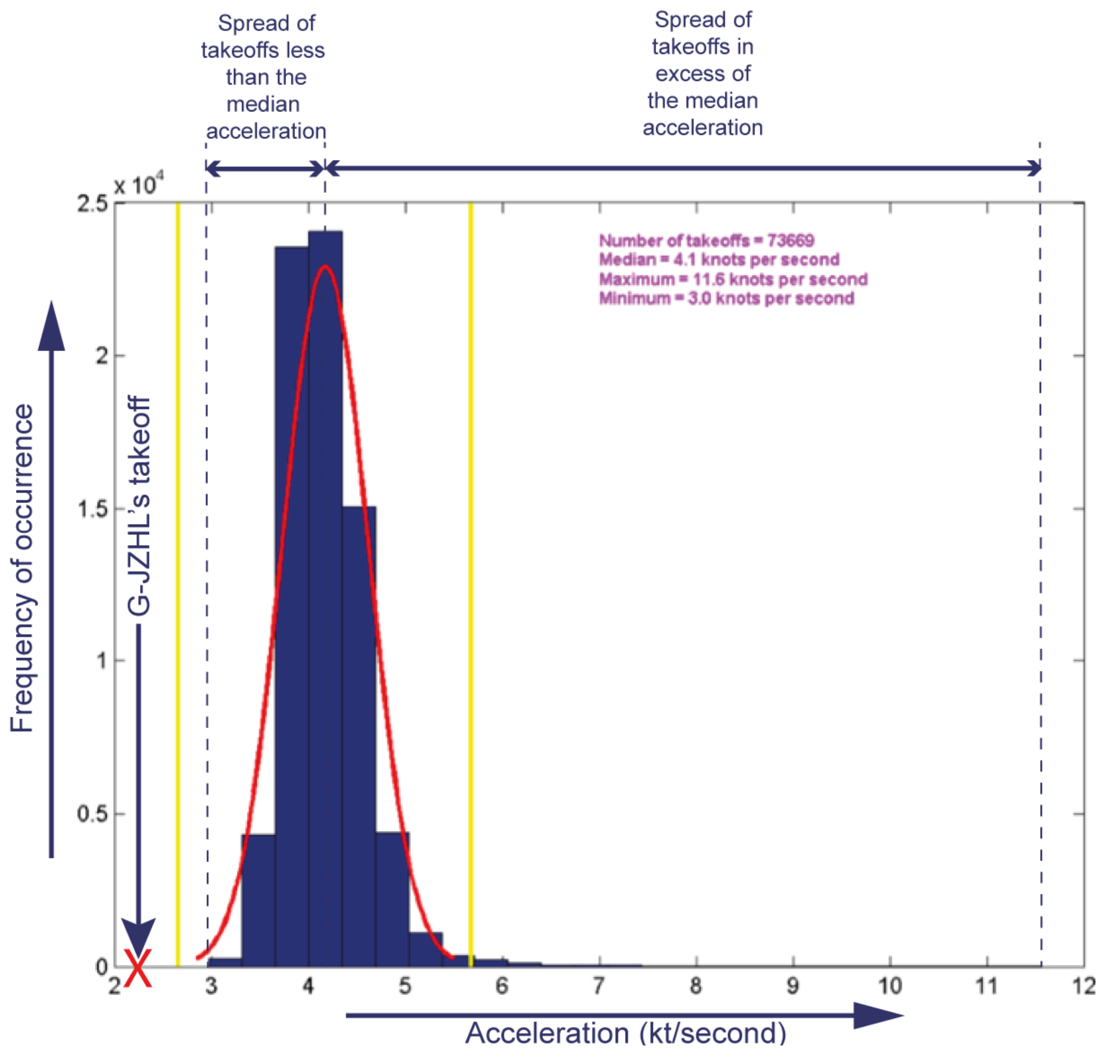


Figure 11

G-JZHL's acceleration on takeoff compared with other 737-800 takeoffs.
Used with permission

The data encompasses a weight range of 43 to 78 tonnes, representing 93% of the Boeing 737-800 operating weight range, and covers both a range of airport elevations, from sea level to 1,900 ft amsl, as well as outside air temperatures of between -1 and 42°C.

This data shows that the minimum acceleration seen on takeoff from the 73,669 takeoffs was 3.0 kt/second and that the median, the midpoint of the frequency distribution shown on the histogram by the peak of the red line, was 4.1 kt/second. The yellow lines represent three standard deviations, or the bounds which enclose 99.7% of the data.

By comparison, G-JZHL was accelerating at 2.25 kt/second, as it passed through 80 kt airspeed. This value is shown on Figure 11 by the red cross.

In this event, which happened at night, both pilots reported that they were aware that something was not right but continued with the takeoff and did not increase engine power before becoming airborne. In the 2017 Belfast incident, despite the prevailing good visibility and daylight conditions, neither pilot recognised that the aircraft was accelerating slowly until nearing the end of the runway, well past the calculated V_1, and engine power was not increased until the aircraft was 4 km from the airport. Both crew members reported that all procedural cross-checks had been completed, yet the data entry error was made and was not detected.

Perception of acceleration

As part of the investigation of the 2017 Belfast Incident, the AAIB commissioned a human factors report which is included in full as an appendix to that AAIB report (see Footnote 4). The human factors report described human perception of longitudinal acceleration and pilots' ability to recognise abnormal acceleration during takeoff. Pilots are unlikely to recognise abnormal acceleration for the following reasons:

- Acceleration is not explicitly monitored during takeoff.
- Pilots become accustomed to different rates of acceleration.
- Perception of motion is primarily governed by visual rather than vestibular cues, and the visual system has a high detection threshold and general insensitivity to acceleration.
- The visual cues in slower acceleration do not differ enough for pilots to detect until presented with an atypical visual scene (such as the end of the runway approaching).

Reliability of checks conducted by humans

Human performance is variable, and no task undertaken by humans is performed completely accurately on every occasion. Because of this, there are numerous requirements for people to check their own work or for someone's work to be checked by a co-worker. Such checks are either intended to prevent errors or to catch any errors made before they have a safety consequence. They contribute to the overall safety of the system but are prone to being missed out or being completed but not detecting errors. A NASA research paper[9] published in 2010 examined the frequency of deviations from prescribed procedures, checks and monitoring on 60 normal flights in three operators. They observed 194 deviations in checklist use and 391 in monitoring. 14% of checklist deviations and 6% of monitoring deviations were caught and corrected by the flight crew. Most deviations observed resulted in a small reduction in efficacy of safeguards but no adverse outcome for the flight. Although the number of deviations was high, when considering the number of items to be checked and monitored the overall rate of deviations compared to the opportunity for deviation was less than 1%. This is similar to the error rate observed for many types of skilled human performance and difficult to improve upon further in a cockpit environment.

Footnote

9 Dismukes, R. K. and Berman, B. (2010) *Checklists and monitoring in the cockpit: why crucial defences sometimes fail*, NASA.

Takeoff acceleration monitoring

The histogram in Figure 11 is heavily skewed, showing a much larger spread of takeoffs where the acceleration exceeded the median value of 4.1 kt/second than for accelerations below the median. The maximum recorded value (11.6 kt/second) is 7.5 kt/second above the median, whereas the minimum value (3.0 kt/second) is only 1.1 kt/second below the median.

Because the range of low acceleration takeoffs to the left of the median value in Figure 11 is so sharply defined and there are so few low acceleration takeoffs, technology could be used to alert flight crew, early in a takeoff roll, to acceleration that is grossly low but which may not be recognised as such by them. Such a system, termed a Takeoff Acceleration Monitoring System, is fully described in the report into the Belfast incident (see Footnote 4).

Takeoff Acceleration Monitoring Systems (TAMS) are inherently less complicated than solutions that compare actual aircraft performance against predicted aircraft performance, or those that extend this prediction to include stopping after rejecting a takeoff or continuing with a takeoff following, for example, an engine malfunction. These solutions typically rely upon crew input, which despite the presence of data entry cross-checks, may be in error thereby invalidating the predictions. Further, an industry working group that last looked at these more technically complicated solutions found several areas of concern, including:

- The lack of real-time environmental parameters and/or parameters derived from navigation and airport databases or service providers.
- A lack of standardisation in reporting runway conditions.
- A lack of good assessments of runway braking friction.
- A lack of suitable aircraft performance models.

These concerns do not apply to TAMS, which use empirical data on takeoff performance and are only concerned about the acceleration of the aircraft on the runway.

The reporting of takeoff performance events

The CAA mandates occurrence reporting through Regulation (EU) No 376/2014[10] (EU 376/2014), '*On the reporting, analysis and follow-up of occurrences in civil aviation',* which requires any organisation established in the UK to report safety related occurrences to the CAA in a Mandatory Occurrence Report (MOR).

In Article 4 of EU 376/2014, *'takeoff and landing-related occurrences'* are listed as events that must be reported, and in Commission Implementing Regulation (EU) 2015/1018, '*laying down a list classifying occurrences in civil aviation to be mandatorily reported according to* [EU 376/2014]*',* the following example occurrences are listed:

Footnote

[10] Regulation (EU) No. 376/2014 as retained (and amended in UK domestic law) under the European Union (Withdrawal) Act 2018.

> *'Use of incorrect data or erroneous entries into equipment used for navigation or performance calculations which has or could have endangered the aircraft, its occupants or any other person.'*

and

> *'Inability to achieve required or expected performance during takeoff, go-around or landing.'*

Furthermore, ICAO Annex 13, which contains the Standards and Recommended Practices for aircraft accident and incident investigation, defines the term *'Serious incident'* and lists in Attachment C examples of events that could constitute such an incident. They include:

> *'Gross failures to achieve predicted performance during takeoff or initial climb'*

Serious incidents are reportable to the State of occurrence (usually the Safety Investigation Authority (SIA)) independently from the mandatory reporting scheme.

However, an analysis of events that occurred in UK airspace, from the AAIB's list of validated takeoff performance occurrences since mid-2017, showed that in many cases MORs were not submitted and, when they were reported, the report was often significantly delayed. Furthermore, in only a few cases was the AAIB promptly notified of the occurrence.

During this investigation, the CAA stated its intention to promote awareness among AOC holders and pilots of the causes and safety implications of compromised takeoff performance, and the importance of pro-active reporting.

FDM detection of takeoff performance events

In February 2016 the EASA published a Safety Information Bulletin (SIB), entitled *'Use of Erroneous Parameters at Takeoff'*, to alert operators and flight crew to the safety issue and to recommend the implementation of operational mitigation measures[11]. The SIB, which followed a survey of operators, recognises that under-detection of takeoff performance events is a potential industry-wide issue and states:

> *'it is likely that other events have occurred but were not reported, either because they were uneventful or because the issue was not identified by the flight crew during the takeoff or through the Flight Data Monitoring (FDM) programme. It is therefore important that this safety issue is monitored more closely and that operators collect more data in order to gain better awareness and understanding of the frequency and potential severity of these events, as well as to monitor associated trends and to assess the effectiveness of any remedial action.'*

Footnote

[11] EASA Safety Information Bulletin No. 2016-02R1, available at: https://ad.easa.europa.eu/ad/2016-02R1 [Accessed 30 May 2022].

It goes on to state that:

> *'implementing even a few specific FDM event algorithms or measurement algorithms could help to improve the detection of related events and assess their frequency and severity...and consequently, to evaluate the effectiveness of the risk mitigations put in place in their organisation.'*

The SIB suggests that there is under-reporting, perhaps because the outcomes were '*uneventful*' or because the crew did not notice anything abnormal at the time. Data entry errors can lead to unpredictable outcomes. They can have a significant effect on acceleration that is not noticed but may, at the same time, profoundly undermine the validity of the takeoff performance calculation. Day-to-day variability in performance calculation output due to the use of optimised takeoff performance calculations, and the use of intersection takeoffs, degrade flight crews' abilities to distinguish performance on a particular takeoff from the norm.

The SIB goes on to say that the European Operators Flight Data Monitoring (EOFDM) forum has produced guidance for the implementation of FDM to identify precursors to these types of events[12]. They note that this may require the recording or computing of flight parameters that are not readily available, as well as designing new FDM events or measurement algorithms, but it is thought these precursors could be implemented by the majority of operators. The SIB makes the following recommendation:

> *'EASA recommends operators to implement specific FDM event algorithms (or FDM measurement algorithms) that are relevant to the monitoring of takeoff performance in their FDM programme and to analyse events and adverse trends detected by these algorithms.'*

The AAIB is aware of a European operator that routinely analyses whether the takeoff data entered into the aircraft's flight management system matches that calculated by the flight crew prior to departure using their performance tool. Used alone, this technique would not capture all events – such as if erroneous data was initially entered into the performance tool – but it does show an additional approach that would complement a robust set of FDM algorithms.

However, despite EASA's recommendation on the use of FDM to monitor takeoff performance events and the publication of the EOFDM's guidance material, the AAIB is aware that very few operators, including in the UK, have fully implemented FDM algorithms to detect relevant precursors for takeoff performance events. This was confirmed, in part, in a survey carried out by the EOFDM group in early 2022, which showed that only one out of 19 respondents had implemented FDM algorithms for one of the key precursors.

Footnote

[12] EOFDM Working Group B, *Guidance for the implementation of flight data monitoring precursors*, available at: https://www.easa.europa.eu/downloads/119200/en [Accessed 30 May 2022].

Several reasons have been suggested for this including a lack of resource within operators' FDM teams, especially after the Covid-19 pandemic; the lack of interoperability of IT systems involved in computing takeoff performance; and, for some of the more complicated FDM algorithms, the ability to establish and program the algorithm into the operators' FDM system.

Analysis

During a pre-takeoff engine run-up the thrust was increased to 70% N_1 as required by the supplementary procedure. However, the thrust was not subsequently increased to the required 89% N_1 and remained at 70% throughout the takeoff roll. This occurred because the co-pilot did not press the TOGA button and neither pilot checked the thrust was correctly set during the takeoff roll. Several factors contributed to these omissions, which are discussed below. The low thrust was not detected until after the aircraft was airborne.

The aircraft became airborne with 400 m of runway remaining. If the aircraft had suffered an engine failure after V_1 it would not have been able to safely get airborne with the thrust of 70% N_1 on the operative engine.

TOGA button

The co-pilot reported that he omitted to press the TOGA button because he was startled by the aircraft starting to slide and drift toward the snowbanks.

It is likely that the aircraft was rolling rather than sliding as the co-pilot was applying insufficient brake pressure to hold the aircraft stationary against the 70% N_1. Co-pilots at this operator do not taxi the aircraft so are rarely required to use significant brake pressure. This meant the co-pilot did not have any experience of applying significant brake pressure. During simulator training after the incident, the co-pilot discovered the brake pedals have significantly more travel than he had been using.

After the incident the operator reviewed their FDM data and discovered several previous events where insufficient brake pressure had been applied during engine run-ups. The operator took safety action to alert pilots to the issue and is using FDM data to monitor further trends.

Whilst the subsequent analysis showed the aircraft was rolling, in the moment the co-pilot's perception was that the aircraft was sliding. The pilots had briefed that the aircraft might slide and that, if it did, the co-pilot would release the brakes and continue the takeoff. So, when they perceived that the aircraft was sliding, they did as they planned and the co-pilot released the brakes. It is possible that because they were primed that the aircraft may slide, when it started to move, they were more likely to think it was sliding rather than considering insufficient braking. Briefing what may happen is generally very helpful but, in this case, it may have primed the crew to expect a particular outcome.

The co-pilot reported that he was startled by how readily the aircraft started to slide and by the aircraft starting to drift towards the snowbanks. A startle response can be defined as '*a* *complex, involuntary reaction to a sudden unanticipated stimulus*'[13]. It is a '*brief, fast and highly physiological reaction to a sudden, intense or threatening stimulus*'[14]. He perceived that the threat was the aircraft sliding towards the side of the runway and his attention was drawn to controlling the aircraft. NASA's technical memorandum titled '*Effects of acute stress of aircrew performance*'[15] describes how a threatening stimulus can cause a pilot to focus their attention on addressing that threat and can lead to errors or omissions in other concurrent tasks. It is likely that, in the moment of the startle, suddenly faced with a threatening situation, the co-pilot's attention was solely drawn to controlling the aircraft and this caused him to omit to press the TOGA button.

The operator's SOPs require the co-pilot to remove their hand from the thrust levers '*immediately*' after TOGA is pressed (the operator had added an additional note to the manufacturer's standard takeoff procedure to state exactly when the co-pilot's hand should be removed). This normally occurs at the start of the takeoff roll as the aircraft starts to accelerate, so the co-pilot would be used to having both hands on the control column as the aircraft travels down the runway. During this incident, as the aircraft started to move, with his attention focused on controlling the aircraft, it would have felt natural to move his hand from the throttles to the control column.

'Thrust set' check

The takeoff procedure requires both pilots to check that the correct takeoff thrust is set. Once the pilot monitoring has checked the thrust, they are required to call 'thrust set'.

During a normal takeoff, with the co-pilot handling, the commander will place their hand on the thrust lever as soon as the co-pilot presses the TOGA button. They can then watch the N_1 gauges increasing until the actual N_1 matches the target and then call 'thrust set'. However, during the incident takeoff, this normal sequence was interrupted.

As the co-pilot started to advance the thrust levers to 70% N_1, the commander was expecting a 30 second stationary run-up. He had the secondary engine instruments displayed and was ready to start his timer. As the aircraft unexpectedly started to move, he had to clear the secondary engine instruments, start his timer and place his hand on the thrust levers. As this was happening, the commander made a radio transmission (as the aircraft accelerated though 6 kt) which was probably him confirming they were taking off. The FISO then made a further transmission to the aircraft asking them to confirm if they would be turning right after departure. By the time the commander had replied to the FISO the aircraft was passing 53 kt. The commander reported that it was this distraction that caused him to omit the thrust set check and call.

Footnote

[13] Reber, A. (1985) *The Penguin dictionary of psychology*, Penguin.

[14] Landman, A., Groen, E.L., van Passen, M.M. Bronkhorst, A. & Mulder, M. (2017) 'Dealing with unexpected events on the flight deck: A conceptual model of startle and surprise' in Human Factors, Vol 59 pp 1161-1172.

[15] Dismukes, R. K., Goldsmith, T. E., Kochan, J. A. (2015) *Effects of Acute Stress on Aircrew Performance: Literature Review and Analysis of Operational Aspects*, NASA.

When an action is normally cued by a sequence of preceding events, if those events are changed or if a distraction occurs during those events, people are vulnerable to omissions. Having missed the action, with the normal cues now passed, it is unusual for a person to remember to return to the omitted item, particularly in a time limited situation. A report published in Aero Safety World in December 2008[16] discussed how common this is and how it has caused previous accidents.

Having omitted the thrust set check after answering the radio call, the commander had seven seconds until the aircraft passed 80 kt, a further five seconds until V_1 then a further 25 seconds before V_R. During the takeoff roll the pilot monitoring would normally be monitoring the aircraft for any abnormal indications. There were several indications on the flight deck which might have alerted him that the thrust was not set correctly and that TOGA had not been pressed. The needles on the N_1 gauges would not have been aligned with the target bugs and the digits would have been different from the target digits (Figure 8). With hindsight these indications may seem obvious, but it is common for humans to see what they expect to see or 'look without seeing' (Footnote 8). This is more common with an indication which is normally correct. Experienced pilots who have seen hundreds of takeoffs will nearly always have seen the thrust correctly set. On the one occasion when it is not set, it is possible that they will not see it, they will just see what they expect to see.

The PFD also had indications to tell the pilots that something was abnormal. The FMAs at the top of the PFD were subtly different to a normal takeoff and the flight directors were not displayed. There is no requirement for the pilots to check the FMAs during the takeoff roll so they may not have looked at them. Even if they did notice the FMAs were abnormal or saw the lack of flight directors, it may not have been immediately obvious why. The pilots had not seen a takeoff without TOGA being pressed before so it may have taken some time to understand why the indications were abnormal. The length of the trend arrow on the speed tape would also have been smaller than on a normal takeoff, but there is no requirement to check the trend arrow on the takeoff roll and this difference from normal may not have been sufficient to be detected. The trend arrow is also dynamically calculated and therefore can fluctuate significantly with wind gusts on the takeoff roll making it hard to interpret.

The co-pilot is also required to check the thrust is correctly set during the takeoff roll. However, having been startled by the unexpected aircraft movement, his focus was on controlling the aircraft. His visual attention would have been outside the cockpit ensuring the aircraft was tracking down the runway centreline. It is likely that the effect of the startle and with his attention captured by controlling the aircraft, the co-pilot did not have the capacity to check the thrust.

Footnote

16 'Deadly Omissions' Aero Safety World December 2008, available at https://flightsafety.org/wp-content/uploads/2016/12/asw_dec08_p10-16.pdf [Accessed 25 February 2022]

Radio transmission during the takeoff roll.

During the takeoff roll the FISO made a transmission to the aircraft which distracted the commander. The FISO was expecting the flight crew to confirm their routing when they reported they were taking off. When the flight crew did not do this, the FISO felt she was required to ask for confirmation before the aircraft took off.

From the flight crew's perspective, they had been cleared to route via a waypoint to the south of the airport and their charts included an instruction to turn right. Therefore, they intended to turn right but were not aware of any requirement for them to report this.

