AAIB Bulletin 12/2020

TO REPORT AN ACCIDENT OR INCIDENT PLEASE CALL OUR 24 HOUR REPORTING LINE

01252 512299

Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
Aldershot
Hants GU11 2HH

Tel: 01252 510300
Fax: 01252 376999
Press enquiries: 0207 944 3118/4292
http://www.aaib.gov.uk

AAIB investigations are conducted in accordance with Annex 13 to the ICAO Convention on International Civil Aviation, EU Regulation No 996/2010 and The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 2018.

The sole objective of the investigation of an accident or incident under these Regulations is the prevention of future accidents and incidents. It is not the purpose of such an investigation to apportion blame or liability.

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

AAIB Bulletins and Reports are available on the Internet
http://www.aaib.gov.uk

This bulletin contains facts which have been determined up to the time of compilation.

Published 10 December 2020

Cover picture courtesy of Stuart Hawkins

ISSN 0309-4278

Published by the Air Accidents Investigation Branch, Department for Transport
Printed in the UK on paper containing at least 75% recycled fibre

CONTENTS

CONTENTS Cont

AAIB CORRESPONDENCE INVESTIGATIONS Cont

(ALL TIMES IN THIS BULLETIN ARE UTC)

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:	Bombardier BD-700-1A10 Global 6000, 9H-VJM
No & Type of Engines:	2 Rolls-Royce BR710A2-20 turbofan engines
Year of Manufacture:	2013 (Serial no: 9630)
Date & Time (UTC):	11 December 2019 at 0550 hrs
Location:	Liverpool Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	11,506 hours (of which 3,864 were on type) Last 90 days - 104 hours Last 28 days - 48 hours
Information Source:	AAIB Field investigation

Synopsis

The aircraft suffered a nosewheel steering failure shortly after touchdown. During the subsequent landing roll, directional control was lost due to the inadvertent application of right braking and the aircraft departed the runway surface onto the grass.

History of the flight

The aircraft was engaged in ad hoc, long haul VIP charter operations. The pilots involved were both on variable rosters, but they had been operating together since 4 December 2019. They flew to Sao Paulo, Brazil on 7 December 2019 where they spent approximately 48 hours before flying back to Newark, USA on the evening of 9 December 2019. After a rest period of 14 hours the crew reported for the incident duty at 2020 hrs. The aircraft departed Newark at 2230 hrs and made a 50 min transit, without passengers, to Bedford Airport, Massachusetts, USA. The co-pilot was under training and he was Pilot Flying (PF) for the sector to Bedford. The aircraft was serviceable, and no issues were recorded in the technical log.

In Bedford, the aircraft was refuelled, and the catering replenished for the upcoming transatlantic flight. Having embarked the one expected passenger, the aircraft departed Bedford at 0020 hrs with the co-pilot as PF and the commander as Pilot Monitoring (PM). The crew described the flight as being completely routine.

Approaching Liverpool, the aircraft was radar vectored for an ILS to Runway 27 which is 2,285 m long with a grooved asphalt surface. The crew reported that Liverpool ATC vectored them to the approach centreline quite early, but they stated that there were no difficulties with the approach. The 0520 hrs meteorological report gave a wind 190° at 9 kt, visibility greater than 10 km and a cloudbase of 3,400 ft aal. The runway surface was damp in all three sectors.

The aircraft was on the centreline of the approach at approximately 7 nm and achieved stable approach criteria by 1,000 ft aal. The approach was flown with Autopilot (AP) engaged until approximately 600 ft aal. At that point the PF deselected the AP and continued with a manually flown approach in visual conditions. The reference speed for the approach was 115 kt.

The commander described the landing as good. The touchdown was gentle, and the PF gradually lowered the nosewheel onto the runway. The autobrakes were not selected as the crew planned to brake manually, and the co-pilot recalled that the intention was to use Exit E from the runway (Figure 1). The co-pilot did not brake hard and set approximately 50% reverse thrust. In the early stages of the landing roll the crew did not recall any sense of the aircraft deviating from the centreline of the runway. It is the operator's SOP for the PM to call '80 kt' as the aircraft decelerates through that speed and for the commander to take over control of the aircraft as it decelerates below 60 kt. However, before 80 kt was reached, the commander noted the aircraft deviating to the right and took control. At 100 kt, the FDR data showed that a MASTER CAUTION was activated, associated with a NOSE STEER FAIL caution message displayed on the Engine Indicating and Crew Alert System (EICAS). While there is an audio warning associated with the appearance of a MASTER CAUTION, neither pilot recalled hearing it sound.