From the FISO's perspective, there is no clearance between the airport and the first waypoint so an aircraft's commander could take any routing at their discretion. The rules of the air state that aircraft should normally turn left after takeoff, but if they intended to turn right, they must report this intention. The requirement to do this is also stated in the Finnish AIP. Therefore, the FISO expected the commander to report his intention to turn right.

The FISO felt she must obtain this confirmation before the aircraft was airborne because:

1. Kuusamo does not have radar, so once the aircraft was airborne, with limited visibility at night and in snow, the FISO would not have been able to determine the aircraft's routing.
2. Once the aircraft is airborne the FISO is not able to issue any further instructions to aircraft.
3. The FISO needed to confirm the restricted area to the east of the airport along the FIR boundary would not be infringed.

The FISO was aware of the requirement not to call an aircraft during the takeoff, but because of the proximity of the restricted area she believed she was required to obtain confirmation of the intended turn direction.

The operator subsequently included in their OM C the requirement to report direction of turn to the FISO for all Finnish airports.

When a radio transmission is made to an aircraft on a takeoff roll it is difficult for flight crew to ignore the message. The message could contain vital information (for example, informing the commander of smoke coming from the aircraft, or a blocked runway), so the crew must listen to the message and understand what they are being told. It was therefore difficult for the commander, on this takeoff, to avoid being distracted by the radio transmission.

Lack of acceleration

Both pilots reported that something was not right during the takeoff but, at the time, neither could resolve what was wrong. They felt the acceleration and the cadence of the takeoff was slightly slow but thought this might be due to the runway contamination. The feeling was not compelling enough for them to abort the takeoff.

This is in common with many of the previous takeoff performance incidents that the AAIB and other SIAs have investigated. Human perception of acceleration in combination with the nature of the takeoff task means that pilots are generally not able to recognise when the acceleration is slower than required, even when the difference in acceleration is significant.

Takeoff Acceleration Monitoring Systems

During this incident, the takeoff performance was correctly calculated and correctly loaded into the FMC. The incident occurred because the planned takeoff thrust was not set. There is a barrier in place to detect this error, in the form of a human check, but this incident shows this check is vulnerable to distraction.

The AAIB and other SIAs have investigated many takeoff performance incidents which have resulted in aircraft taking off with insufficient thrust. The circumstances of each incident differ but the outcome is the same. The human checks currently in place do not always stop these incidents occurring. Learning from past events and research shows that, whilst they are effective in many cases, such checks are occasionally omitted or fail to detect errors. Operational interventions maximise crew performance as far as possible but there is a limit to the reliability that can be achieved with any human task. Higher levels of reliability are likely to require a technological intervention. TAMS could detect these events and alert the flight crew at a low speed and enable them to safely reject the takeoff.

Following the Belfast incident, the AAIB made the following Safety Recommendation to EASA and the FAA:

Safety Recommendation 2018-014

It is recommended that the European Aviation Safety Agency, in conjunction with the Federal Aviation Administration, sponsor the development of technical specifications and, subsequently, develop certification standards for a Takeoff Acceleration Monitoring System which will alert the crew of an aircraft to abnormally low acceleration during takeoff.

As the issue of monitoring takeoff acceleration affects civil aviation worldwide, the following Safety Recommendation was made to ICAO:

Safety Recommendation 2018-015

It is recommended that the International Civil Aviation Organization note the conclusions of this report and introduce provisions addressing Takeoff Acceleration Monitoring Systems.

EASA's response to Safety Recommendation 2018-014 stated that:

'The safety issue "Entry of aircraft performance data" was included in the agency's safety risk portfolio for commercial air transport fixed-wing in 2016.'

and they also published SIB 2016-02R1, discussed earlier, to alert operators and flight crew to the safety issue and to recommend the implementation of operational mitigation measures. The SIB largely focused on flight crew training including recovery techniques in the event of a takeoff performance issue, data entry procedures, and management of the operator's exposure to the risk through their Safety Management System. The recommendation to sponsor the development of technical specifications has not been addressed, however, and the AAIB has not received any further information to say that it is under active consideration. The Safety Recommendation, therefore, remains open.

Safety Recommendation 2018-014 was published when the UK was part of the European Union (EU) and so the recommendation was made to EASA and not directly to the CAA. The UK left EU institutions when it left the European Union and therefore:

Safety Recommendation 2022-018

It is recommended that the UK Civil Aviation Authority, in conjunction with other regulatory authorities, develop a set of technical specifications and, subsequently, develop certification standards for an on-board system that will alert the crew of an aircraft to abnormally low acceleration during takeoff.

ICAO's response to Safety Recommendation 2018-015 stated the topic would be discussed with ICAO's Flight Operations Panel Working Group and, although this meeting did take place, the consensus was to look at making procedural improvements, rather than to look to technological aids, so this Safety Recommendation also remains open.

Reporting of takeoff performance events

In this event, the flight crew of G-JZHL recognised that a takeoff performance event had occurred and submitted a safety report. The operator filed an MOR with the UK CAA and contacted the AAIB. The AAIB then liaised with the Safety Investigation Authority of Finland who delegated the investigation to the AAIB.

However, the AAIB's analysis, across all operators, suggests that for many cases that have occurred in UK airspace, MORs are not submitted and, when they are, the report is often significantly delayed. Furthermore, in only a few cases have the AAIB been promptly notified of the occurrence. If, as is likely, this type of event is under-reported, the associated risk will be underestimated, thereby undermining the basis upon which any risk-based decisions are taken on potential mitigating action. It is therefore important that UK AOC holders report the example takeoff-related occurrences referred to earlier in this report[17] and contained in EU 2015/1018. The CAA stated that it intended to promote awareness of the causes and safety implications of compromised takeoff performance and the importance of pro-active reporting.

FDM events can also be used to monitor the frequency of occurrence of takeoff performance events and to ensure they are reported appropriately. EASA has published guidance material on the subject and has recommended that operators implement in their FDM programmes

Footnote

[17] See: *The reporting of takeoff performance events.*

specific algorithms to detect precursors relevant to the monitoring of takeoff performance. However, very few operators have implemented such algorithms and, therefore:

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.*

Conclusion and recommendations

The aircraft took off with insufficient thrust set because the TOGA button was not pressed. It was not pressed because the co-pilot was startled by the aircraft moving as he commenced the run-up against the brakes. The aircraft started to move because insufficient brake pressure was applied. Human checks designed to detect the insufficient thrust were ineffective because both pilots were attending to other tasks. The commander was responding to a radio call from the FISO during the start of the takeoff roll. Neither pilot detected the low thrust until after the aircraft was airborne.

The AAIB and other SIAs have investigated numerous previous takeoff performance incidents, and this incident provides further evidence that the current barriers in place to prevent such incidents are not always effective. A Safety Recommendation is therefore made to establish technical specifications and, ultimately, certification standards that would allow a technical barrier to be developed.

Takeoff performance-related incidents are likely to be under-reported, and a Safety Recommendation is made to encourage operators to implement FDM algorithms that identify precursor signals associated with compromised takeoff performance so that they can be reported.

Safety action

The operator:

- Issued a flight crew general notice highlighting the importance of applying sufficient brake pressure during a pre-takeoff engine run-up.
- Began to monitor FDM data to detect any further issues with brake pressure during pre-takeoff engine run-up.
- Included a pre-takeoff engine run-up and distraction during the takeoff roll in an LOE sector during their next simulator cycle.
- Updated their FCOM procedure of pre-takeoff engine run-ups.
- Updated their OM C for all Finnish Airports to include a requirement to report the intended direction of turn to the FISO before takeoff.

Published: 6 October 2022.

Appendix A

Known takeoff performance incidents since mid-2017

Date	Aircraft type	Location of incident	What happened?
15/07/17	B747-8F	Tokyo/Narita	Took off from Runway 16L using a correct assumed temperature, but the fixed derate applicable to a Runway 16R departure.
21/07/17	B737-800	Belfast	Took off from Runway 07 using an incorrect thrust setting – the result of entering the OAT for the cruising level, instead of the field-level OAT combined with an assumed temperature derate.
16/11/17	B737-700	Seletar, Singapore	Took off using an incorrect assumed temperature of 67 degrees, resulting in a thrust setting of 90.4%, not as required 102.5%.
28/03/18	B787-900	Gatwick	Took off from Runway 26R displaced threshold and not from the start of Runway 26R. TODA effectively reduced by 417 m.
29/03/18	B787-900	Tel Aviv	Took off using a ZFW 40t lower than the actual ZFW.
10/06/18	B737-800	Amsterdam	Took from Runway 09 at intersection N4 using the performance for Runway 09, intersection N5.
15/07/18	A220-300	Porto	Took off with insufficient thrust (AT armed but didn't engage as throttles not advanced to the required position). Crew realised at 90-100 kt and advanced the throttles. Spoilers were also deployed due to low thrust setting.
18/07/18	E170	Prague	Flap 1 used to takeoff instead of Flap 4.
28/07/18	B737-800	Birmingham	Took off from Runway 15 with the performance calculated for the ZFW instead of the TOW.

Appendix A (cont)

Date	Aircraft type	Location of incident	What happened?
18/09/18	A320-200	Sharjah	Took off in the wrong direction (Runway 12 rather than Runway 30), after lining-up on the runway from an intersection. Commander selected TOGA and changed flap setting, aircraft received minor damage and became airborne some 20-40 m after the end of the runway.
02/10/18	B787-900	New York	Took off from Runway 22R using the performance for Runway 22L.
11/12/18	E190	London City	TO3 thrust setting used to takeoff instead of TO1.
April 2019	B737-800	Toulouse	Took off from Runway 32R at intersection N4 using data for intersection N2. Thrust was not increased.
05/08/19	B737-800	Moscow/ Domodeovo	Overran Runway 32L, damaging lights & tyres, but climbed away safely. Suspected weight entry error.
24/04/19	A320-200	Lisbon	Took off from Runway 21, intersection U5 (TORA 2410 m) using the full-length performance figures (TORA 3805 m).
07/05/19	A320-200	Lisbon	As the 24/04/19 event.
07/06/19	A319-100	Marrakech	Took off using Flap 1 but performance calculated for Flap 2.
17/06/19	B787-900	Johannesburg	Took off using the performance for Runway 03R on Runway 03L.
29/08/19	A319-100	Nice	Took off using the performance for Runway 04R, intersection Q3 but actually from intersection B3.
30/08/19	A320-200	Basle	Took off from an intersection (slot pressure) without valid performance data.
16/09/19	A320-200	Lisbon	As per the 07/05/19 event.

Appendix A (cont)

Date	Aircraft type	Location of incident	What happened?
20/09/19	A350-1000	Shannon	Incorrect runway inserted into the FMS. Believe the aircraft performance was not compromised. Low speed RTO performed upon ECAM message.
02/10/19	A319-100	Heathrow	Took off using the performance for Runway 27L, intersection N2W but actually from intersection N4E.
17/11/19	B737-800	Paphos	Takeoff performance compromised, as headwind changed into a tailwind, and due to a lengthy ground roll as thrust stabilised.
24/11/19	A321-200	Glasgow	Flex of 79° used instead of 49°. Error not detected. TOGA applied.
28/02/20	B737-700	Gatwick	Flight crew did not enter V speeds into the FMC, derate information was correct.
21/07/20	B737-800	Birmingham	Incorrect assumed weights used for adult female passengers – assigned child weights instead due to a computer glitch. Invalid V speeds and derate, 1.2-ton error in TOW.
03/03/21	B737-800	Lisbon	As per the 16/09/19 event. *This was the aircraft operator's third almost identical event at Lisbon in less than five months.* Took off from runway intersection U5 (TORA 2410 m) using the full-length performance figures (TORA 3805 m).
23/07/21	B737-800	Yerevan	Unknown, but confirmed as a performance error.
01/12/21	B737-800	Kuusamo	70% N_1 used for takeoff, as aircraft slipped during ice shedding procedure and the throttles weren't advanced from 70% N_1 until the aircraft was airborne.

Appendix A (cont)

Date	Aircraft type	Location of incident	What happened?
04/03/22	B787-900	Brussels	GW entered into the FMC ZFW box instead of ZFW. Approx. 10-ton error. Multiple distractions on ground.
12/04/22	A330-900	Luanda	Took off from runway intersection E (TORA 1900 m) using the full-length performance figures (TORA 3700 m), resulting in a flex to 85% N_1. Crew applied TOGA power and rotated just before the end of the runway.

ACCIDENT

Aircraft Type and Registration:	Britten Norman 2B-26 Islander, J8-VBI
No & Type of Engines:	2 Lycoming 0-540-E4C5 piston engines
Year of Manufacture:	1980 (Serial no: 2025)
Date & Time (UTC):	29 September 2021 at 2133 hrs
Location:	John A. Osborne Airport, Montserrat
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 6
Injuries:	Crew - None Passengers - 1 (Minor) 5 (None)
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	2,650 hours (of which 712 were on type) Last 90 days - 105 hours Last 28 days - 22 hours
Information Source:	AAIB Field Investigation

Synopsis

On landing at John A Osborne Airport, Montserrat, the pilot was unable to maintain directional control of the aircraft, later reporting the left brake felt "spongy". The aircraft veered off the right side of the runway and came to rest in an adjacent drainage ditch.

An inspection of the aircraft's braking system revealed a slight brake fluid leak from one of the pistons in the left outboard brake calliper. This would have prevented full brake pressure being achieved on the left brakes, resulting in an asymmetric braking effect. Difficulty in maintaining directional control was compounded by the use of an incorrect braking technique on landing.

The investigation identified shortcomings with the operator's manuals, procedures and regulatory oversight.

One Safety Recommendation is made.

History of the flight

The pilot was based at V.C. Bird International Airport, Antigua and on the day of the accident reported for a planned split duty at 1100 hrs (0700 hrs local time). The pilot operated a return flight to the nearby island of Barbuda followed by a return flight to the island of Montserrat, both flown on J8-VBI. The aircraft was operated with a single pilot and no cabin crew, as was normal. The pilot then went off duty at 1355 hrs and returned home before reporting for duty again at 1930 hrs to operate the same sequence of flights he had flown in the morning.

After an uneventful return flight to Barbuda, the aircraft departed Antigua at 2114 hrs (1714 hrs local) for John A Osborne Airport, Montserrat, with the pilot and six passengers on board. The aircraft cruised at 2,000 ft enroute and the pilot recalled there were good visual meteorological conditions throughout the 19 minute flight. On arriving at Montserrat there were no other aircraft operating in the vicinity of the airport and the pilot positioned the aircraft visually on a downwind leg for Runway 10.

The pilot reported he commenced the approach, flying an approach speed of 65 kt, reducing to 60 kt as the aircraft touched down. The runway surface was dry and the pilot described the landing as “smooth”. After the main landing gear touched down, but prior to the nosewheel contacting the runway, the pilot applied the brakes. He reported that the left brake felt “spongy” and did not seem to act, but that the right brake felt normal. The pilot was unable to maintain directional control of the aircraft which veered to the right two seconds after touchdown, departing the runway a further three seconds later. The aircraft continued across the adjacent grassed area before impacting an embankment close to the runway (Figure 1).

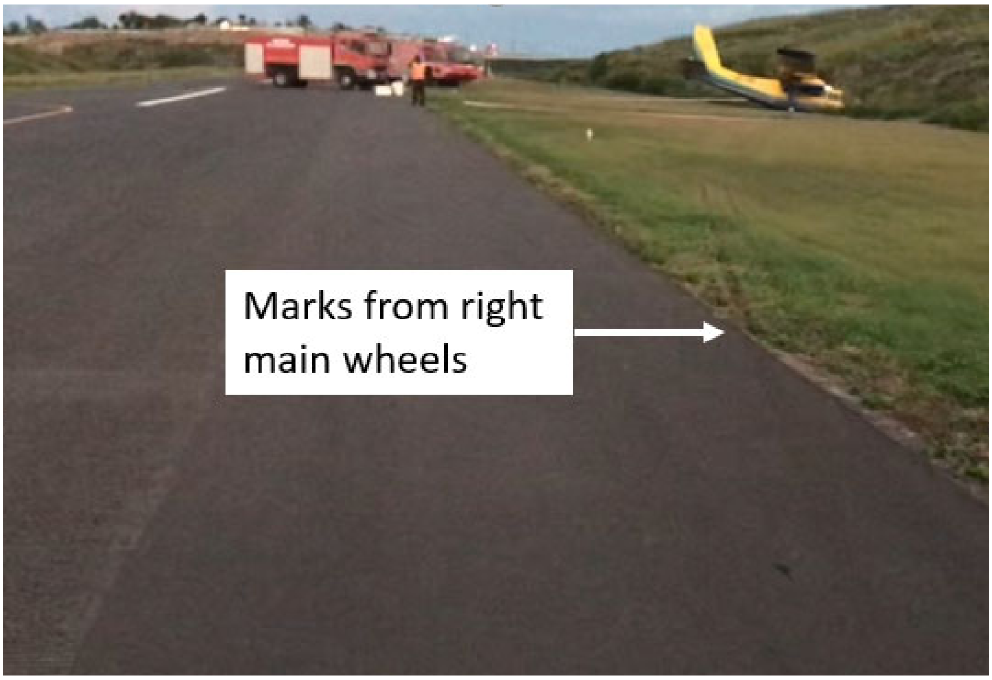


Figure 1

Still image captured from a video showing the aircraft’s departure point from Runway 10 and final resting place

After the aircraft had come to a stop, the pilot shut down the engines using the normal shut down procedure. The left main gear had collapsed and rendered the left cabin exit unusable (Figure 2). The pilot evacuated through the flight deck door which was on the left of the aircraft. The six passengers were able to evacuate through the right cabin exit. The airport fire service then arrived at the aircraft, less than one minute after the accident.

Figure 2

Collapsed left main landing gear blocking left cabin door

Accident site

Tyre marking on the paved surface of Runway 10 indicated that the wheels of the right main landing gear began to skid approximately 153 m from the runway threshold. These markings also indicated the aircraft had veered to the right and off the paved surface approximately 242 m from the threshold. The skid marks fluctuated in density, consistent with modulating brake pressure. The marks from the left mainwheels were less well defined, but there was a short indication of a skid from the left inboard mainwheel at the start of the ground markings and a further short skid indication just after the left main gear crossed the runway centreline. The less frequent skid marks from the left wheels and the veer to the right indicated more braking was coming from the right brakes than the left. The nose wheel is not braked but there was a mark indicating it touched down at the same time the left main wheel was already crossing the runway centreline.

After the aircraft departed the paved surface, marks in the grass show that the right main wheels continued to be braked more than the left main wheels, whose marks more closely match those of the unbraked nose wheel (Figure 3).

The tyre marks indicated the aircraft continued veering right until it came to rest in a drainage ditch close to the boundary of the airport; this was just over 160 m from the beginning of the skid marks. There was no fire.

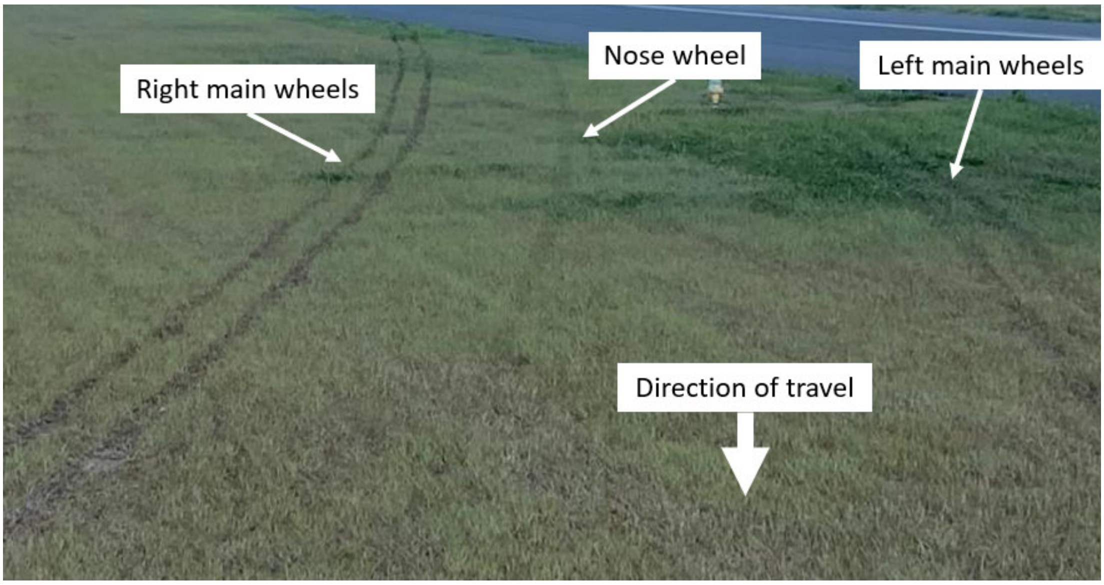


Figure 3

Wheel marks in grass beside runway showing evidence of asymmetric braking

Recorded information

The aircraft was not fitted with either a flight data recorder or a cockpit voice recorder; neither was required to be fitted under the applicable regulations. The pilot, however, was using a portable touchscreen GPS navigation device, which recorded position and time at intervals based on changes in position, rather than after a specified distance or time interval.

The data from the GPS device was downloaded and, together with airport CCTV footage and video taken from within the cabin by a passenger, an approximate track of the aircraft's ground track was generated (Figure 4).

Figure 4

GPS ground track based on CCTV (white crosses) and GPS (yellow circles)

The last point recorded on the GPS device before touchdown positioned the aircraft on the approach at about 50 ft aal. The next recorded point, 11 seconds later, was after the aircraft had landed, and about three seconds before it went off the edge of the runway. From the CCTV footage it was evident the aircraft first touched down on the right main landing gear and then the left, less than a second later. After a period of three seconds, tyre screeching can then be heard on the onboard passenger video which lasted for about half a second, after which the nose gear touched down. This was quickly followed by a second short period of tyre screeching and then another (each about half a second in duration) before the aircraft was seen to veer off the righthand edge of the runway.

The passenger video included footage of some of the aircraft flight instruments, providing confirmation of an approach speed of 65 kt.

Aircraft information

The Islander is a twin-engine light commuter aircraft that has good short takeoff and landing characteristics. It seats a maximum of nine passengers. A door on the front left of the aircraft allows access to the two pilot seats, whilst access to the passenger seats is through a door midway along the cabin on the right and a door at the rear of the cabin on the left. All the aircraft doors are nominated as emergency exits. The aircraft is constructed primarily of aluminium and has conventional fixed landing gear. The single nose wheel is steerable and the twin main wheels on each main landing gear are braked.

The brake system consists of master cylinders attached to each of the pilot's rudder pedals. Operation of the left brake pedal supplies brake fluid under pressure to the left brake calliper. Pistons in the calliper push friction pads against a brake disc in proportion to the pressure applied to provide braking. Likewise, operation of the right pedal supplies pressure to the right brakes to provide braking. The pilot operates the individual brake pedals to obtain the required braking action. During the landing roll, this would normally be both equally together to ensure the aircraft stops in a straight line. The co-pilot's rudder pedals are also fitted with master cylinders and operation of these pedals supplies pressure to the brakes in a similar way to the pilot's but through shuttle valves which allow the highest pressure applied to supply the brakes. In common with other similar aircraft, there is no anti-skid system and as a result, the pilot is required to adjust the brake pressure manually to ensure the braked wheels do not skid. A parking brake is available and when applied it maintains any pressure applied to the brakes (Figure 5).

Aircraft maintenance

The aircraft's Certificate of Airworthiness was in date and the aircraft was being maintained in accordance with an approved maintenance schedule. The most recent scheduled inspection was a 50 hour Check A, which was completed on 28 September, the day before the accident. At the same time the left outboard mainwheel wheel was replaced as its tyre was worn to limits. The brake friction pads on the same wheel were replaced as they were also worn to limits.

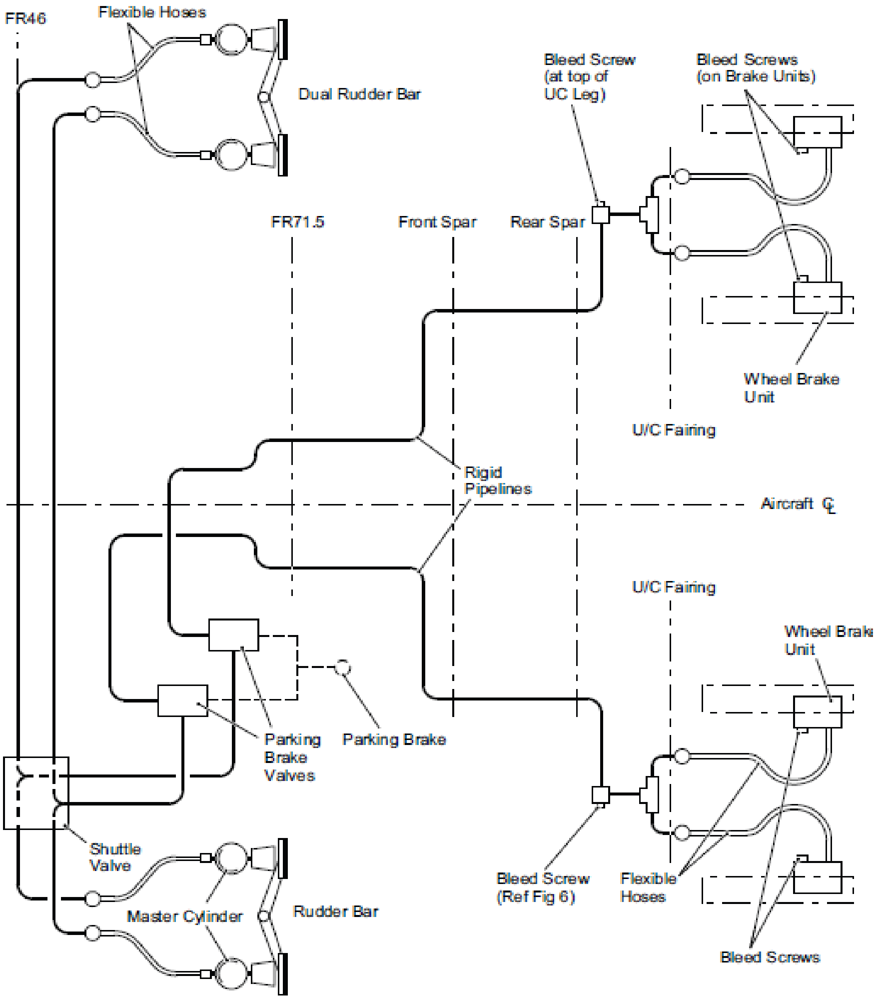


Figure 5

Schematic diagram of braking system

Aircraft examination

The AAIB did not travel to the accident site due to COVID-19 considerations. Examination of the aircraft was conducted under the supervision of the Accredited Representative from the East Caribbean Civil Aviation Authority.

Due to damage sustained in the accident it was not possible to function test the pilot's left brake system, but the pilot's right brake system was found to operate normally. The left and right brake systems were visually inspected, and no leaks were apparent. Selected components from the left brake system were removed from the aircraft and shipped to the UK for more detailed inspection.

Detailed component examination

Both master cylinders from the pilot's pedals were dismantled and examined. They were found to be in similar condition, there was contamination within the fluid reservoirs but because the components had not been blanked for transport it could not be determined whether it was there before the accident. The main seals and main bores were in satisfactory condition. The dust seals around the input rod from the pilot's pedals were in poor condition (Figure 6).

Figure 6

A dust seal from one master cylinder showing degraded condition

The calliper assembly of the left outboard brake was examined as it appeared to have a slight leak from one of its pistons (Figure 7). When the piston was removed, the piston bore had scoring in the area where the leak was apparent (Figure 8). The piston's 'O' ring seal was found to be flattened rather than the circular cross section of a new seal (Figure 9).

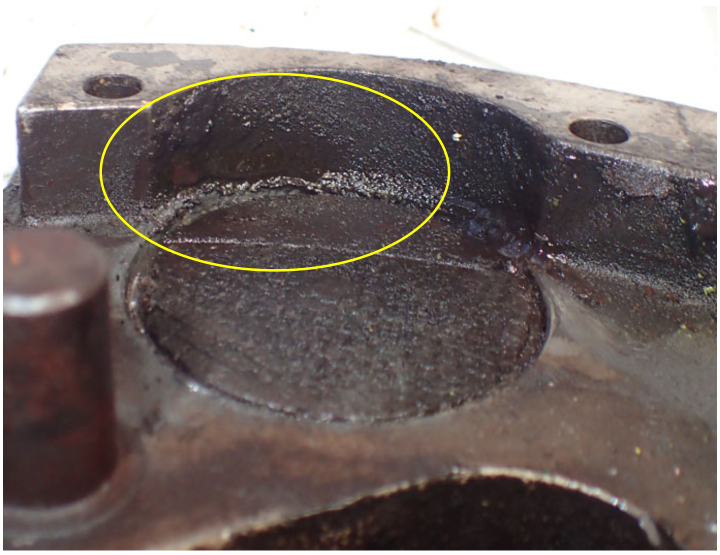


Figure 7

Leak apparent from piston of left outboard calliper

Figure 8
Scoring in piston bore in area of leak

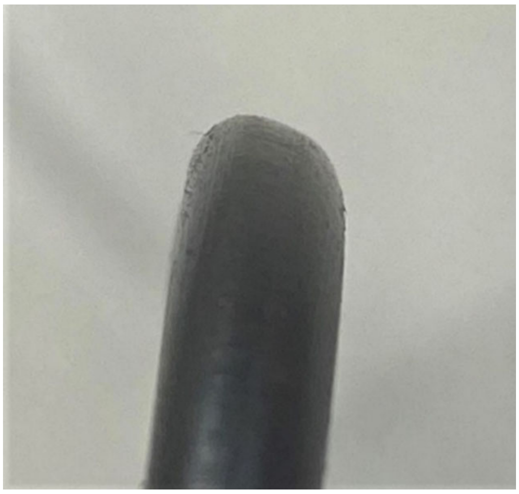


Figure 9
Flattened cross-section of piston 'O' ring seal

Personnel

The pilot gained his CPL in 2008 since which time he had flown a variety of aircraft types around the Caribbean. His licence and medical were both valid at the time of the accident.

The pilot first qualified on the Islander in 2019, since which time he had gained 712 hours as PIC on the type. He underwent an assessment by the operator to fly to John A Osborne Airport on 25 September 2019 conducted during two flights that day to the airport. Details of these flights were not recorded, but would have not been sufficient to comply with Governor's Instruction Mon 004 which included a requirement to complete at least five landings (three to Runway 10 and two to Runway 28) as well as a go-around from an approach to each runway.

The pilot's last annual line check was completed on 17 January 2021 on a flight from Guadeloupe to Antigua. The report stated that he '*operated as per the operator SOPs and within AFM limitations*' and no concerns were noted.

The pilot also operated regularly to Barbuda Codrington Airport on the island of Barbuda which, with a runway length of 1,640 ft, is slightly shorter than that at John A Osborne Airport.

Meteorology

The METAR for Montserrat Airport published at 2100 hrs reported a light wind of 5 kt from 050°, good visibility and 2-3 oktas of cumulonimbus clouds at 1,600 ft. The temperature was 29°C and there were cumulonimbus clouds reported to the north-east, south and north-west of the airport.

Montserrat has a tropical climate with significant rainfall throughout the year, particularly between July and November.

Airfield information

Background information

John A Osborne Airport opened in 2005 and was built after the previous airport, W H Bramble Airport, was destroyed in 1997 by a volcanic eruption. It is the only airport on Montserrat. The location of the original airport is uninhabitable due to the risk of further volcanic eruptions and the island's mountainous terrain limited potential sites of the new airport.

Figure 10

John A Osborne Airport

John A Osborne Airport has a single asphalt Runway 10/28 and sits at an elevation of 550 ft amsl. The runway was resurfaced in 2021 with grooves cut into the surface to improve runway friction in wet conditions. Both runways have a take-off run available (TORA) of 553 m / 1,814 ft and a LDA of 540 m / 1,771 ft, being constrained in length by a steep downhill gradient at either end. Recent improvements to the runway include renewed and re-positioned approach guidance lighting, and 'throw away' markings to help guide pilots judge when to go around.

Runway friction assessment

The airport conducted a Grip Test friction assessment of the runway surface shortly after the accident. The results indicate the runway friction was good and therefore it was not considered a factor in this accident.

Governor's Instruction MON 004

The requirements for operating to John A Osborne were defined in Governor's Instruction MON 004, issued on 24 February 2020. This included details of the risk assessment required to be submitted by operators to Montserrat's aviation regulator, Air Safety Support International (ASSI). It also provided specific pilot training and experience requirements, training captain requirements and details of the related supporting documentation.

The operator stated it was not familiar with Governor's Instruction MON 004 and had not submitted any of the required pilot training documents required. The operator had, however, submitted a risk assessment to ASSI on 26 February 2020 although this did not adequately assess a number of the points required. These included:

- Arithmetic errors in performance calculations
- Omission of aircraft performance for wet runway conditions
- Omission of non-punitive approach to go-arounds from unstable approach
- AFM crosswind limitations
- Actions to be taken following an engine failure after take off

In response, ASSI reported that other operators to the airport were not similarly affected but that they were reviewing their processes to ensure full compliance with the Governor's Instruction's for all future operations at Montserrat. This included, with the operator involved, the nomination and approval of training captain(s), the completion of the necessary 'check flight' forms for each pilot and the submission of a satisfactory risk assessment.

Operator airfield specific briefing sheet

The operator had a briefing sheet which detailed specific procedures for operating to and from Montserrat. It stipulated a list of criteria in which a takeoff or landing shall not be carried out, including when the runway is contaminated. However, this list did not prohibit landing on a wet runway. The briefing sheet detailed the braking procedure for landing on a dry or wet runway as follows:

'After touchdown the nosewheel is to be lower to the runway and wheel brake applied progressively throughout the deceleration process while applying slow back pressure on the yoke to transfer the weight back on the main wheels.'

Aircraft performance

The BN2B-26 Islander is a performance class B[1] aircraft. Performance requirements include a safety factor of 43% of the unfactored landing distance required (LDR). The Approved Flight Manual (AFM) performance charts included the 43% safety factor. There was no performance data available for landing distance required with reduced braking capability.

The landing weight of the aircraft was 6,293 lbs, which had a factored LDR on a dry runway of 1,480 ft, 291 ft less than the LDA of 1,771 ft.

Operating procedures and aircraft manuals

Performance

The Operations Manual (OM) contained no Standard Operating Procedure (SOP) requiring pilots to conduct performance calculations.

The AFM on board the aircraft contained the procedures and data to allow the calculation of dry runway performance. It did not contain data allowing the calculation of performance on wet or contaminated runways. The relevant regulations[2] state that, where there are no wet runway performance figures provided in the AFM, the LDA shall be at least 115% of the LDR. Under these requirements, at the aircraft's published maximum landing weight (MLW), the LDR exceeded the LDA if the runway was wet.

The operator stated that they operated when runways were wet, but not when runways were contaminated. This prohibition was not written in the operations manual, nor a method for determining when a runway was contaminated.

The Eastern Caribbean Civil Aviation Authority (ECCAA) had regulatory oversight of the operator. The ECCAA Part 9, Implementing Standards for Air Operator Certification and Administration, states that the holder should maintain an operating manual which contains:

- limitations on wet and contaminated runways
- procedures for operation on wet and contaminated runways
- takeoff and landing performance data for dry, wet and contaminated runways

Footnote

1 Aeroplanes powered by propeller engines with a maximum operational passenger seating configuration of nine or less and a maximum take-off mass of 5,700 kg or less.

2 Saint Vincent and the Grenadines Statutory Rules and Orders No. 16, Civil Aviation (Amendment) Regulations, 2014.

- speeds applicable for various flight stages (also considering wet or contaminated runways)

The ECCAA did not respond to enquiries by the AAIB on this aspect.

Pre-landing brake checks

The operator stated that pilots were trained to perform a brake check as part of the pre-landing checks. This required the brake pedals to be depressed to check the pressure in the system. There was, however, no brake check included in the operator's documented 'before landing' checklist and the pilot did not recall this check being demonstrated during training. He did not perform this check during the accident flight. The AFM 'pre-landing checks' required the brakes to be confirmed off. The manufacturer stated they would expect this check to include confirmation the parking brake is off and the aircrew toes are clear of the brakes. They further stated that a full press of the brakes with virtually no resistance could potentially indicate a brake issue.

Braking technique on landing

The AFM states '*maximum wheel braking is applied immediately after touchdown'.* The manufacturer commented that braking prior to the nosewheel touching down '*is not an approved or advised technique'* and potentially invalidates the scheduled landing performance.

The OM stated '*the nose wheel should be brought into contact with the runway promptly following main wheel contact. Using wheel brakes while holding the nose wheel off is not to be done'.*

The operator considered that the main risk from braking before the nose gear touched down was the increased likelihood of the nosewheel contacting the runway with greater force. Two experienced Islander pilots operating in the region reported that braking prior to nose wheel touchdown was not considered unusual. A similar description of braking technique on an Islander has also been described in a previous AAIB report[3].

Emergency procedure

Neither the OM nor the AFM contained a published procedure for a loss of braking. The operator stated that should a pilot identify a brake failure during the pre-landing check they should land at an airfield with an LDA in excess of 2,000 ft. This may require a go-around followed by a diversion to a suitable airfield. The operator stated the LDA of 2,000 ft had been determined through experience rather than calculation, to be a sufficient distance to stop the aircraft with only one operational brake. The pilot did not recall being trained to carry out this procedure during initial or recurrent training.

Footnote

[3] AAIB Bulletin 2/2014 VP-MNT available at: https://www.gov.uk/aaib-reports/britten-norman-islander-bn-2b-26-vp-mnt-16-october-2012 [accessed 15 Feb 2022]

Analysis

Technical aspects

Examination of the left brake components determined that the 'spongy' feel and lack of effectiveness reported by the pilot was most likely due to a slight brake fluid leak from one of the pistons in the left outboard brake calliper. This leak prevented full brake pressure being achieved and therefore reduced the braking effect from the left brakes.

The brake friction pads on the left outboard brake had been replaced the night before the accident. This process involved pushing the pistons back in to the calliper to allow for the greater thickness of the new friction pads. Since replacement, the aircraft had made six landings including one at Montserrat and two at Barbuda, which has a shorter runway than Montserrat, all without incident.

There were no reported issues with the brakes for the first six flights after the friction pad replacement and the leak appears therefore to have developed after these flights. The leak was likely due to scoring of the piston bore and the flattened piston seal, both of which could not be identified unless the calliper was disassembled.

Directional control

It is considered that the leak identified in the left braking system resulted in sufficient asymmetric braking, when both brakes were fully applied, to cause the pilot to lose directional control.

The video footage from the cabin shows the effects of asymmetric braking prior to the nose wheel touching down, indicating the pilot applied the brakes almost immediately after the main gear touched down. This meant that, with the nosewheel off the ground, early application of nosewheel steering to try and maintain directional control was not possible. Aerodynamic directional control from the rudder would have also rapidly reduced as the aircraft slowed. This left the pilot with releasing the right brake as the only way to regain directional control. Due to the short nature of the runway and the steep drop at the end, this is likely to have been counter intuitive.

Whilst the operations manual published the correct braking technique, it was possible that pilots were influenced by the short nature of runways in choosing to brake before nosewheel touchdown.

Go around

There was no published brake failure procedure available to the pilot. Faced with a brake failure on touchdown, the pilot had two options. The first would have been to control and stop the aircraft on the remaining runway available. Given the limited LDA at Montserrat, this may not have been achievable. The second option would have been to go around and divert to an airfield with a longer runway.

The speed with which the event occurred and the difficulty in maintaining directional control, restricted the pilot's ability to remain on the runway. This also left little opportunity for the pilot to make the decision to abandon the landing and go around.

If the brakes had been applied in accordance with the published procedure, when the nose gear was down, then the failure would have been realised later in the landing roll, with less runway remaining. However, the pilot would have had greater directional control of the aircraft as the nosewheel steering would have been available. The aircraft would have been more likely to remain on the runway, making a go-around a more viable option. This would still have remained a challenging decision to make, especially without prior training or knowledge of the failure.

Performance

The runway was dry with measured levels of friction being good. The calculated landing distance required was 291 ft less than the landing distance available. As there was no performance data available for landing distance required with reduced braking capability it is not known whether this additional 291 ft would have been sufficient for the aircraft to have stopped on the runway. However, if this reduction in braking capability had occurred on a longer runway, or with a better runway overshoot area, using the published braking technique would be more likely to lead to a favourable outcome.

The absence of any performance procedures in the OM for wet or contaminated runway operations was considered a significant safety issue, not least because of the limited length of the runway and the abundance of rain throughout the year in Montserrat. It was also not compliant with the Civil Aviation (Amendment) Regulations, 2014, or the criteria for the issue and maintenance of an AOC as required by the ECCAA in IS Part 9. In response, the operator stated it intends to amend its Operations Manual to comply fully with the Civil Aviation (Amendment) Regulations, 2014 and ECCAA IS Part 9. The following Safety Recommendation is also made:

Safety Recommendation 2022-016

It is recommended that the Eastern Caribbean Civil Aviation Authority (ECCAA) should ensure SVG Air Operations Manual complies with Saint Vincent and the Grenadines Civil Aviation (Amendment) Regulations, 2014 and ECCAA Part 9 Implementing Standards for Air Operator Certification and Administration.

Brake check

The AFM pre-landing checks simply required the brakes to be confirmed off. Whilst not called for in the checks, the manufacturer stated that should the brakes be fully pressed as part of these checks, a lack of resistance could potentially indicate a brake issue.

Whilst not an approved procedure, had the pilot pressed the brake pedals on this occasion it is possible he would have detected the problem with the left brake, allowing him to divert to an airfield with a longer runway.

Governor's Instruction

Governor's Instruction MON 004 formed an important requirement for operating flights to John A Osborne Airport, reflecting the challenging nature of the airport. As such, the operator should have been aware of the requirements and appropriate checks made by the regulator to ensure they had been complied with. This situation has been resolved with the operator now being in full compliance and ASSI having reviewed its own compliance-checking process.