Once he took control, the commander instinctively applied left rudder to try and keep the aircraft on the centreline. He quickly reached full left rudder deflection[1] but could not keep the aircraft straight. At this point he recalled noticing the NOSE STEER FAIL caution on EICAS. The co-pilot recalled feeling it was likely that the commander was trying to steer into Exit E (Figure 1). The commander did not recall making any use of differential braking to correct the aircraft's path. Neither pilot recalled making any significant braking effort nor any sensation of the antiskid system operating.

Footnote

[1] The pilots stated during interview that the only time they had previously used full rudder deflection was in training for engine failures during takeoff.

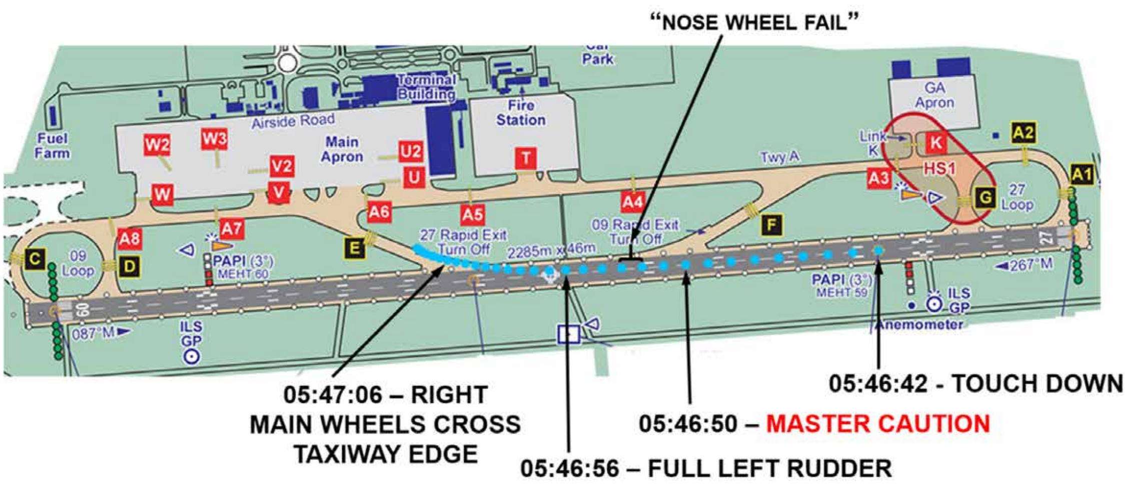

Figure 1

Liverpool Airport with the aircraft's ground track shown as blue dots (at one second intervals)

As the speed reduced, the aircraft turned more rapidly to the right and the commander was unable to keep the aircraft on the paved surface. The commander did not recall the speed at which the aircraft left the paved surface, but the co-pilot believed it was approximately 50 kt and he recalled seeing the NOSE STEER FAIL caution on the EICAS before the aircraft left the runway.

Once on the grass, the aircraft rapidly came to a halt. The crew informed ATC of their situation, started the Auxiliary Power Unit (APU), retracted the flaps and completed the aircraft shutdown checklist. The airport fire services were quickly on scene and, following a discussion with them by radio, the commander shut down the APU. During the shutdown checklist the crew noted that the brake temperatures were lower than normal. The temperature is indicated on a scale of 0 to 39 and the right outboard brake was hottest although it only indicated 2. The scale indicates red if the value exceeds 16.

Once the aircraft was shut down, the crew and passenger vacated via the forward air stairs door.

Incident site

The aircraft had left the runway just before the start of runway rapid exit turnout (Exit E) to the right. It travelled approximately 30 m on the grassed area and its landing gear wheels sank into the topsoil and brought the aircraft to a stop. Mud and soil encased the lower parts of the landing gear (Figure 2). The flaps and slats were up, and mud and soil had been thrown upwards to become entrapped within the flap track mechanisms and fairings. Mud was also present on the wing leading edges and wheel bays and there were mud spatters on the engine intake rings.

Figure 2
9H-VJM on the soft ground

The aircraft had left a pair of faint right mainwheel tyre tracks on the runway surface up to the point where it had run on to the grass. There were no discernible marks made by the left mainwheels or nosewheels.

The aircraft had been shut down and made safe; the first responders had inserted the ground lock pins. All the tyres remained inflated and there was no evidence of any fluid leakage. At the time of the incident the aircraft contained approximately 5,000 kg of fuel.

Apart from the deep wheel tracks in the grass there was no damage to any of the airport signage or fixtures.

Heavy recovery vehicles were used to recover the aircraft backwards on to the runway. The soil contamination was hosed off by the airport fire service and an initial inspection of the landing gear was carried out to ensure that it was safe, before the aircraft was towed to a secure hangar.

Recorded information

Following the event, the aircraft's flight data recorder (FDR) and cockpit voice recorder (CVR) were removed from the aircraft to be downloaded at the AAIB. A copy of the quick access recorder (QAR) data (containing the same data recorded by the FDR) for the event flight was also provided by the operator. Data for the event is plotted in Figure 3.