Conclusion

When the pilot applied the brakes on landing, a leak from one of the pistons of the left outboard brake calliper rendered the left brakes less effective than the right, causing the aircraft to veer to the right and depart the runway. Difficulty in maintaining directional control was compounded by the limited size of the runway and the use of an incorrect braking technique on landing.

The investigation identified shortcomings with the operator's manuals, procedures and regulatory oversight.

Safety Action

The operator has ensured it now complies with the requirements of Governor's Instruction MON 004.

The airport regulator, ASSI has reviewed its processes to ensure better compliance monitoring of commercial operators using John A Osborne Airport.

Published: 22 September 2022.

INCIDENT

Aircraft Type and Registration:	Leonardo AW189, G-MCGT	
No & Type of Engines:	2 General Electric Co CT7-2E1 turboshaft engines	
Year of Manufacture:	2014 (Serial no: 92006)	
Date & Time (UTC):	30 July 2021 at 1530 hrs	
Location:	Near Heads of Ayr, South Ayrshire	
Type of Flight:	Training	
Persons on Board:	Crew - 4	Passengers - None
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	41 years	
Commander's Flying Experience:	5,276 hours (of which 1,228 were on type) Last 90 days – 78 hours Last 28 days – 14 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a pre-fight brief for a SAR training flight, the co-pilot highlighted an event on a previous flight which had resulted in unexpected pitch oscillations following the selection of the Transition Down mode of the Automatic Flight Control System (AFCS). On the conclusion of the other training priorities for the flight, the crew replicated the circumstances that had triggered the pitch oscillations previously; this resulted in similar unexpected flight path oscillations in the pitch axis. The crew reported this second event to the operator.

The event was caused by a shortcoming in the design of the Phase 5 version of the AFCS software SAR upper modes which also resulted in incorrect AFCS mode indications to the flight crew. To address this issue pending the correction of the AFCS software in the Phase 9 release, the helicopter manufacturer issued a Technical Information Letter detailing actions to be taken in the event of a re-occurrence and updated the FMS Pilot's Guide for Phase 5, Phase 6 and Phase 8 software. The manufacturer has corrected the design shortcoming in the Phase 9 release of the AFCS software.

Safety action has been implemented by the operator regarding automation management and incident reporting.

History of the flight

On 30 July 2021, during the briefing for a regularly conducted SAR training flight, the co-pilot commented that, on a previous flight on 5 July 2021 when he was acting as co-pilot in the PF role, he had experienced unexpected flight path oscillations in pitch following the selection of Transition Down (TD) mode during a Flight Management System (FMS) directed Sector Search using Autonomous Groundspeed (NGSPD). The co-pilot explained that the crew had been unsure if this behaviour had resulted from incorrect set up of the parameters and switch selection and requested that they fly the helicopter in the same profile and configuration during the training flight.

The crew discussed the autopilot configuration and switch selection that had seemingly caused the behaviour and ascertained that there was nothing published advising against the configuration. Owing to concern of the hazard that this flight path behaviour may present in a degraded visual environment, the crew decided to fly the same profile and configuration in day VMC to see if the unexpected flight path oscillations re-occurred. The weather at the time of the incident gave a scattered cloud covering at 2,500 ft amsl with more than 10 km visibility and a north-westerly wind of around 10 kt.

After completing the other planned training, the crew set up the helicopter for an FMS-directed Sector Search pattern and re-briefed the switch selection that may have caused the unexpected flight path oscillations. The rear crew were advised to fasten their seatbelts as a precaution. The aircraft was above 1,000 ft agl over the water with Altitude hold (ALT) captured and Sector Search configured with NGSPD captured. As soon as the PM selected TD mode, the aircraft began to oscillate in pitch. The crew reported this felt “uncomfortable” with a sensation of lower ‘g’ force but were not able to determine the extent of the pitch variation, nor which modes were annunciated on the Primary Flight Display (PFD) as they were looking outside at the time of the event. However, they estimated that it was 20° nose-up followed by a nose-down pitch change of 40° based on their visual perceptions. On recognising the unusual flight path behaviour of the aircraft, the PF deselected the autopilot modes and returned the aircraft to normal stabilised flight.

After the flight, the commander raised an Air Safety Report (ASR) to highlight the potential issue of selecting TD with NGSPD mode captured during a Sector Search.

Previous flight – 5 July 2021

During the flight on 5 July 2021, on completion of some training conducted over land, the crew headed west towards open water. The PM set up the aircraft for a FMS directed Sector Search pattern with the groundspeed set at 60 kt in the FMS. The PM selected lateral navigation (NAV) mode and the Automatic Flight Control System (AFCS) subsequently captured NGSPD while at cruise speed when the Sector Search pattern activated; the aircraft then began to decelerate. Once over the water the PM then selected TD, at which point the aircraft began to oscillate in pitch. Although the PM could not be certain, he thought that he saw Winch Trim (WTR) SAR upper mode annunciated momentarily on the PFD in the pitch channel, before reverting to NGSPD. The PM described the aircraft behaving in a “nodding dog cycle” which, although not aggressive, was sufficient for the PF to de-select all the upper modes completely after observing the behaviour for a number of cycles; the PF then re-selected the desired modes for each channel. The PF described the oscillations as “not violent but uncomfortable.”

The weather at the time of the incident gave a scattered cloud covering at 1,000 ft amsl with more than 10 km visibility and a south-westerly wind of around 10 kt.

During the debrief for the flight, the crew discussed the event but were unsure whether it was the result of incorrect switch selections or entry parameters, or it was a behaviour of the AFCS. The crew did not consider the 5 July event merited an ASR, but they did brief the oncoming crew of the event.

Event reporting

The degree of pitch oscillation during the event of 5 July 2021 did not trigger an alert in the operator’s helicopter flight data monitoring (HFDM) programme, and the operator’s safety department only became aware of this AFCS issue following reporting of the second event on 30 July 2021. In response, the operator raised a fault report with the helicopter manufacturer. Subsequently, following assessment of the data from the second event, the manufacturer and the operator each separately informed the AAIB several days later.

Aircraft examination

The AAIB did not examine the aircraft owing to the time that had elapsed between the event and the reporting of it to the AAIB. As part of a separate unrelated investigation, the AAIB was present during on-ground testing of G-MCGT’s AFCS on 27 July 2021 and no issues were found.

The pre-flight test is carried out daily; the AFCS performs a power-up test each time it is powered up and it also performs continuous testing in-flight. No faults were found, and no anomalies were reported by any of the AFCS tests in the intervening period.

Aircraft information

General description

The SAR AW189 helicopter is a derivative of the commercial air transport version with specialist role equipment and an enhanced AFCS. EASA issued the type certification in February 2014 for VFR and IFR operation by two pilots carrying up to 19 passengers.

AFCS

The AFCS is a four-axis dual-duplex redundant, predominantly electromechanical system, that provides varying levels of automatic control of flight. The helicopter software installation, that includes AFCS software, was at Phase 5 for both events. At the time of publishing this report, the majority of the civil AW189 fleet uses Phase 5 or 6 software. Phase 7 was never released for operational use. At the time of the event, the latest operational software certified was Phase 8 and was in use on military helicopters and was soon to be used on civil helicopters.

This investigation concerns SAR modes which are only enabled on helicopters configured for SAR operations. SAR modes can only be enabled by the helicopter manufacturer by means of a dedicated configuration file specific to the helicopter's serial number.

AFCS controls

The Autopilot Control Panel (APCP) provides the controls for mode arming and selection, and mode status display for the AFCS. It is also used for pre-flight testing. The APCP is in the centre of the inter-seat console between the pilots. It has 16 push buttons and two rotary/push knobs each annotated with its function (Figure 1). The APCP mode buttons illuminate green when a particular mode has been selected.

Figure 1
Autopilot Control Panel

The cyclic and collective grips have several controls for the AFCS.

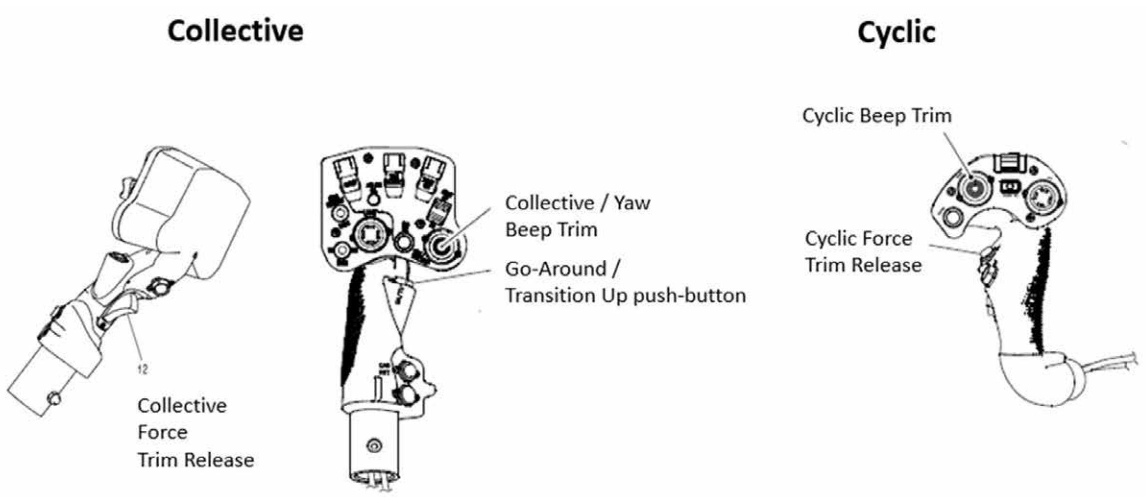


Figure 2
Collective and Cyclic AFCS Controls

Most modes are selected and deselected using the APCP. Some specific modes can be selected using the pilot controls on the cyclic or collective. The cyclic Force Trim Release (FTR) deselects all selected upper modes, while the collective FTR button temporarily deselects the collective trim while it is depressed. When a mode is captured on that axis, such as Radar Height Hold (RHT), the act of depressing and releasing of the collective FTR button resets the associated datum to the current value.

AFCS mode status display

The PFD Annunciator, located at the top of the PFD (Figure 3), provides a visual display to the pilots of which modes are armed or captured in each of the axes, collective, pitch and roll/yaw (from left to right). Captured modes are illuminated green, outlined by a box which blinks for a few seconds when first captured, while armed modes are white, next to the captured modes. Any degraded mode is illuminated in yellow. In addition, all mode changes are annunciated aurally with a single tone chime.

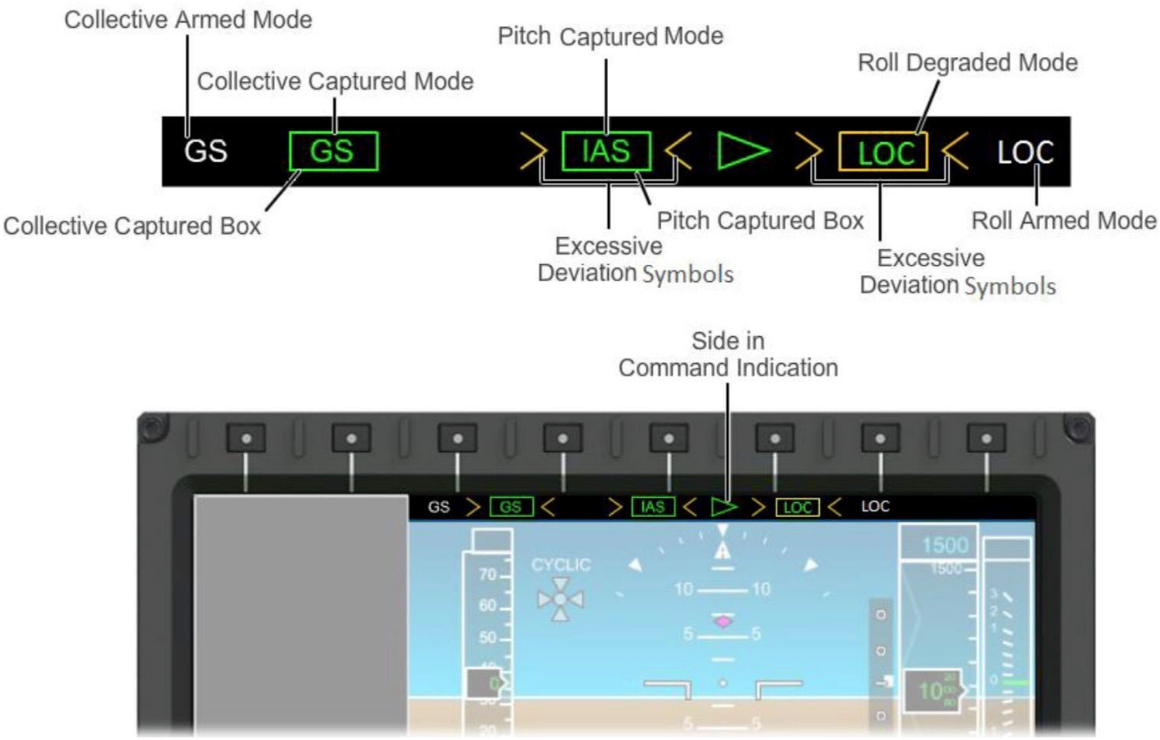


Figure 3
PFD Annunciator

AFCS modes

The AFCS upper modes, which consist of Primary, Flight Director (FD) and SAR upper modes, control the helicopter in four axes – (longitudinally in pitch, laterally in both roll and yaw, and vertically in the collective axis). Primary upper modes provide control of aircraft parameters and performance such as altitude, rate of climb or descent and speed (both air and ground), while FD upper modes control the flight path of the helicopter, both for NAV and approach modes, by coupling the AFCS to the FMS. Aircraft configured for SAR operations, of which this was one, have additional AFCS SAR modes which provide SAR-specific capability.

The Phase 5 operational software introduced a number of design modifications and new functionality which included the introduction of primary upper Ground Speed Mode (GSPD) and the SAR upper mode, NGSPD.

AFCS modes relevant to the investigation

The AFCS functions and modes that are relevant to the investigation are as follows:

Attitude Hold (ATT) is the default mode of the system when the pilot is flying manually and provides the capability to acquire and hold an attitude reference in each of the axes independently.

The AFCS Primary upper modes relevant to the incident include:

- RHT mode captures a radio altimeter height through the collective axis.
- ALT mode captures a selected barometric altitude through either the collective or pitch axis. The collective axis is used if another mode is controlling the pitch axis.
- Airspeed Hold (IAS) mode captures a pilot selectable reference airspeed through the pitch axis.
- GSPD mode captures a pilot selectable reference groundspeed through the pitch axis.

The relevant FD mode is NAV

- NAV mode provides AFCS coupling to roll steering provided by the FMS. This operates through the roll axis with roll coordination achieved through the yaw axis.

The relevant SAR modes are:

- TD mode provides an automatic descent profile. The AFCS uses the collective axis to control vertical speed to reduce the radio altimeter height to 200 ft agl. Once it achieves this the collective axis switches to RHT mode which holds the radio height datum reference. TD mode also uses the pitch axis to reduce the airspeed to 80 kt, capturing IAS mode once achieved to hold the airspeed datum reference.
- For flying Sector Search patterns, the crew can define the search pattern using the FMS and then use NAV mode to allow the FMS to steer the aircraft. The crew can set the desired groundspeed (GS) for the Sector Search in one of two ways:

    - by selecting GSPD mode on the APCP and then adjusting the GS datum on the cyclic beep trim,

  or

    - by setting the desired GS in the FMS when configuring the Sector Search[1] pattern.

- WTR mode can only be selected and captured when Hover (HOV) mode is captured, and it enables the winch operator to adjust the position of the helicopter using dedicated controls at his station. It operates through the pitch and roll axes.

Low height collective safety function

The Low Height safety functions prevent inadvertent descent below certain thresholds in forward flight or the hover when a collective mode is captured. If these thresholds are inadvertently exceeded the system will automatically increase collective as necessary to take the helicopter back to the threshold values. The Low Height protection function relevant to the incident is as follows:

- 75 ft agl if RHT or TD is captured while in the cruise condition.

The system also provides protection in the following circumstance:

- 17 ft agl when TD/H (and certain other SAR modes) are captured while in the hover condition.

When the Low Height protection function activates, a LOW HT caption will appear below the PFD Annunciator and the single tone chime will sound.

AFCS test functions

The AFCS has an in-built facility for self-test that allows the monitoring of system performance. The AFCS test functions are:

- Power up Built-in Test (PBIT) is automatically carried out when power is first applied to the AFCS.
- Continuous BIT (CBIT) runs continuously while the AFCS is in operation.
- Pre-flight Test (PFT) tests functions and components whose failures cannot be detected at CBIT and to detect failures prior to departure of the helicopter.

Footnote

1 In this case, NGSPD will automatically be captured on the pitch axis at the point that the Sector Search mode is initiated, whenever NAV mode is captured.

Recorded information

The aircraft was fitted with a combined flight data, cockpit voice and airborne image recorder. The incidents were reported too late to recover audio or cockpit image recordings as they had been overwritten, but the parametric flight data included the incident on the 30 July 2021. Flight Data Monitoring (FDM) data from the 5 July 2021 event was made available and is shown in Figure 4.

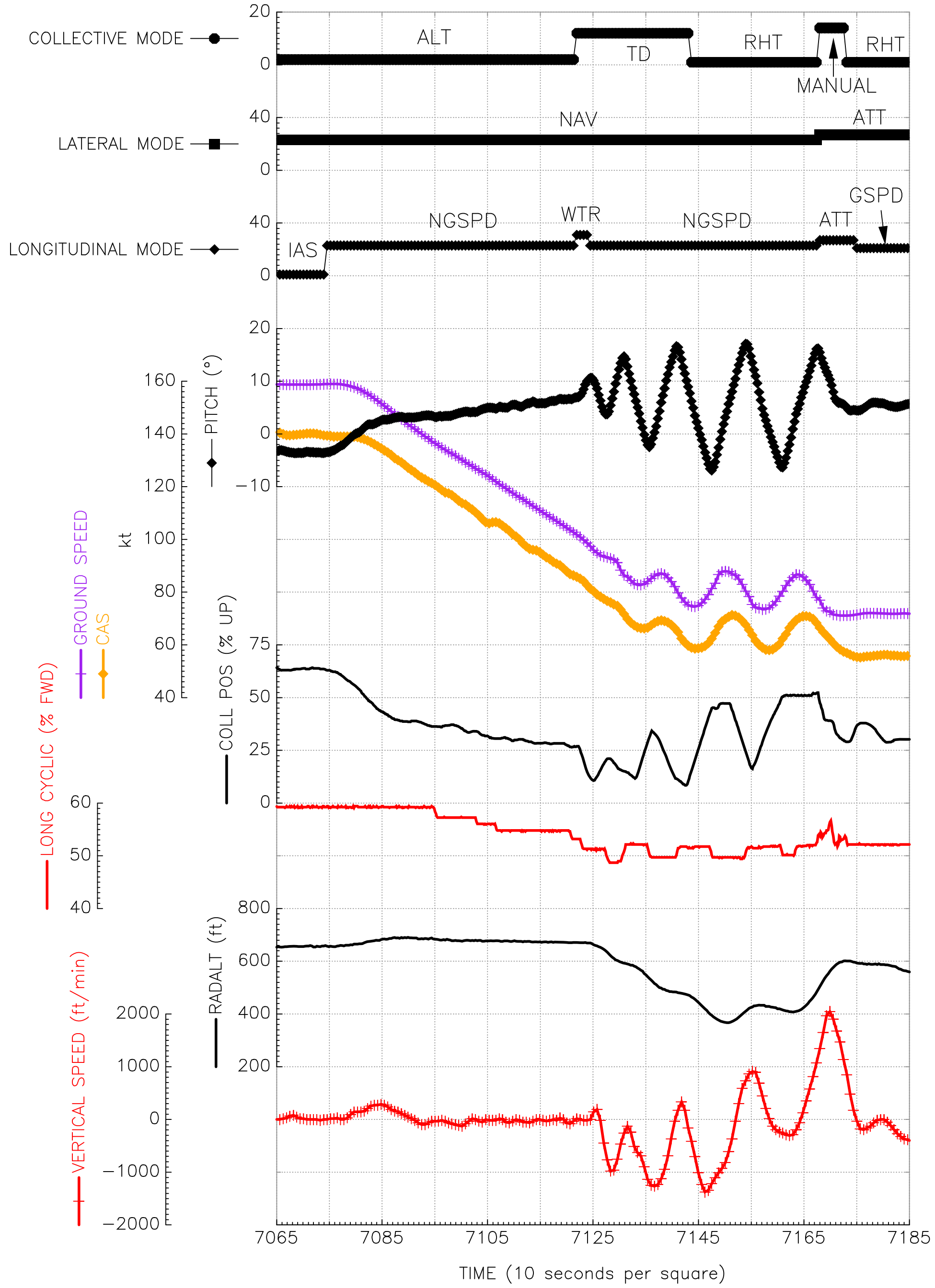


Figure 4

Pertinent extracts of FDM data from the 5 July 2021 incident

One aspect of the investigation centred on the AFCS modes displayed to the crew. The recorded AFCS modes are stored as numbers that are then referenced to a table that identifies the relevant mode. These are the same numbers that are sent to the displays that control the PFD mode annunciations. Figure 4 is annotated with what is displayed when the recorded numbers are sent to the displays. As discussed later in the report, the investigation identified that this does not accurately reflect the actual AFCS active modes under certain circumstances.

Description of 5 July 2021 data

The sequence shown in Figure 4 started with AFCS collective mode ALT captured, maintaining a selected altitude, lateral NAV mode captured, following an FMS path, and longitudinal IAS, holding approximately 140 KCAS. The longitudinal mode switched to NGSPD indicating that a search pattern had been activated. The helicopter pitched up slowly to decelerate to a target groundspeed associated with the search pattern.

The collective mode switched from ALT to TD to descend the helicopter from its radio height of about 670 ft to an updated radio height datum of 200 ft. Under these conditions, TD is associated with the IAS longitudinal mode to target 80 KCAS. The longitudinal mode recording showed a change to WTR mode, which was shortly followed by the helicopter pitching up. The criteria for capture of WTR were not met and information from the manufacturer (discussed later in this report) shows that it was not in fact captured and that the WTR indication was erroneous. The recorded longitudinal mode then switched back to NGSPD. The helicopter entered a cycle of pitching up and down manoeuvres, with the biggest transition being from 6.9° nose down to 17.1° nose up about 6.5 seconds later.

The collective mode was recorded to switch to RHT as the helicopter descended through a radio height of 470 ft with an increasing descent rate. This would have been triggered by pressing the collective FTR. At this point the helicopter pitch was approximately 8° nose up but with a nose-down pitch rate of 4.1°/s. The radio height datum updated to helicopter height as the RHT mode captured. During the following oscillation, the height reduced to 367 ft before recovering, and further radio height datum adjustments were made. This deviation was after more than two complete cycles of pitch oscillations.

The pitch oscillations continued for more than 40 seconds before the upper AFCS modes were deselected, and the crew took manual control of the helicopter using the primary ATT modes.

Description of 30 July 2021 data

The data recorded on 30 July 2021 is shown in Figure 5.

This event started with the helicopter flying at approximately 1,100 ft agl and 100 KCAS, with the AFCS collective ALT mode captured, along with the NAV and IAS modes. The longitudinal mode switched to NGPSD indicating the activation of an FMS directed search pattern. The helicopter started pitching up to reduce speed. The collective TD mode was selected to initiate a descent, and the recorded longitudinal mode switched to WTR. This was the same behaviour as observed on the 5 July 2021 incident and resulted in the same erroneous indication that WTR was captured. The switch to TD resulted in an increased rate of pitching up. The helicopter reached a peak of approximately 12° nose up and then started pitching down. As the pitch reached approximately 3° nose down, the AFCS upper modes were deselected, and the crew took manual control.

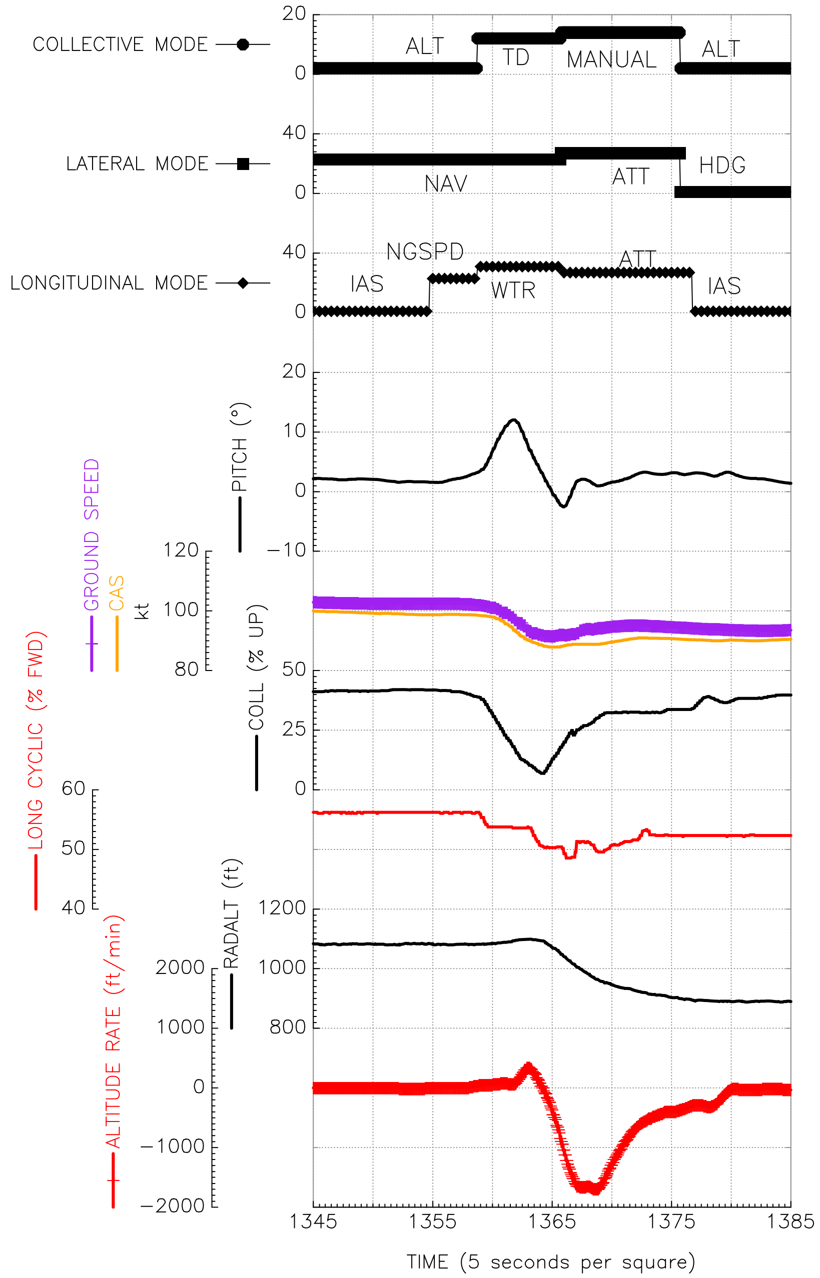


Figure 5

Pertinent extracts of flight recorder data from the 30 July 2021 incident

The helicopter manufacturer's assessment and response

The helicopter manufacturer was asked to review the data from the 5 and 30 July events and both were subsequently reproduced in their engineering flight simulator.

Software priority conflict

The manufacturer identified a software design shortcoming that had been introduced in Phase 5 of the software with the addition of NGSPD as an AFCS FD mode. The NGSPD mode, which uses the longitudinal axis to target a groundspeed, conflicts with the TD and IAS modes, which use the longitudinal axis to target an airspeed, when the TD mode is engaged with a RADALT higher than 150ft and an IAS greater than 80kts. Pitch attitude is used to control speed and so the conflicting speed requirements resulted in pitch oscillations. The manufacturer report concluded:

> *'The investigation identified the following:*
>
> > *2) …the … performance degradation is the result of a conflict in the priority allocated to the Groundspeed and Airspeed control algorithms in case and only if the TD mode is requested to engage when the NGSPD mode is engaged during a SAR pattern and all the following conditions are verified:*
> >
> > *a) Radar Height greater than 150 ft*
> >
> > *b) airspeed greater than 80 kts*
> >
> > *In the above flight conditions, Transition Down engagement request result in "TD" mode engagement….'*

In addition, the manufacturer's report stated that:

> *'No degradation of control performance has been identified in case the Transition Down engagement request, while the NGSPD mode is engaged during a SAR pattern execution, results in "TDH" mode engagement (that is if none of the flight conditions 2a, 2b is verified).'*

Height loss

The manufacturer assessed the maximum flight path profile deviation during the 5 July 2021 as about 100 ft, contributed to by the delay in pilot intervention after the onset of conditions detectable by the crew. It was also noted that high initial airspeed drives the least favourable initial conditions because of the large difference between target air and ground speeds. This drives the largest pitch oscillations which create altitude rate oscillations creating vertical profile deviations.

Erroneous WTR mode annunciation

The recorded data indicated that the AFCS longitudinal WTR mode was captured during the incident. An actual WTR engagement would have been of concern as the speed was too high for this mode and would have meant that the winch trim controls were active. However, the helicopter manufacturer confirmed that this was an incorrect annunciation of the mode which resulted from two modes being simultaneously captured on the same longitudinal axis. The mode to be displayed to the crew is encoded in a binary word and sent to the display and recording systems. The binary encoding for the modes of relevance is shown in Table 1.

Mode	Binary representation
TD	01100
NGPSD	10111
IAS	00001
WTR (Winch Trim)	11111

Table 1

AFCS coding of the pertinent longitudinal modes
for display and recording

Two AFCS modes active on the same axis at the same time results in the binary coding of the modes being combined. This is done in a bitwise OR operation which means that each bit of the combined code is set to 1 if either of the corresponding bits for the clashing modes is a 1. Thus, when NGSPD (10111) and TD (01100) modes are active, the combination results in all 1s which equates to the WTR mode (11111). WTR is then displayed to the crew in the mode annunciators and the value of 11111 is captured by the recording systems. When NGPSD (10111) and IAS (00001) are both active, the combined code remains as 10111 and so NGPSD is annunciated and 10111 is recorded. Erroneous mode indications can be misleading for the flight crew as they do not reflect how the AFCS is controlling the helicopter.

Implications for flight

The manufacturer identified that the most critical phase of flight for the erroneous mode indications would be *'Hands-off IFR Flight…'* where it would require the pilot to '*to recognise deviation from flight path and initiate recovery action, resulting in significant reduction in safety margins and increase in pilot work-load.'*

However, the manufacturer, following a risk assessment performed in accordance with the applicable EASA Part-21 procedures, concluded that:

> *'…. there are no contributions to Catastrophic and/or Hazardous functional failures. The event frequency is still deemed acceptable for a MAJOR severity*

in terms of risk assessment. In case a non-compliance would exists [sic] this has been shown not to result in an unsafe condition.

Hence, the event occurred on AW189 s/n 92006 is classified as "NOT UNSAFE" and no short term mandatory action (AD) is necessary on the fleet.'

The European (EASA) and UK (CAA) Regulators have agreed with this assessment.

The manufacturer also advised that:

'Moreover in line with LHD products continuous improvement policy, the weakness identified within the AW189 AFCS SW has been traced… LHD has evaluated appropriate design improvement to solve [the weakness]. *This improvement is introduced within the scope of the next AW189 AFCS Software certification phases.'*

As a precautionary measure to alert flight crews to the software anomaly, the manufacturer issued Technical Information Letter (TIL), T-189-22-001 REV A, 'AFCS behaviour with Avionic Software Phase 5 or 6', applicable to the AW189 fleet, on 17 March 2022. The TIL states:

'With the present letter, Leonardo Helicopters (LH) wishes to provide advanced information on the Flight Management System (FMS) Pilot's Guide next revision that is going to be released to introduce the applicable information related to a specific Automatic Flight Control System (AFCS) helicopter behaviour.

Following an event reported by a SAR Operator, dedicated evaluation was conducted by LH and AFCS performance degradation was observed in specific flight conditions, for helicopters equipped with Avionic Software Phase 5 or 6. In details, in case that the Transition Down (TD) mode is selected when flying in a SAR pattern with FMS Autonomous Ground Speed Control (NGSPD) mode already engaged, an undesired pitch oscillation behaviour could be observed.

At the same time, temporary activation of the WTR caption on the PFD could occur. The activation does not result in the engagement of the related mode.

As precautionary measure LH will review all the applicable AW189 FMS Pilot's Guides, section "SAR Steering in Groundspeed" pertaining to the SAR Patterns, to introduce appropriate notes aiming to inform that if a TD procedure is desired when flying in NGSPD mode, the NGSPD mode shall first be replaced by Ground Speed (GSPD) mode before engaging the TD mode (by pressing TD pushbutton on Autopilot Control Panel).

In addition, LH is currently working to modify the AW189 AFCS accordingly at the next favourable AW189 Avionic Software Phase and to avoid any undesired pitch oscillation behaviour.'

The manufacturer also presented on the issue at the Helicopter Association International (HAI) Heli-Expo 2022 in Dallas and advised that AFCS performance degradation had been observed in specific flight conditions during an event reported by a SAR operator. In particular, it stated that '*undesired pitch oscillation'* could be observed *'when activating the TD… upper modes while NGSPD is active.'* This had been observed in helicopters '*equipped with Avionic Software Phase 5 or 6'* and the issue had been reproduced at its manufacturing facilities. The UK CAA has indicated that it will work with the operators of UK AW189 helicopters who use the AFCS SAR upper modes at software Phase 5 or 6 to ensure they are appropriately managed.

The manufacturer reviewed the AW189 FMS Pilot's Guide, for helicopters equipped with Phases 5, 6 or 8 of the avionics suite, and added the following note in the section on '*SAR STEERING IN GROUNDSPEED*' in the chapter on '*SAR PATTERNS*':

> *'When flying Search pattern with GSPD control (NGSPD mode active) if a TD procedure is desired the NGSPD mode must always be replaced by GSPD mode before press TD pushbutton on APCP and engage TD mode.'*

The manufacturer incorporated the software correction, along with other software changes, into the Phase 9 version of the avionics software, which was certified on 29 July 2022. It has also advised that it intends to issue an optional Service Bulletin to allow customers to install this version. The UK CAA has advised that it will monitor the uptake of the Phase 9 software by UK operators of AW189 helicopters used for SAR.

Operator incident reporting

On safety reporting, the operator's SMS manual states:

> *'Reporting is an essential element of the SMS and all employees are encouraged to ………… report incidents, accidents, and areas for improvement.'*

It defines an incident as:

> *'An occurrence, other than an accident, that affects or could affect the safety of the operation.'*

The operator stated to the AAIB that it expects flight crews to raise observations on system performance using an Air Safety Report (ASR) as the formal reporting mechanism.

The flight crew of the 5 July occurrence did not consider that the event merited the submission of an ASR.

Interviews with the crew of the event on 5 July 2021 highlighted among the crew a perception of insignificance to the event, confusion about exactly what had led to the pitch oscillations resulting in the existence of significant doubt among the crew whether it was the result of incorrect automation selection or a fault with the AFCS.

Various crew expressed confidence to report events and the operator provided evidence of a strong reporting culture. However, some crew also expressed the need to be able to repeat an event to ascertain the facts relating to an AFCS behaviour clearly before feeling confident to report a system performance issue through an ASR.

Following the submission of an ASR by the flight crew of the second event on 30 July, the operator's safety team categorised both events as a loss of autopilot stability at a critical phase of flight. A Safety Action Group (SAG) meeting was held where the events were assessed according to the operator's risk register, and it classified the events as high risk but with a remote probability.

Through the reporting of other incidents by crews, the operator's SMS had captured a number of previous AFCS performance behaviours on the AW189 which were associated with the introduction of functionality and software phase updates. Flight crews reported to the AAIB that they had, at times, encountered instances where the AFCS operated contrary to their expectation or understanding. The operator had sought to address this through the issuing of Flight Safety Instructions (FSIs) and amendments to procedures and sought rectification of these issues in the longer term through engagement with the helicopter manufacturer.

Following the July 2021 events, the operator reminded flight crews, through briefings, of the importance of reporting all incidents to highlight issues. It also emphasised the importance of accuracy and completeness when submitting an ASR.

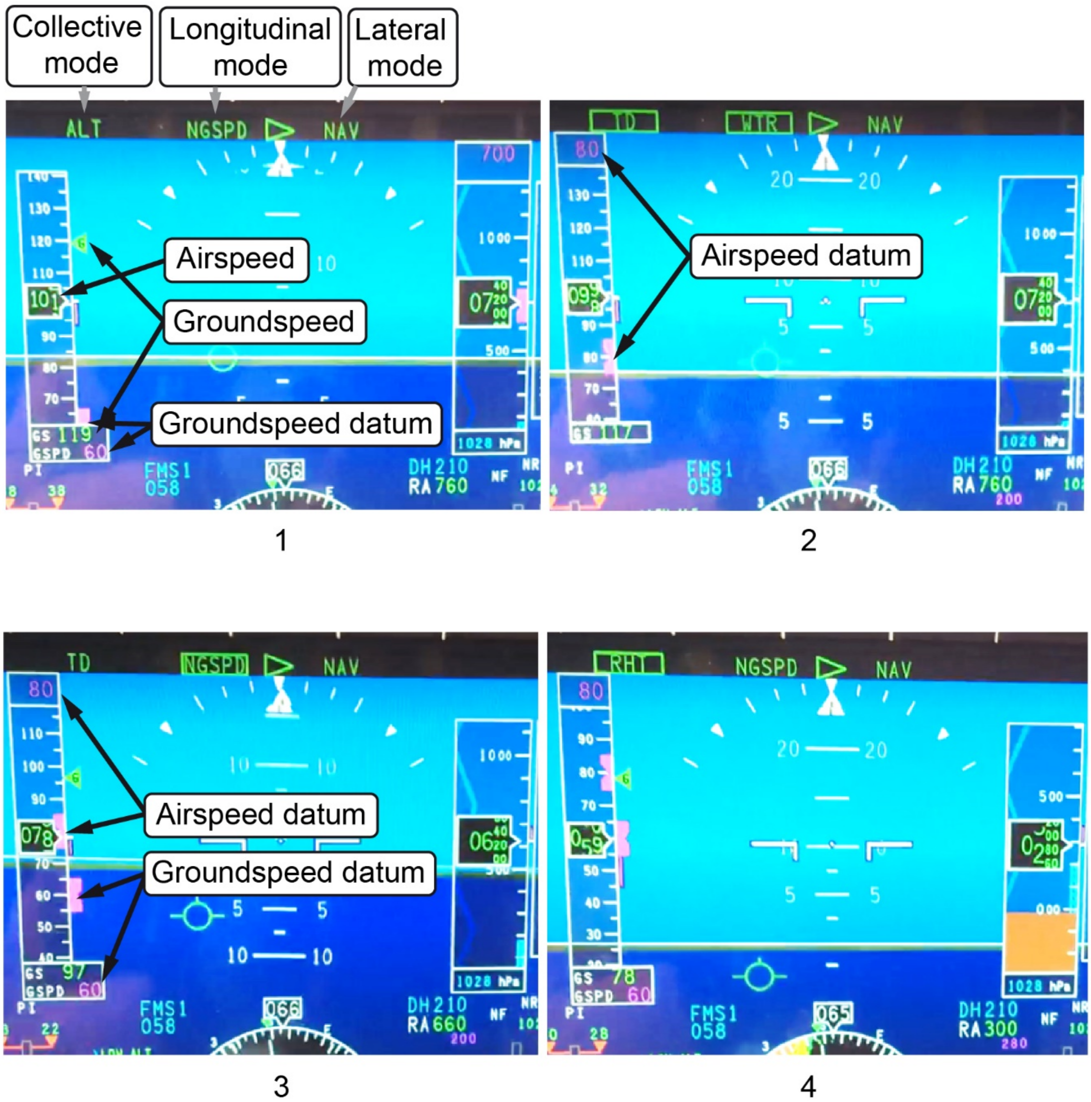
The operator was also concerned that a flight crew had sought to replicate the event that had led to a potentially undesired state. While the operator recognised that the intentions of the flight crew arose from lack of certainty if their automation selections had been the cause, it emphasised that *'putting the aircraft in a potentially dangerous configuration, for the purpose of investigation is not acceptable'.*

Tests and research

Operator test flights

In September 2021, the operator conducted a number of test flights in the simulator and on differing airframes. Although the pitch oscillations could not be replicated in the simulator, the operator's Test Pilot was able to replicate the AFCS behaviour on the airframe in which the original events occurred. Subsequently, he was able to replicate the pitch oscillations behaviour during test flights on other airframes.

A video recording of the PFD was made on the test flights conducted by the operator. Heights and speeds were not reproduced but the behaviour associated with the incorrect annunciations and the simultaneous groundspeed and IAS target speeds were recorded. Figure 6 shows a similar sequence to that which occurred during the 5 July event.



1 NGSPD active.

2 TD activated, longitudinal mode WTR annunciated, pitch oscillations start.

3 Slowed through 80 KIAS, longitudinal mode of TD switch to IAS, annunciation change to NGSPD, both groundspeed and airspeed datums.

4 FTR triggered height datum change, collective mode change to RHT, two speed datums persist, pitch oscillations persist until NGSPD deselected.

Figure 6

PFD mode annunciations and speed targets during reproduced sequence

The operator's Test Pilot made the following observations:

- The trigger to the behaviour was the selection of TD mode before the search speed datum had been achieved, ie during the deceleration phase to capture the demanded GS.

- The oscillation typically ranged between a pitch attitude of 17° nose up and 8° nose down. However, the oscillation would remain within those limits and not become divergent.
- The behaviour could be replicated irrespective of whether there was a tailwind or a headwind. However, the oscillations were greater when flying into wind with either a rate of climb of 2,250 fpm or a rate of descent of 1,950 fpm.
- WTR was annunciated on the PFD Annunciator. However, the corresponding button on the APCP did not illuminate, indicating WTR was not captured. This was confirmed by a crewman monitoring his station in the rear of the aircraft.

The behaviour would stop temporarily while cyclic FTR was depressed, and completely on selection of GSPD on the APCP, or on the deselection of the upper modes. It was noted that the behaviour could not be replicated when RHT was captured prior to the selection of TD.

The test pilot observed that *'the rate of flight path change could be alarming especially within a* [degraded visual environment] *DVE.'*

In October 2021, following the conclusion of the above tests, the operator issued an FSI to crews restricting the use of NGSPD in conjunction with TD. The operator also included information on this issue in the ground school training as part of its Operator Proficiency Check programme which all of its SAR AW189 crews have received.

Analysis

The events occurred during the day in VMC whilst conducting training flights. These are usually conducted on a regular basis and provide the opportunity by which crews maintain currencies and practise skills, competencies, and procedures, including the use of automation.

5 July 2021 event

For the event of 5 July 2021, the crew initiated the descent from 670 ft agl once they were over water. Although the crew recognised the amount of pitch change that occurred and the subsequent oscillations as unusual, they considered this only as an example of the AFCS operational performance being contrary to expectation. Other important indications occurred momentarily at the point of entry to the manoeuvre; notably, WTR mode was only briefly displayed on the PFD Annunciator. The PM stated he could not be certain that he had seen this annunciation, probably because he was surprised at the unexpected onset of the pitch oscillations and such an annunciation would also have been contrary to expectations. The crew also doubted whether they had set up the automation correctly for the intended search mode, as this required several inputs. Consequently, although the crew recognised the pitch oscillations were unusual, it is understandable why they perceived this as an operational performance issue rather than a safety event. It could also explain why they did not have confidence, as stated to the AAIB, to raise an ASR to report the event since they did not understand exactly what had happened, how the event was triggered, or what they had seen and experienced.

30 July 2021 event

The replication of the event by the crew on 30 July 2021 also occurred during a training flight. As such, the intent among the crew to replicate the same use of automation as on 5 July would not necessarily have seemed inappropriate. The uncertainty surrounding the cause of the AFCS behaviour, together with the perception that it was less a safety issue but more one of operational system performance, may have contributed to the desire to establish the facts of the event through repetition and replication before reporting it. A number of other crews expressed this desire to confirm unusual AFCS behaviours before reporting them.

With that perspective, although the crew had not sought the guidance of the operator's Test Pilot prior to the flight, the decision to replicate the event to establish exactly what happened is understandable. Following the July 2021 events, the operator reminded flight crews, through briefings, that such events are to be reported and managed by the operator's SMS. This is to ensure that the investigation of reported events is conducted by appropriately qualified crews and reducing the risk of line crews putting a helicopter into a potentially hazardous configuration.

During both of the above flights, the unexpected AFCS behaviour stopped when the PF deselected the upper modes; it is likely that the collective Low Height safety protection would also have acted as an additional safety barrier against controlled flight into terrain. All these factors mitigated the potential hazard arising from the AFCS behaviour which resulted in an undesired aircraft state. The impact upon safety may have been greater if this had occurred to a crew on a task at a lower height, with a higher workload and in degraded visual conditions or at night, where disorientation is a real threat.

Incident reporting

The evidence indicates that the operator's reporting culture was strong, and crews did report AFCS system performance issues that had a potential impact on safety, enabling the operator to address these both through its SMS and discussion with the manufacturer. Nonetheless, the crew of the event of 5 July did not feel that the event was significant enough to merit reporting. The fact that this event was not detected through the HFDM programme highlights that there can be events where the safety of the aircraft can be potentially put at risk, without other elements of the SMS detecting it. This reinforces the importance of crew reporting of unusual events, even if they are not perceived to affect the safety of the aircraft.

The AFCS system on the AW189 has undergone a programme of development since certification. The development was driven both by the manufacturer's continual improvement policy as well as customer feedback, resulting in both design modifications and added functionality with each iteration. AFCS operational software development can present its own challenges as a result of this continuous development. The exposure of crews to perceived unexpected AFCS behaviour at times may have contributed to increasing the threshold at which they may consider an event as being safety related and reportable.

Prompt resolution of any issue by the manufacturer through its airworthiness processes, and appropriate management by the operator through its SMS, can only be achieved with the reporting of all events by crews, even if crews may find it difficult to provide meaningful or complete information. Following these events, the operator has reinforced the need for flight crews to report events regardless of the perceived severity or completeness of the detail.

AFCS performance behaviour

During Phase 5 software development, while improving the AFCS FD behaviour for SAR operational capability, the manufacturer did not identify a design shortcoming which resulted in a priority conflict between different inputs of the TD / TDH modes. When using the AFCS to control the horizontal position and groundspeed of the helicopter as directed by the FMS to conduct a search pattern, under certain circumstances, selecting the AFCS mode to transition the helicopter down to a search radio height creates a conflict whereby the system is trying to acquire both a groundspeed and a separate airspeed datum. Pitch is used to control speed and the different speed targets result in pitch oscillations.

The maximum flight path deviation during the flight on 5 July 2021 was assessed to have been approximately 100 ft. This was more than 20 seconds after the onset of the condition, after more than two complete pitch oscillation cycles. The crews stated that, as they were engaged on training sorties, they allowed the situation to develop for longer than they would have done under other circumstances. The AFCS software issue is not triggered below 150 ft agl and, as the collective protection afforded by the Low Height function is unaffected, it would have been expected to act as an additional safety barrier if the loss of height from a similar event had occurred at a lower level.

The software issue also results in the mode annunciator displaying incorrect mode information to the crew. With TD and NGSPD captured, the WTR longitudinal mode is displayed, and when both IAS and NGSPD are using the longitudinal axis to target separate air and ground speeds, NGSPD is displayed. This is misleading because it does not reflect the datums being targeted by the AFCS when controlling the helicopter.

The manufacturer reproduced the AFCS software behaviour and carried out a risk assessment in accordance with the applicable EASA Part-21 procedures which determined the behaviour of the AFCS was a non-compliance and was “NOT UNSAFE”. The European (EASA) and UK (CAA) Regulators concur with this assessment.

The manufacturer has incorporated the software fix into the Phase 9 software (which was certified on 29 July 2022) and has advised that it intends to issue an optional Service Bulletin to allow its customers to install this version. The UK CAA has advised that it will monitor the uptake of the Phase 9 software by UK operators of AW189 helicopters used for SAR.

Conclusion

Investigation of the pitch oscillations behaviour by the manufacturer determined that it was the result of a design shortcoming in the Phase 5 version of the AFCS software. This resulted in a conflict between airspeed and groundspeed priority on selection of the Transition Down autopilot mode during a sector search pattern using Autonomous Groundspeed. While analysis of the FDR data identified the annunciation of the Winch Trim SAR autopilot mode on the primary flight display following the selection of the Transition Down mode, it was confirmed that this was displayed in error. The manufacturer and Regulators have assessed this AFCS behaviour to be "NOT UNSAFE", in accordance with the applicable EASA Part-21 procedures.

Safety action taken

The helicopter manufacturer has issued a Technical Information Letter advising operators of this behaviour and the actions that should be taken in the event of its occurrence. It also briefed the helicopter community on the issue during HAI Heli-Expo 2022 and has updated the FMS Pilot's Guide for Phase 5, Phase 6 and Phase 8.

The design shortcoming in the AFCS software has been corrected in the Phase 9 release.

The helicopter operator has restricted the use of NGSPD in conjunction with TD by its flight crews and has reinforced the importance of reporting incidents to ensure that issues that could affect safety are dealt with appropriately.

The operator also included information on this AFCS issue in the ground school training as part of its Operator Proficiency Check programme which all of its SAR AW189 crews have received.

Published: 29 September 2022.

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.

SERIOUS INCIDENT

Aircraft Type and Registration:	Agusta AW169, G-KSST
No & Type of Engines:	2 Pratt & Whitney Canada PW210A turboshaft engines
Year of Manufacture:	2016 (Serial no: 69014)
Date & Time (UTC):	2 July 2022 at 1710 hrs
Location:	Epsom, Surrey
Type of Flight:	Emergency Services Operations
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - N/A Other - 1 (Minor)
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	7,260 hours (of which 352 were on type) Last 90 days - 5 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

As the helicopter transitioned to forward flight after departing from an in-town landing site, the downdraught of the helicopter caused a significant amount of flying debris in a local garden. One person in the garden was hit in the face by a flying object and suffered a significant cut to his face.

History of the flight

The crew of G-KSST had been attending an incident in the local area but had been re-tasked. The crew prepared for departure, which included moving spectators back to a safe area and completing a visual check of the departure area. After a normal start, G-KSST lifted into a hover and completed a clearing turn. The helicopter performed a 'ground and elevated heliport/helideck variable takeoff decision point procedure' (also known as a variable helipad profile to a takeoff decision point). This meant that the helicopter climbed backwards until it reached the calculated decision point (in this case 200 ft agl) before transitioning to forward flight and climbing away on the departure route.

The injured person was in the garden in which he had been constructing a climbing frame. There was a large amount of cardboard packaging in the garden as well as a patio umbrella which was up at the time. Although he had heard the helicopter start up, he did not see it initially as there were large trees at the end of the garden. He saw the helicopter as it reversed up for its departure and as it reached the decision point just before the tall trees at the end of the garden. As the helicopter transitioned to forward flight, the householder described his garden as being “affected by a tornado”. The cardboard packaging was picked up by the wind with one item found around 15 m away from the garden in a local car park. The heavy patio umbrella was lifted from its stand and struck the householder in the face, causing a significant cut, before becoming embedded in the house wall. Two others in the garden escaped without injury.

Recorded information

Data was available for the flight of the helicopter. Figure 1 shows the landing site of the helicopter and its track rearwards on its departure. It also shows the garden in which the injury occurred.

Figure 1

The location of the helicopter and garden in which the incident occurred

Aircraft information

The speed of the downwash produced by a helicopter is a function of weight, air density and rotor diameter. The rotor downwash reaches its maximum velocity between 1.5 and 2 times the rotor diameter below the helicopter before beginning to dissipate. This maximum velocity can be twice the speed at the rotor head. It is possible to calculate the speed of the downwash at the rotor and estimate the height below the helicopter at which the maximum downwash speed will be reached.

G-KSST is a AW169 with a rotor diameter of 12.12 m. The AW169 has a maximum takeoff weight of 4,800 kg, although on this flight it was operated below that weight at 4,272 kg. Calculations of the velocity of the rotor downwash at the rotor head showed that at the time of the departure this would have been around 44 kph (27 mph). The maximum velocity would have been reached around 24 m (80 ft) below the helicopter, with the maximum speed dissipating from this height. The physical layout of the area under the downwash can affect both the velocity of the downwash and the rate of dissipation, with alleyways, small roads between fences and hedges, and houses causing the downwash to be accelerated or directed in a particular direction.

Analysis

The crew of G-KSST performed a takeoff decision point departure, which saw the helicopter climb backwards to 200 ft agl from the landing site. This departure took it towards the tall trees at the end of a residential garden. As the helicopter transitioned into forward flight, the garden of the house was affected by the downdraft which blew around a number of items, including a patio umbrella which struck one person in the face causing a significant cut.

With the helicopter at 200 ft agl the velocity of the rotor downwash should not have been significant, but local effects, such as funnelling by the physical geography of the location, may have further accelerated the air causing the significant downwash experienced in the garden.

Conclusion

Downwash from helicopters can be a significant risk, especially operating in an urban environment. Although the height of the helicopter meant that the downwash should not have been of a significant magnitude, the event caused a significant injury as items in the garden were blown around.

SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A320-232, G-EUUT
No & Type of Engines:	2 International Aero Engine V2527-A5 turbofan engines
Year of Manufacture:	2007 (Serial no: 3314)
Date & Time (UTC):	14 June 2022 at 1309 hrs
Location:	London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 pilots, 4 cabin crew; Passengers - 159
Injuries:	Crew - None; Passengers - None
Nature of Damage:	None reported
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	13,786 hours (of which 8,373 were on type) Last 90 days - 136 hours Last 28 days - 55 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilots noticed a strong unpleasant smell in the cockpit during an approach to London Heathrow Airport. The aircraft landed uneventfully but after landing both pilots suffered ill effects from the fumes. A PAN was declared when on stand but there was a 17-minute delay until ground personnel could access the aircraft. The commander was taken to hospital but released the same evening following medical checks.

History of the flight

The aircraft, an Airbus A320 (Figure 1), was operating a passenger service from Malaga-Costa del Sol Airport, Spain, to London Heathrow Airport. During the arrival procedure, Heathrow ATC gave the crew radar vectors, which reduced the ground track to landing. The aircraft was therefore going to capture the ILS glidepath from above and the crew described their workload on the approach as "quite high". Just before intercepting the glidepath, at approximately 3,000 ft agl and five minutes from landing, the co-pilot noticed a strong unpleasant odour in the flight deck. He described the smell as being like "a wet dog or sweaty socks". Once the co-pilot had reported the smell the commander also noticed the odour. Neither pilot felt any sense of impairment and given their high workload, they briefly discussed the odour and decided to continue the approach without actioning the smoke/fumes removal procedure. Neither pilot was therefore on oxygen, though the much-increased workload that would have been incurred by carrying out the procedure was avoided.

Figure 1
Airbus A320

The approach was continued, and the aircraft made a normal landing. After clearing the runway, the aircraft was taxied toward Stand 548L at Heathrow and the crew had stopped noticing the smell. As the aircraft approached the stand, the crew noticed the parking guidance system was not active. There was a delay of approximately 10 minutes in waiting to park before an airport Marshaller guided the aircraft onto the stand. During this period, as the pilots were no longer noticing the smell, they asked the Senior Cabin Crew Member to come into the flight deck to ask if they noticed anything. They did not. The co-pilot began to feel nauseous and lightheaded during the wait to park but did not tell this to the rest of the crew. When the aircraft reached its final parking position the co-pilot was feeling very unwell and had begun coughing and retching. The co-pilot described himself as “quite scared” by the level of the symptoms. The commander shut down the aircraft, made a PAN call via RTF requesting Emergency Services assistance and opened his cockpit window.

The commander was also now feeling unwell and so the cabin crew gave both pilots portable oxygen sets, which they used. Due to a lack of appropriately trained personnel at Heathrow, there was a 17-minute delay from the aircraft parking until an airbridge was attached. The Emergency Services did not enter the aircraft until the airbridge was attached, when paramedics entered the flight deck to assess the pilots’ condition. The RFFS also entered the flight deck with gas monitors, which gave a negative result. This equipment can detect combustible gases and vapours, as well as oxygen, carbon monoxide, hydrogen sulphide, nitrogen dioxide and sulphur dioxide. The RFFS have a set of mobile evacuation stairs which could be deployed to such incidents if more rapid access to the aircraft is required.

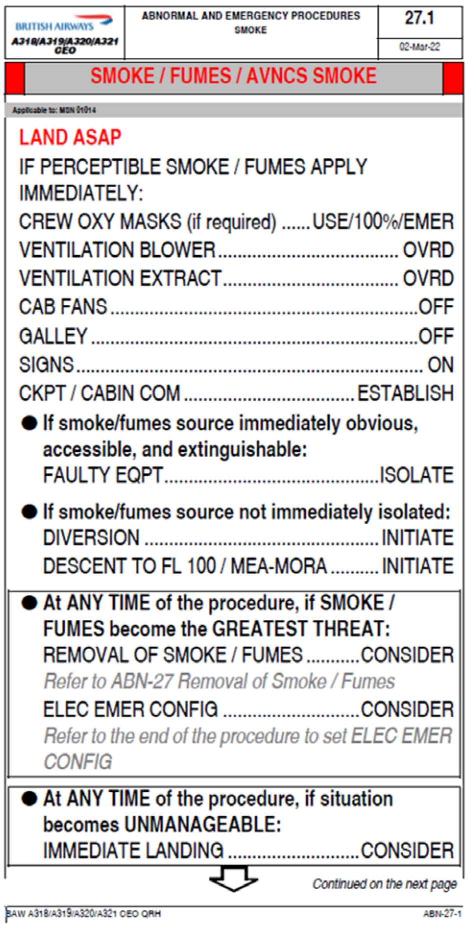
The co-pilot felt anxious but was reassured by the paramedics and it was not judged that he required any further medical checks. Due to elevated blood pressure and pulse rate, the paramedics took the commander to hospital for further assessment. During that assessment the commander had a blood test for exposure to toxic gases which gave a negative result. The commander was released from hospital following the medical checks.

None of the cabin crew noticed any unusual smells at any stage of the flight. All of the passengers were disembarked without further incident. Neither of the pilots suffered any further ill effects post flight.

Smoke / Fumes / Avncs Smoke Procedure

The aircraft's Quick Reference Handbook (QRH) contains a procedure for when smoke and fumes are detected. When the pilots smelt the unusual odour, however, their workload was high and neither felt any sense of impairment. The aircraft was only a few minutes from landing and the so the pilots landed without carrying out the QRH procedure. The first action in the procedure is to land as soon as possible.

The procedure in the QRH gives guidance on immediate protection of the crew through the use of oxygen masks and then offers a structured system to diagnose the source of fumes and eliminate that. Should the smoke or fumes become the greatest threat, the procedure has guidance on removing smoke from the cabin. These procedures are long and would have taken more time to complete than the few minutes left to landing. The first page of the QRH procedure is shown at Figure 2.



BRITISH AIRWAYS A318/A319/A320/A321 CEO | ABNORMAL AND EMERGENCY PROCEDURES SMOKE | 27.1 | 02-Mar-22

SMOKE / FUMES / AVNCS SMOKE

Applicable to: MSN 01014

LAND ASAP

IF PERCEPTIBLE SMOKE / FUMES APPLY IMMEDIATELY:

CREW OXY MASKS (if required) USE/100%/EMER
VENTILATION BLOWER.................................... OVRD
VENTILATION EXTRACT................................... OVRD
CAB FANS ....OFF
GALLEY ....OFF
SIGNS.. ON
CKPT / CABIN COM .... ESTABLISH

- **If smoke/fumes source immediately obvious, accessible, and extinguishable:**
  FAULTY EQPT...ISOLATE
- **If smoke/fumes source not immediately isolated:**
  DIVERSION ....INITIATE
  DESCENT TO FL 100 / MEA-MORA .... INITIATE
- **At ANY TIME of the procedure, if SMOKE / FUMES become the GREATEST THREAT:**
  REMOVAL OF SMOKE / FUMES ....CONSIDER
  Refer to ABN-27 Removal of Smoke / Fumes
  ELEC EMER CONFIG ....CONSIDER
  Refer to the end of the procedure to set ELEC EMER CONFIG
- **At ANY TIME of the procedure, if situation becomes UNMANAGEABLE:**
  IMMEDIATE LANDING ....CONSIDER

Continued on the next page

BAW A318/A319/A320/A321 CEO QRH ABN-27-1

Figure 2

Smoke/Fumes/Avionics Smoke QRH procedure

In any fumes event, the operator's training department strongly advocates completion of the items to CKPT/CABIN COM as a minimum. This would include the pilots donning oxygen masks and using the Emergency setting. This provides positive oxygen pressure to the mask to protect the user from inhaling noxious fumes.

The QRH procedure is not, however, designed to be carried out by memory. One of the pilots would have had to read the actions from the QRH and this would have increased crew workload.

Aircraft examination

The aircraft was removed from service after the event and examined using a maintenance protocol for smoke and fumes events that was developed as a Safety Action during a previous AAIB investigation.[1] No technical cause was identified, and the aircraft was returned to service without any rectification being required. For all aircraft in the operator's fleets that have been examined post fumes events, a definitive technical cause has only been identified in approximately 5% of occurrences.

Union cabin air quality campaigns

Unions representing both pilots and cabin crew have been campaigning on the issue of fumes on board commercial aircraft. These campaigns have supplied information on how to respond to such events to the respective union members. The information contains descriptions of common symptoms, and suggests that crews should report all such events via the operator's reporting systems and via MORs to the CAA. It also recommends that crew should use oxygen in such events and that they should seek medical advice if they suffer any ill effects. The descriptions of events used in these campaigns frequently appear in the reporting of fumes events.

NHS Care Pathway

The CAA has an information page for fumes related events[2] which gives guidance to health professionals caring for those exposed to them. The page describes the situation as follows:

> *'The pattern of symptoms reported is quite variable and health professionals have asked for guidance on how best to manage such patients. The Care Pathway has been developed by an independent working group including experts in toxicology, epidemiology, aviation medicine and primary care, in order to provide advice to health professionals in managing such patients.'*

The principal response mentioned is the NHS Care Pathway. This is outlined in the flow chart at Figure 3.

Footnote

1 https://www.gov.uk/aaib-reports/aaib-investigation-to-airbus-a320-232-g-euyb [accessed August 2022].
2 https://www.caa.co.uk/Passengers/Before-you-fly/Am-I-fit-to-fly/Guidance-for-health-professionals/Aircraft-fume-events/ [accessed August 2022].

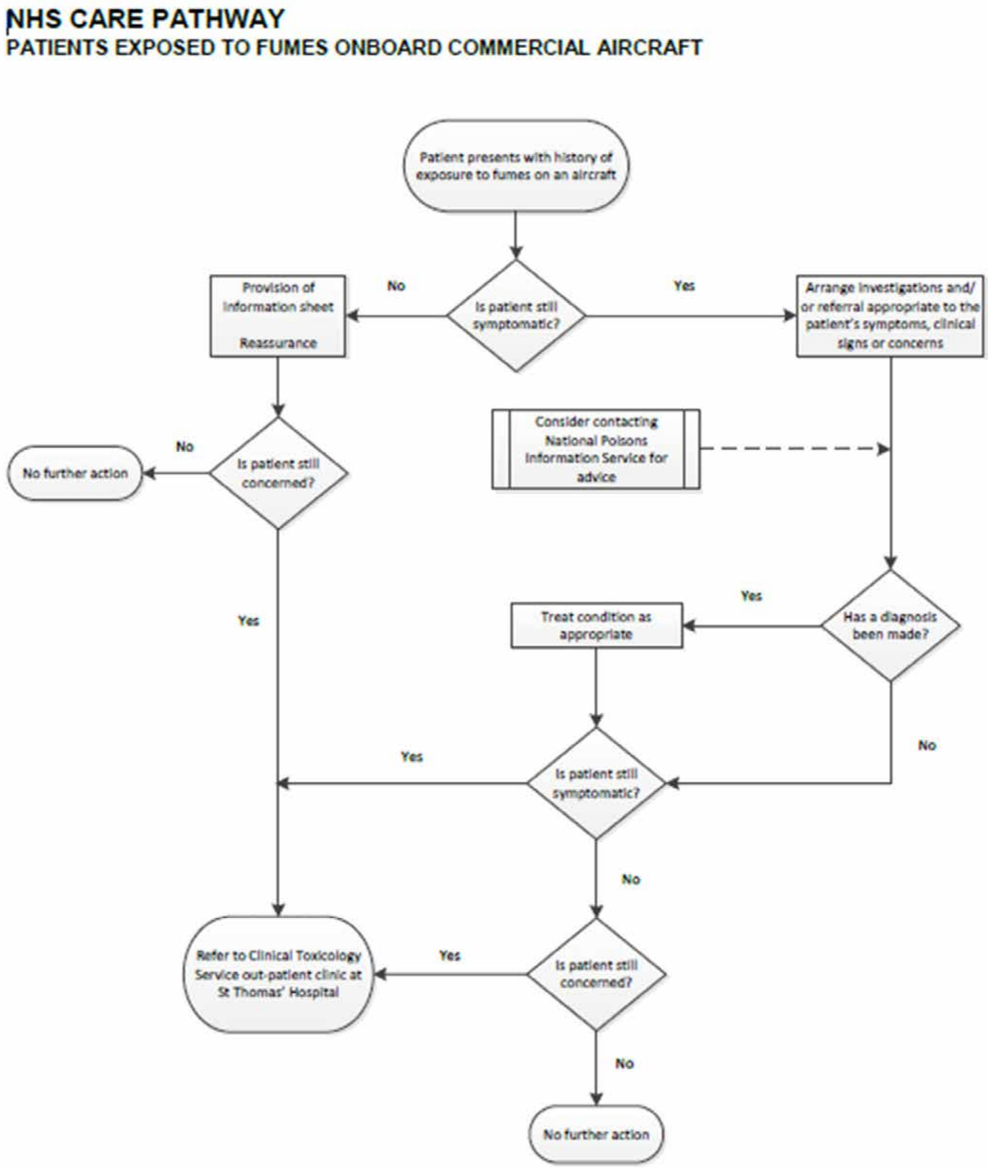


Figure 3
NHS Care Pathway flowchart

The CAA Information also considers the possibility of a *'Nocebo effect'* where there may be a psychologically mediated response (see note) triggered by awareness of irritation or an odour. In such cases illness, often with physical symptoms and signs, is triggered through psychological processes in response to a perceived harmful exposure. The phenomenon is analogous to a placebo effect in which symptoms improve in response to a perceived beneficial exposure.

There is no specific medical test which the CAA recommends for crew who have been exposed to fumes events. Advice from the CAA Medical department for fumes exposure is as follows:

'The likely background to the Poisons Service referral is that they have the 24/7 NHS expertise/mechanics to investigate specific 'potential poison' incidents which could be technically almost anything from a chemicals perspective, and because there is not a firm/causative link between what is found in fume events and clinical symptoms / pathology etc. each case would need individual assessment as described in the guidance.'

Meteorology

The Heathrow weather at the time of the event gave a wind of 220° at 8 kt varying between 170 and 260°. The visibility was greater than 10 km and no cloud was detected. Some previous reports of fumes events on A320 aircraft have been associated with the passage of cloud. This was not a factor in this case, and so weather was not considered to be a factor in the event.

Organisational information

The operator has duty managers who provide immediate support to crew members who have been involved in operational events. Such occurrences are followed up by flight crew management and the level of support offered is tailored on a case-by-case basis. The support offered can include dealing with significant post-event issues such as Post Traumatic Stress disorder.

The operator has it own medical service, which does not advocate post-event testing of crew unless there are symptoms or physical signs on which to base a medical investigation. Their view is that:

'The most appropriate medical management is to get a person with symptoms to the most appropriate medical facility, i.e. an acute care facility such as A&E if needed. Such a department will then investigate, based on symptoms and, if necessary, consult the National Poisons Service.'

Other information

The operator's maintenance personnel use Aerotracer equipment to measure the presence of odours, such as those from oils. The equipment allows detection and identification of common volatile compounds used in connection with aircraft, for example hydraulic fluids or lubricating oil. Another system, GrayWolf, allows for the detection of a range of toxic gases. Both systems gave a negative result aboard the aircraft.

Analysis

The pilots noticed the presence of an unusual and unpleasant odour only a few minutes before landing. Aside from the odour there were no other indications of a fault with the aircraft and, initially, neither pilot felt any sense of impairment from the odour in the cockpit. They briefly discussed the issue but, as their workload was high and both felt unaffected, decided to continue with their approach without undertaking any QRH procedures. As a result, neither pilot was wearing an oxygen mask. The operator strongly recommends that during fumes events pilots complete at least the initial actions of the '*Smoke / Fumes / Avncs Smoke'* QRH procedure. These actions would have directed the pilots to don their oxygen masks and use the Emergency setting on the mask. The positive oxygen pressure thus delivered would provide a high degree of protection against inhaling toxic fumes. The aircraft landed safely and taxied toward its parking stand, and by this point both pilots had stopped noticing the odour.

During the 10-minute delay waiting with engines running for the parking stand guidance to be turned on, the co-pilot began to feel nauseous. As the aircraft parked, the co-pilot felt increasingly unwell and the severity of his symptoms increased. The commander carried out the shutdown check, made a PAN call to ATC and opened his window. During these actions the commander also began to feel lightheaded.

The Senior Cabin Crew Member entered the cockpit and provided both pilots with oxygen, although he did not perceive any odour. There was a delay of approximately 17 minutes before an airbridge was attached to the aircraft, which allowed paramedics and the RFFS to enter the flight deck. If toxic fumes were present in the flight deck this long delay would have increased exposure to them. The RFFS conducted gas checks which proved negative. Nevertheless, after both pilots were checked by the paramedics, the commander's symptoms were considered sufficient to warrant assessment in hospital.

The odour was not noticed by any cabin crew or passengers and nor did any display any symptoms.

There have been a significant number of suspected fumes events in the operator's A320 fleet, but no decisive technical findings have been made. The awareness of such events has been raised by the campaigning conducted by pilot and cabin crew Unions, and the CAA indicates the possibility of a psychological response to the perceived problem of aircraft fumes events. That cannot be discounted but neither can the occurrence of toxic fumes.

The operator has no formal medical blood test protocol for crew that could capture evidence of symptoms or exposure to toxins because its policy, based upon its own medical service's recommendations, is to take anyone with symptoms to the most appropriate medical facility. The CAA does not recommend any specific medical test which could be deployed to detect exposure to toxic fumes in crew. Each medical case is assessed individually.

The issue has previously been given prominence by the CAA, and a Care Pathway has been created to give information to healthcare professionals caring for those exposed to such events. The pilots in this event recovered quickly and have shown no subsequent ill effects.

Conclusion

The pilots noticed an unpleasant odour in the flight deck shortly before landing. Due to their high workload and lack of symptoms they decided to continue the approach without carrying out QRH procedures. The aircraft landed safely but, due to a delay in ground handling, there was a delay in emergency services gaining access to the flight deck. Both pilots developed symptoms and were given medical attention by Emergency Services personnel. After medical checks both recovered and suffered no further ill effects.

ACCIDENT

Aircraft Type and Registration:	Cessna A185F Skywagon, G-SAUO
No & Type of Engines:	1 Continental Motors Corp IO-520-D piston engine
Year of Manufacture:	1974 (Serial no: 185-02324)
Date & Time (UTC):	30 August 2022 at 1008 hrs
Location:	Luxters Farm Airstrip, Henley-on-Thames, Buckinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	69 years
Commander's Flying Experience:	28,000 hours (of which 350 were on type) Last 90 days - 38 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was on a cross-country flight from Shelsley Beauchamp Airfield, Worcestershire, to Luxters Farm Airstrip, Buckinghamshire. Luxters Farm Airstrip is a private 950 m grass airstrip, oriented 10/28, surrounded by trees. The weather was fine and the pilot reported that after flying an approach to Runway 28, the aircraft bounced on landing and he decided to go-around. The aircraft struck trees at the far end of the runway and came to rest on the ground, partially supported by the tree canopy (Figure 1).

The pilot and his passenger received minor bruising in the accident but were otherwise unharmed. The aircraft had been modified with full four-point seat restraints[1] and the pilot stated that, in his opinion, these restraints prevented the occupants from receiving further injuries. The pilot assessed that an earlier decision to go around, following the bounced landing, would have prevented the accident.

Footnote

[1] The standard seat belt arrangement for the Cessna A185F is a lap belt.

Figure 1
G-SAUO accident site

ACCIDENT

Aircraft Type and Registration:	DA 40 NG, G-CTSR
No & Type of Engines:	1 Austro E4-A piston engine
Year of Manufacture:	2015 (Serial no: 40.N304)
Date & Time (UTC):	3 September 2021 at 1257 hrs
Location:	Cranfield Airport, Bedfordshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Damaged beyond economical repair
Commander's Licence:	Student pilot
Commander's Age:	42 years
Commander's Flying Experience:	23 hours (of which 23 were on type) Last 90 days - 23 hours Last 28 days - 14 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

While flying a solo visual circuit the student pilot elected to go around due to an unstable approach. During the go-round the aircraft descended as it flew along the runway. It subsequently struck the airport perimeter hedge and came to rest in an adjacent field. The pilot sustained minor injuries.

It was discovered that the aircraft did not have the performance to climb during the go-around as the engine power applied during the go-around was recorded to be about 13%.

History of the flight

The student pilot was planning to fly some solo visual circuits at Cranfield Airport, Bedfordshire having recently completed her first solo. Runway 03 was in use and the weather was good with a wind from 030° at 6 kt. The aircraft completed the circuit without event until it was on the approach.

During the final approach, on the first circuit, the pilot realised the aircraft was too fast and high. Despite trying to correct the approach by selecting flaps to FULL, the pilot realised the approach was still unstable so elected to execute a go-around (GA). The flaps were retracted to TAKE OFF and the aircraft was pitched up, and the pilot believed that full power was applied. However, it soon became apparent that the aircraft was not climbing as expected and the pilot felt there was not enough power. Upon looking at the ASI it was noticed that the IAS was decreasing, so the aircraft's nose was lowered to maintain the airspeed. This resulted in the aircraft descending.

The pilot continued to lower the nose to maintain an appropriate airspeed but the aircraft was by now at a low height and approaching the end of the runway. The pilot momentarily retracted the flaps, to see if that would help, before re-selecting them to TAKE OFF and then FULL.

As the aircraft crossed the end of the runway the pilot noted that the IAS was "dangerously low". The flaps were retracted to the takeoff position to try to extend the aircraft's range and clear the approach lights to Runway 21 and the hedge on the airfield boundary. However, the aircraft continued to descend and struck the hedge. As it did so, the stall warning sounded and the pilot noted that the IAS was about 60 kt. The aircraft came to rest in a field on the other side of a road that bounded the airfield (Figure 1).

The pilot completed the shutdown checks and vacated the aircraft unassisted with minor injuries. A passer-by stopped to assist the pilot, and the local and airport's RFFS were quickly on scene where they administered first aid and made the aircraft safe.

The aircraft was damaged beyond economical repair.

Figure 1
G-CTSR after the accident

Pilot's comments

The pilot commented that she was convinced she selected full power, and she did not remember if there were any caution messages during the event. She added that a lack of experience contributed to the accident in that she focused on trying to solve the lack of performance and continued trying to get the aircraft to climb when it would have been preferable to convert to a landing.

Recorded Information

Electronic flight instrument system

The aircraft was fitted with an integrated electronic flight instrument system (EFIS), and its removable memory card was downloaded. Pertinent data from the flight is shown in Figure 2. The data shows that the GA was initiated at about 215 ft aal, at which point the IAS was 100 kt, and the pitch attitude of the aircraft slowly increased to about 4° nose up. The IAS then decreased to 68 kt as the height increased slightly to about 240 ft aal. The aircraft then began a descent during which the IAS increased to about 80 kt. The aircraft's height then varied slightly, although it stayed predominantly below about 60 ft aal, and the IAS began to reduce again. Finally, the aircraft descended further and struck the hedge. Throughout the GA the engine power remained stable at about 13%.

Throttle and flap positions and stall warning were not recorded by the EFIS.

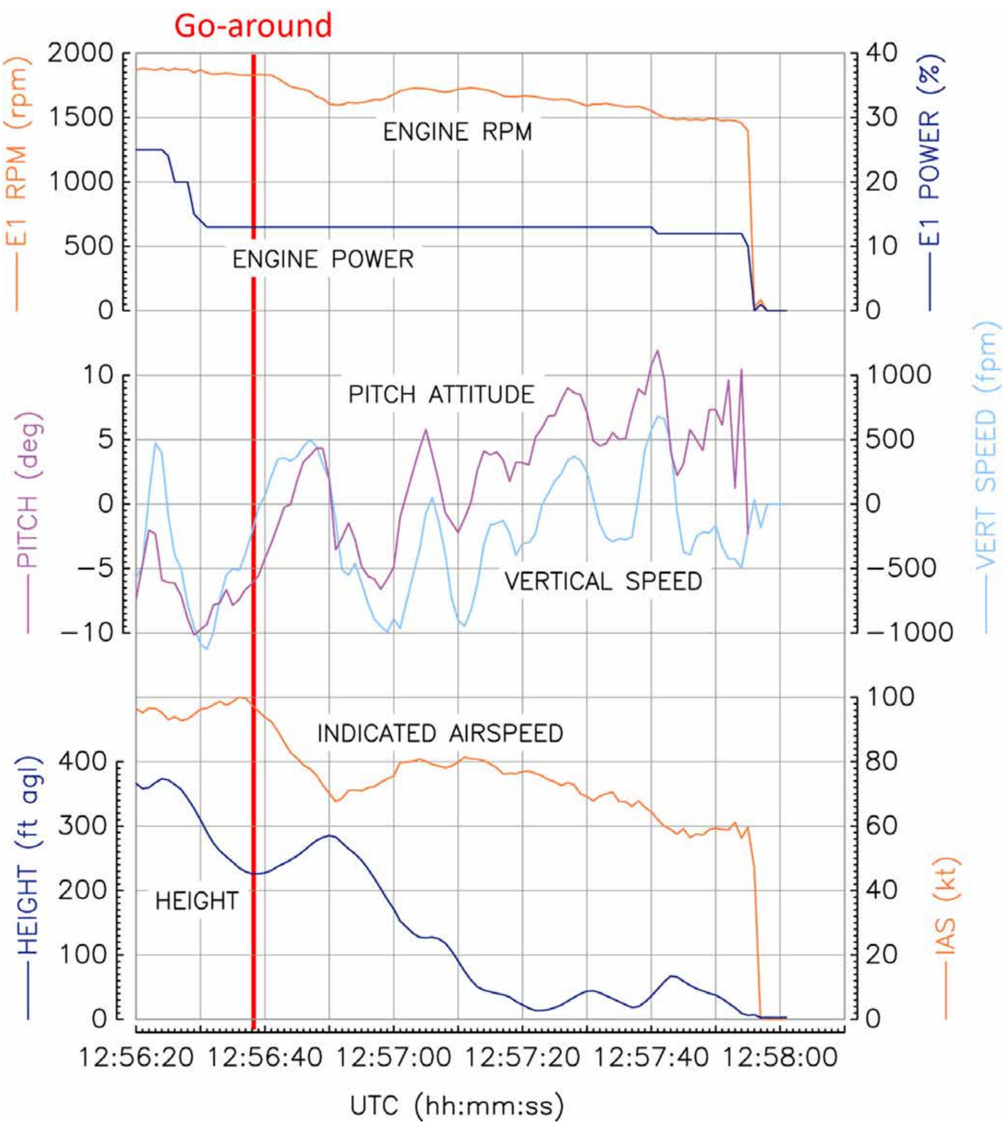


Figure 2

Graph showing pertinent data from the EFIS

Engine control unit

The engine control unit was sent by the operator to the engine manufacturer for analysis. There was no electrical failure recorded and all the engine parameters were correct and in the normal range. The manufacturer concluded there had been no technical issue with the engine or its control system.

Analysis

This was the student pilot's second solo flight. Having noticed that the approach was unstable, the pilot's decision to execute a GA was in accordance with CAA guidance[1]. However, the evidence from the EFIS was that the power did not increase above 13% during the GA, and the aircraft's subsequent lack of performance indicated that this was insufficient power for the aircraft to climb.

The pilot commented that a lack of experience contributed to the accident as she tried to solve the lack of performance and became slightly distracted by moving the flaps down and up. While distractions can be difficult to ignore, especially when inexperienced, the first priority is always to fly the aircraft, which during a GA includes ensuring full power is applied. The pilot closely monitored the IAS and made appropriate corrections to keep the aircraft at a suitable speed, although this resulted in it descending. Had the pilot not done this, it is possible the aircraft would have stalled at a low height, after which the outcome may have been more serious.

Conclusion

The aircraft did not have enough performance to climb after a go-around was initiated by the pilot. The pilot was insistent that the throttle was advanced, but the recorded data from EFIS showed the power remained at 13%. The manufacturer considered that the engine and its control system were operating normally, and no cause could be established to explain why the power did not respond to the reported throttle movement. While the pilot lowered the nose to maintain an appropriate speed, the aircraft descended and eventually struck a hedge on the boundary of the airfield.

Footnote

[1] CAA Safety Sense Leaflet 1e, *Good Airmanship,* paragraph 30. Available: http://publicapps.caa.co.uk/docs/33/20130121SSL01.pdf [Accessed June 2022].

ACCIDENT

Aircraft Type and Registration:	DH82A Tiger Moth, G-AXAN
No & Type of Engines:	1 De Havilland Gipsy Major 1F piston engine
Year of Manufacture:	1942 (Serial no: 85951)
Date & Time (UTC):	14 May 2022 at 1515 hrs
Location:	Private Farm Strip, near Duxford, Cambridgeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	3,687 hours (of which 533 were on type) Last 90 days - 67 hours Last 28 days - 25 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further AAIB enquiries

Synopsis

While landing at a private farm strip the aircraft touched down in soft ground and the left landing gear failed. The aircraft bounced and became inverted, but the occupants were uninjured. Examination of the failed components showed evidence consistent with a hard landing. It was not possible to determine whether the conditions encountered during the accident landing were sufficient in isolation to have caused the damage, or whether any pre-existing defects might have contributed to the failure.

History of the flight

Following a normal approach to grass Runway 22 at a private farm strip near Duxford, the pilot reported that the touchdown felt unusual, and the aircraft bounced. It then landed in a three-point attitude and came to a sudden stop, resulting in the aircraft nosing over and becoming inverted. Both occupants were uninjured and exited the aircraft without assistance.

Inspection of the aircraft and runway showed that the left wheel had touched down in soft ground, causing the landing gear to fail at the lower fork end fitting on the compression leg (Figure 1).

The pilot had walked the runway several times prior to the flight to check the ground conditions and identified several areas of soft ground at the side of the runway but considered the conditions adequate. The pilot considered it unfortunate that the aircraft had touched down in an isolated area of soft ground.

Figure 1

G-AXAN after coming to rest inverted

The pilot provided a diagram of the accident site and ground marks (Figure 2) which shows a depression in the grass surface coincident with the left wheel striking the ground, followed by a long narrow ground mark caused by the lower fork end fitting of the compression leg.

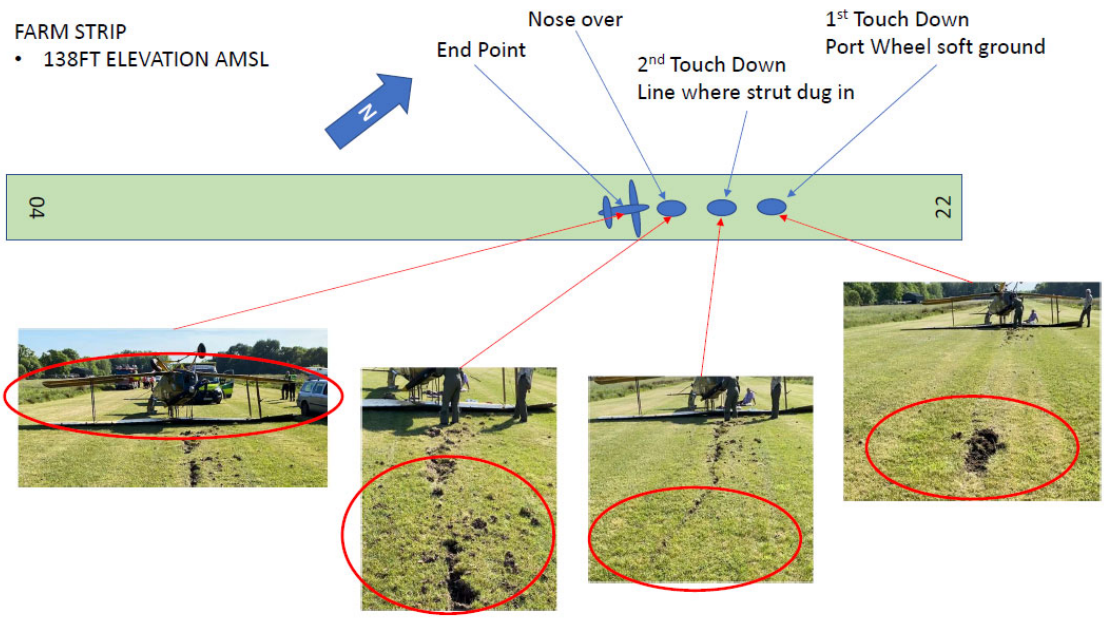


Figure 2

Diagram of accident site and ground marks

Aircraft information

The original design standard for the DH 82 and 82A required the landing gear compression leg lower fork end fitting to be manufactured from aluminium alloy. Service experience indicated that this fitting would fail after repeated hard landings. A steel lower fork end fitting was subsequently introduced. De Havilland Support Ltd Technical News Sheet (TNS) 22, first published in 1990 and re-issued in 2003, recommends fitment of the steel fitting on all standard (unbraked) Tiger Moth aircraft.

Separately TNS 22 describes a widely available modification to fit wheel brakes to Tiger Moth aircraft. Although approved by the CAA, this modification is not endorsed by de Havilland Support Ltd, the design approval holder, or any of its predecessor companies. This is because the landing gear was not designed to take braking loads. On aircraft modified with wheel brakes, cases have occurred where the compression leg lower fork end and/or the axle collar attaching lug have fractured. The design approval holder considered that these failures were caused by torque loads imposed by the brakes, which are in excess of the original design loads. TNS 22 included a warning that operators who choose to fit wheel brakes to Tiger Moth aircraft should ensure that all the components in the landing gear and brake installation have sufficient strength for the static and fatigue loads they will encounter.

G-AXAN had been fitted with the modified steel compression leg lower fork end fitting, in accordance with the TNS 22 recommendation and was also equipped with wheel brakes.

Aircraft examination

The design approval holder considered that the ground conditions encountered by G-AXAN in combination with a hard landing or bounce, may not have been sufficient to cause failure of the compression leg lower fork end fitting. It considered whether braking loads may have contributed to the failure. A representative from the design approval holder examined the aircraft several days after the accident and made the following observations.

The fuselage tubular structure above the compression leg attachment on both sides, was free from damage, suggesting that an extreme hard landing had not occurred. The left compression leg top attachment bolt (where it attached to the fuselage), exhibited signs of shear failure, indicating a very hard landing had occurred, either on the accident flight or a previous flight. The compression leg to axle joint had separated entirely. The pin which passes through this joint had failed, but there were no discernible features on the fracture face. The compression leg lower fork fitting sustained substantial mechanical damage when it struck the ground after the failure, and this had obscured the majority of the fracture face making further analysis difficult. However, there was some evidence of a shear failure on the forward lug. The stub axle was bent slightly upwards, which was indicative of a hard landing.

Comment

Examination of the left landing gear showed damage consistent with a hard landing having occurred, either on the accident flight or at some point in the past. It was not possible to determine whether any pre-existing defect or failure, for example relating to braking loads, may have contributed to the failure. Nonetheless, the design approval holder was keen to draw attention to the warning in TNS 22 relating to the fitment of wheel brakes.

ACCIDENT

Aircraft Type and Registration:	Kolb Twinstar Mk III (Modified SS), G-MZZT
No & Type of Engines:	1 Rotax 582 piston engine
Year of Manufacture:	1999 (Serial no: PFA 205-12596)
Date & Time (UTC):	30 January 2022 at 1230 hrs
Location:	Plaistows Farm, St Albans
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Light Aircraft Pilot's License (LAPL)
Commander's Age:	60 years
Commander's Flying Experience:	Unknown hours (of which Unknown were on type) Last 90 days - Unknown hours Last 28 days - Unknown hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further AAIB enquiries

Synopsis

As the aircraft took off it suddenly veered to the right and climbed very slowly, narrowly missing a person, a hangar, power cables and a farm building. At approximately 100 ft agl the engine stopped, and the aircraft struck the ground. The pilot suffered back injuries and reported that he had been unable to control the aircraft due to a control restriction.

No evidence of a control restriction was found, and it is considered that flight just above the stall speed, resulting in a poor response from the flying control surfaces, was the probable cause of the control issues experienced by the pilot. The engine stopped due to overheating of the rear cylinder, but no cause could be found for this.

The general condition of the aircraft was poor, and no evidence could be provided by the pilot to confirm regular maintenance. Owners of Single Seat Deregulated (SSDR) aircraft are reminded of their legal responsibility to comply with the Air Navigation Order (ANO). The British Microlight Aircraft Association (BMAA) and Light Aircraft Association (LAA) have published guidance to assist with this.

History of the flight

The pilot had flown G-MZZT earlier in the day and reported no problems. Following the flight, the pilot stated he adjusted the pitch of the propeller to achieve an engine speed of

6,500 rpm during static ground running as this was when the engine produced maximum power.

The pilot obtained his weather from Elstree Aerodrome approximately 9 km to the south which he recorded as "calm and nice", clouds at 4,000 to 5,000 ft, visibility over 10 km and winds 4 to 8 mph from 260°. Based on this he lined up to take off from the grass Runway 30. The weather obtained from Luton Airport and RAF Northolt for the time of the accident was 190° at 6 kt.

A witness reported that, immediately after getting airborne the aircraft veered sharply to the right and did not climb. In their opinion the aircraft appeared to be flying "very close" to its stall speed. The aircraft passed low over them, narrowly missing the hangar behind them, some power cables and a farm building. The aircraft continued to fly slowly in a right-hand circuit at an altitude of no greater than 100 ft agl with a repeated small pitching-up motion until it has passed the Runway 30 threshold when the engine stopped. The witness recalled seeing the propeller stationary and then it descended steeply with a slight right-wing drop, until contacting the fallow ground between Runways 30 and 33. The pilot escaped from the aircraft unaided but complained of back pain.

The pilot reported that the aircraft would not respond to any control input and that the aircraft had a control restriction.

Aircraft information

G-MZZT was a Kolb Twinstar microlight that had been modified so that no passengers could be taken and was therefore classified as a SSDR microlight in accordance with Article 24 of the ANO. The passenger seat area had been modified to include a storage tray and the harnesses removed.

The aircraft was powered by a Rotax 582 twin cylinder, two-stroke engine which was mounted above the wing and had a maximum rated power output of 48 kW at 6,500 rpm and a maximum speed of 6,800 rpm. It was fitted with a ground adjustable three-bladed Warp Drive pusher propeller. The high wing had ailerons and flaps along the trailing edge operated by a system of rods and bell cranks. The elevators and rudder were operated by cables passing through the tubular tail boom.

Aircraft examination

The aircraft was recovered to the AAIB for detailed examination and no evidence could be found of a control restriction. The left-wing tip was damaged and there was a significant bend in the right wing at mid span. The right landing gear had detached and the front of the fuselage was disrupted. The tail boom was bent to the right and downwards by approximately 30° with slight collapsing of the aluminium tube but not enough to restrict the movement of the control cables to the tail surfaces. The control rod to the right aileron had detached due to an overload failure and the aft wing to fuselage attachment had also failed in overload from the right wing impacting the ground. The right flap control rod was still attached.

Inspection of the cockpit area revealed many loose items in the storage tray with more items scattered through the cockpit area. Items included charts, pens, plastic cable ties, a water bottle, cloths, a luggage strap and a pencil case. The storage tray was open with no lid. There was evidence of additional electrical wiring having been added, to an amateur standard, with multiple 12v power distribution sockets and provision for a radio. The electric fuel pump was bolted to a length of steel channel which in turn was secured to the airframe with plastic cable ties.

The external inspection of the engine showed no visible damage except for crushing of one of the air filters. The aft left engine mounting bolt was too short with no threads protruding through the nut. Approximately 23 litres of 50:1 two-stroke fuel/oil mix was removed from the two plastic fuel tanks behind the cockpit. The spark plugs were removed from the cylinder head and an unidentified red sealant compound was found on the threads. The colouration of the plugs was considered normal however the electrode gaps were 0.33 to 0.356 mm instead of the recommended gap of 0.5 mm.

Figure 1

Example spark plug showing unidentified red sealant

A borescope inspection of the engine was performed to inspect the cylinders. The forward cylinder exhibited normal wear however the aft cylinder bore showed evidence of overheating with heavy scoring (Figure 2). Furthermore, the piston skirt was scored with black staining, typical of overheating. The total running time for the engine was unknown as the owner did not supply the aircraft or engine logbooks to the AAIB.

The oil from the reduction gearbox was removed and contained an unidentified black contaminant. The gearbox casing was split and it was found that silicone sealant had been used in addition to the paper gasket between the casing mating faces (Figure 3 left). A significant amount of the sealant was also found at the gearbox to crankcase interface (Figure 3 right). Much of the sealant had exuded into the gearbox where it had been ground between the gears to form the black contaminant seen in the oil. The general condition of the gears was good.

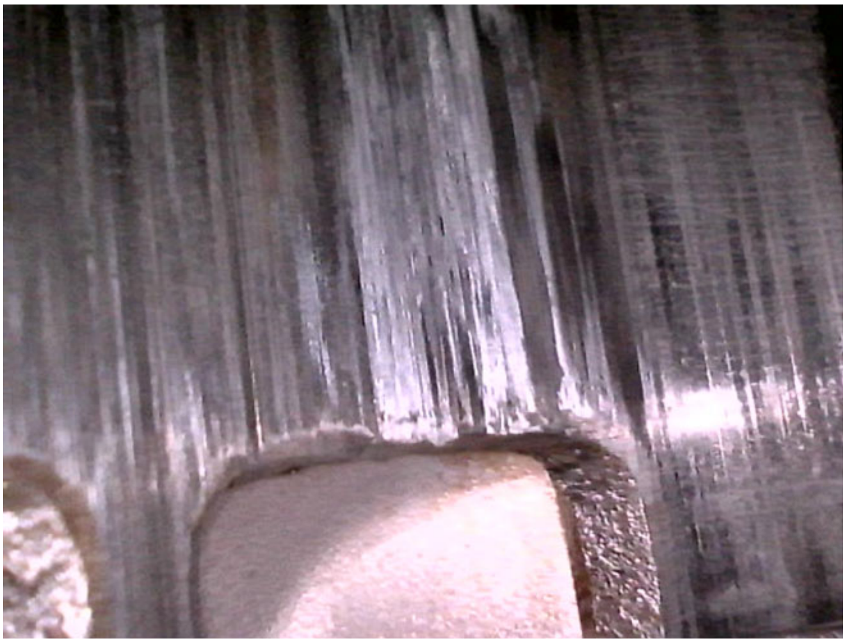


Figure 2
Aft cylinder bore scoring

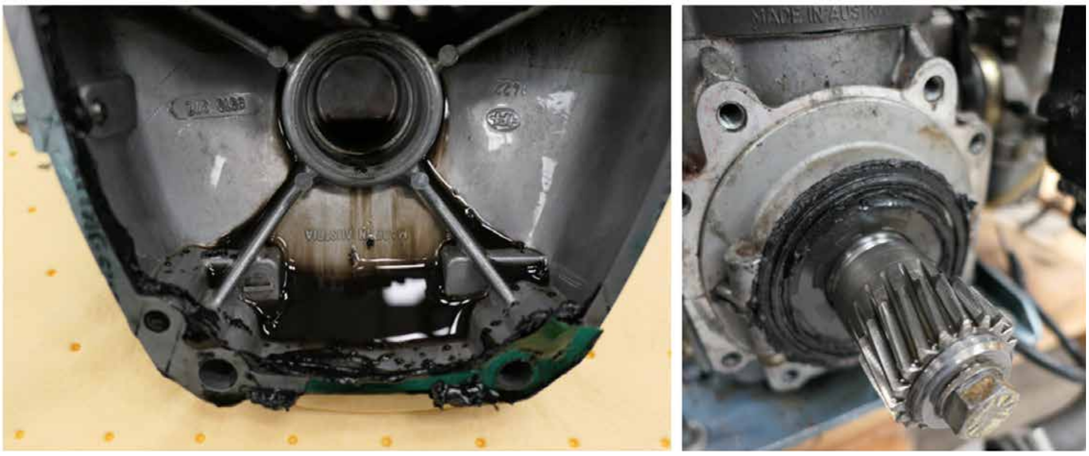


Figure 3
Left – exuded sealant inside casing
Right –sealant on crankcase interface

Prior to removal of the propeller, the pitch of the blades was measured using the Warp Drive blade setting tool. The blade pitch was found to be between 5° 20’ and 4° 50’. The condition of the blades was good, however when the propeller was removed from the gearbox hub, the threads of two of the six retaining bolts were found partially stripped (Figure 4).

Figure 4
Propeller attachment bolts

Tests and research

The engine and related systems were removed from the aircraft and a temporary test bench was made to run the engine. Aircraft components were used extensively where possible to replicate the installation. Fuel recovered from the aircraft fuel tanks was also used.

Three separate engine runs were performed. The first was in the 'as flown' condition, the second using thermal imaging cameras and the third with the propeller pitch changed to the manufacturers recommended pitch of 9° for this specific aircraft configuration.

For the first test the engine was allowed to warm up before increasing the speed to 6,500 rpm indicated on the aircraft engine tachometer. After holding 6,500 rpm for approximately three minutes the engine ran down and stopped. Subsequent attempts to restart the engine failed.

The second test was performed several days later and again the engine was allowed to warm up before the speed was increased to 6,600 rpm. This time the engine ran for over five minutes with no issues and the thermal images showed all components operating at expected temperatures.

The third test was performed with the blade pitch changed to 9° and the maximum engine speed that could be achieved was 5,500 rpm. It ran for over five minutes with no issues.

Analysis

Immediately after takeoff the aircraft veered to the right and climbed very slowly to approximately 100 ft before the engine stopped and the aircraft struck the ground. The pilot complained of a control restriction and that the aircraft did not respond to his control inputs. No evidence could be found of a control restriction to any of the control surfaces.

However it could not be ruled out that a loose item in the cockpit may have restricted the controls. An eyewitness reported that the aircraft was flying very slowly and near the stall speed. The effectiveness of the control surfaces diminishes as an aircraft's airspeed decreases and so it was considered more likely that, with the aircraft flying at low airspeed the crosswind caused the aircraft to veer to the right with little control effectiveness to counteract it.

As the aircraft crossed the Runway 30 threshold the engine stopped. There was evidence in the aft cylinder of overheating and heavy scoring of the cylinder bore which may have caused the engine to stop. It was reported that the pilot had changed the pitch of the propeller blades in an attempt to optimise the performance of the engine prior to the flight and this may have contributed to the engine stopping as it would have been operating at higher speed and temperature. The total operating hours of the engine were unknown as the pilot was unable to provide the AAIB with the aircraft or engine logbooks. Article 226 of the ANO requires that owners of SSDR aircraft must maintain logbooks documenting the maintenance history of the aircraft.

The Rotax 582 engine is not a certified engine, and the following warning is printed in the Operators Manual:

⚠ WARNING

Non-compliance can result in serious injuries or death!
This is not a certificated aircraft engine. It has not received any safety or durability testing, and conforms to no aircraft standards. It is for use in experimental, uncertificated aircraft and vehicles only in which an engine failure will not compromise safety.User assumes all risk of use, and acknowledges by his use that he knows this engine is subject to sudden stoppage.

Proper and timely maintenance will minimise the risk of sudden engine stoppage. There were multiple findings on G-MZZT where the maintenance of the aircraft appeared to be of a poor standard. Although not contributing to the accident it should be noted that, whilst there is no requirement for the aircraft to be regularly inspected for airworthiness, there is a responsibility for the owner of an SSDR aircraft to ensure their aircraft is airworthy. The BMAA[1] and the LAA[2] provide advice and guidance for owner pilots to help them maintain their aircraft but it should be noted that neither the BMAA nor the LAA are responsible for the administration or airworthiness of SSDR aircraft.

Conclusion

It was considered the most likely cause of the loss of control after takeoff was low airspeed resulting in poor flying control response and an inability to counteract the effect of the

Footnote

1 BMAA Technical Information Leaflet No.45 - Til 045 SSDR Handbook (https://www.bmaa.org/files/til_045_ssdr_handbook.pdf) [accessed August 2022]

2 LAA Technical Leaflet 2.17 - (http://www.lightaircraftassociation.co.uk/engineering/TechnicalLeaflets/Operating%20An%20Aircraft/TL%202.17%20Operating%20Deregulated%20Microlights.pdf) [accessed August 2022]

crosswind. The engine stoppage was probably caused by the aft cylinder overheating although no cause could be found for the overheating. The general condition of the aircraft was poor, and no evidence could be provided of regular maintenance and record keeping.

Owners of SSDR aircraft are reminded that although there is no requirement for regular airworthiness inspections, they are still legally responsible for ensuring their aircraft are airworthy and must comply with the ANO. The BMAA and LAA have published guidance to help owners.

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: August - September 2022

30 May 2022 **DJI Inspire II** Hinkley Point C, Somerset

The UA was hovering at a height of 80 m, while being used for filming, when control was lost and it subsequently struck the ground. The UA was extensively damaged.

18 Jun 2022 **iFlight Chimera (modified)** Denton with Wooton, Kent

The UA pitched up rapidly as it approached the limit of its geofencing, collided with a gantry and then fell to the ground. The operator has since revised its geofencing and operational procedures to prevent reoccurrence.

10 Jul 2022 **MA Sebart Evo-50** Edenbridge, Kent

The model aircraft dropped a wing and entered a spin while turning onto the base leg of an approach to the club airfield runway. The aircraft drifted and caused minor damage to a tent under a tree in a field outside the club flying zone.

18 Jul 2022 **MA AtomRC Motorised Glider** Coulsdon, Surrey

The radio controlled model aircraft stopped responding to ground commands. The aircraft's return-to-launch function failed and the aircraft flew away from the operator and struck a house, causing damage to roof tiles.

23 Jul 2022 **DJI Matrice 300** Derby

Control was lost whilst flying in a geofenced area and the UA collided with a tree. The propeller arms and propellers were damaged.

11 Aug 2022 **DJI Mavic Pro 2** Trawsfynydd, Gwynedd

The UA was being used for aerial photography when it began to climb uncontrollably. The remote pilot could still control the UA in azimuth and was able to fly it to, and maintain position over, a large clear area. When the battery ran out of power, the UA dropped to the ground.

11 Aug 2022 **MA Flylogix FX2** Peterhead, Aberdeenshire

During final approach, the model aircraft experienced a loss of power. Its wing struck a fence before contacting the ground.

16 Aug 2022 **DJI Mavic Air 2** Oxford

Whilst being utilised for filming the UA was inadvertently flown into a tree and badly damaged. Although pre-planning and authorisation of the flight was carried out, the potential hazards to the UA on the flight path had not been fully assessed by the operator.

Record-only UAS investigations reviewed: August - September 2022 cont

18 Aug 2022 **DJI Matrice M210** Plymouth, Devon

The UA was undertaking a survey in an area that had been cordoned off from the public. Either a motor or a propeller failed and it descended out of control to the ground.

3 Sep 2022 **MA FMS Olympus** Harefield, London Borough of Hillingdon

The remote pilot lost sight of his model aircraft and shut down the power. The model descended and was lost.

20 Sep 2022 **Autel Evo 2 640T** Tollerton, Nottingham

The UA was being operated at night. It struck a power cable and fell to 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).

BULLETIN ADDENDUM

AAIB File:	AAIB-28511
Aircraft Type and Registration:	Rearwin 8125 Cloudster, G-EVLE
Date & Time (UTC):	28 July 2022 at 08:49 hrs
Location:	RAF Marham, Norfolk
Information Source:	Report received from recovery organisation

AAIB Bulletin No 10, page 126 refers

Following publication additional information has become available. The full text of the report now reads:

> On touchdown in a moderate crosswind the pilot was unable to control a significant right yaw with full left rudder. When he also applied left brake the aircraft pitched over onto its back. The pilot found it challenging to apply the heel-operated disc brakes with full rudder. During recovery the brake was found seized and had probably caused the accident.

The online copy of the report was corrected on 13 October 2022.

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

1/2015 Airbus A319-131, G-EUOE
London Heathrow Airport
on 24 May 2013.

Published July 2015.

2/2015 Boeing B787-8, ET-AOP
London Heathrow Airport
on 12 July 2013.

Published August 2015.

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.

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

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