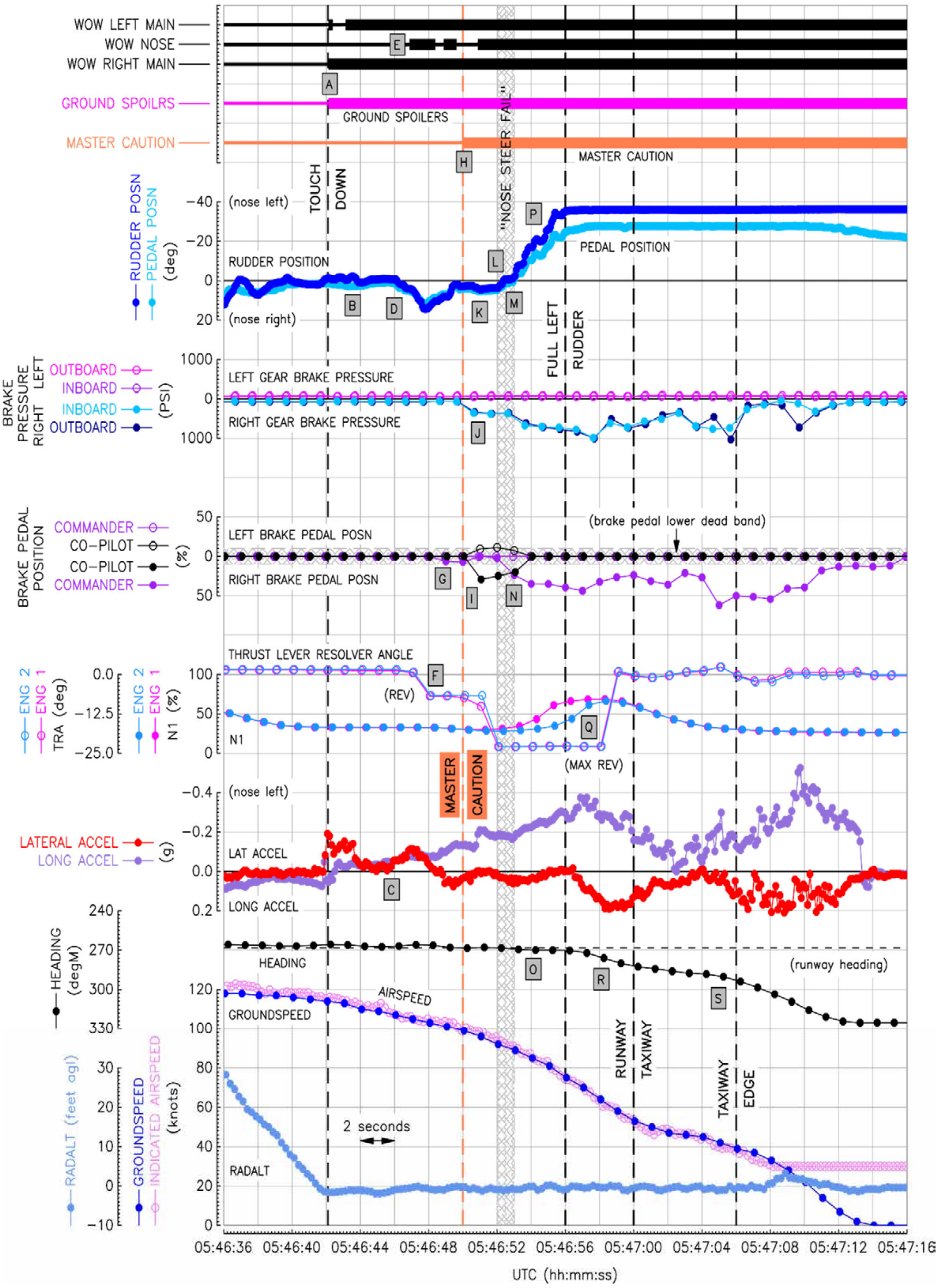

Figure 3

Recorded data for the landing

The key points from Figure 3 are:

- 0546:42 – the aircraft touched down on mainwheels [A] slightly right wing down and nose left. The airspeed was about 115 KIAS and the ground spoilers deployed.
- Small right rudder pedal inputs[2] made [B] to straighten up the aircraft (still on just the main gear).
- The aircraft started to turn left [C] – one of the crew immediately applied right rudder pedal to counter this movement [D].
- The nosewheel touched down nearly five seconds after initial ground contact of the main wheels [E].
- The thrust levers [F] were pulled back from IDLE to REV[ERSE].
- A small input on the commander's right brake pedal is recorded [G] but within the brake pedal's dead band[3] so brake pressure was not applied. The input lasted about two seconds.
- The nosewheel 'bounced' twice over a period of four seconds during which a MASTER CAUTION occurred (with corresponding illumination of the MASTER CAUTION button, and a single chime heard on the CVR recording) [H].
- The co-pilot applied a small input to the brake pedals – left travel is in the dead band and just under one quarter travel on the right [I] so only right gear brakes were applied [J]. A corresponding input on the right rudder pedal is also recorded [K].
- Two seconds after the MASTER CAUTION is issued, the commander verbally announced a "NOSE STEER FAIL" (heard on the CVR recording) [L] just as the thrust levers were pulled back to MAX REV[ERSE]. A left rudder pedal input was made [M] (co-pilot still applying right brake) with a corresponding right brake pedal input by the commander [N].
- The aircraft started to veer to the right [O] and increasing amounts of left rudder (and right brake by the commander) were applied. Maximum rudder deflection was reached after four seconds [P] and no further braking by the

Footnote

2 The rudder pedal input sensor measures the movement of the link between the pedals for commander and co-pilot and so does not discriminate between whose pedal are being depressed. The recording of rudder pedal force was not a requirement of the EASA regulations under which 9H-VJM was operating. Note that for aircraft to meet one of the requirements of the FAR Part 135.152 (flight data recorders), the aircraft manufacturer issued Service Bulletin 700−31−6002 in June 2012 (revised November 2016) to install eight force transducer units (FTU) and activate the crew force measuring system (CFMS).

3 The brake pedal movement has a dead band from 0% to10% and from 80% to100%. Between these bands, the brake pressure rises from 0 psi to 3,000 psi.

co-pilot was recorded from this point. From the CVR recording, for the middle two of these four seconds, the commander can be heard straining, halfway through which the co-pilot started to say "YOUR". As full rudder deflection was reached the co-pilot said what sounds like "YOUR STICK".

- A two-second delay is recorded between the engines each reaching the N_1 corresponding to maximum reverse thrust, with the left engine leading [Q].

- At about 70 kt groundspeed (when full left rudder was reached), the aircraft started to veer more rapidly to the right [R] onto the taxiway before veering further to the right [S] over the edge of the taxiway, which the right main gear crossed at about 40 kt, 10 seconds after full left rudder was applied.

- 0547:14 – the aircraft came to a stop 24 seconds after the MASTER CAUTION was issued; the MASTER CAUTION had remained illuminated throughout.

Aircraft information

The Bombardier Global 6000 is a twin rear-engined long range business jet with a capacity to carry up to 13 passengers. It has a maximum takeoff weight of 45,132 kg and a maximum fuel load of 20,400 kg.

Landing gear

The aircraft is fitted with a tricycle landing gear with dual wheels fitted on the nose and main landing gear assemblies. The landing gear is retracted and extended by electrically controlled hydraulic actuators and is fitted with a manual release system for emergency extension.

Nosewheel steering (NWS) system

The landing gear is fitted with a steer-by-wire electronically controlled NWS. Steering is controlled from the cockpit via the rudder pedals and a handwheel (also known as a tiller). Steering is controlled and monitored by the steering control unit (SCU).

Nosewheel articulation is provided by two cylinder and piston steering actuators mounted on the upper nose landing gear forging. They apply force to the left and right side of a steering cuff which carries the upper arm of the torque link. This imparts leverage and rotation into the lower arm of the torque link attached to the base of the nose shock absorber assembly inner piston. The actuators are sequentially controlled to prevent the actuator pistons going into over centre geometric lock when the cuff is at its full range of rotation. A linear variable differential transducer (LVDT) is fitted in each actuator to provide a nosewheel positional feedback signal.

The nose landing gear is fitted with two weight-off-wheel proximity sensors mounted to detect target plates fitted on the upper torque link arm. They are configured to sense when the aircraft is 'weight-off' and input to the landing gear electronic control unit (LGECU).

During ground handling, when the aircraft is in an unpowered condition, the upper and lower torque link arms can be disconnected by the removal of a pin to prevent damage to the actuators and hydraulic system. This allows rotation of lower shock absorber piston and nosewheel axle assembly when attached to a towing arm, whilst the cuff and actuators remain stationary.

Hand steering

The handwheel is situated on the left side of the cockpit on the pilot side console. It can provide nosewheel articulation of 75° either side of centre, this corresponds to 80° of handwheel movement between the stops which limit the movement. The handwheel is viscous damped to provide self-centring and artificial feel. This also provides a positive breakout force and a speed sensing damping force. The handwheel shaft movement drives a rotary variable differential transducer (RVDT) which converts handwheel movement to an electrical steering command input to the SCU.

A fault is recorded by the SCU if, during an air-to-ground transition, the position of the handwheel is beyond 7.5° from neutral.

Rudder steering

Movement of either set of rudder pedals actuates an RVDT attached to the top of the pivot shaft on the co-pilot's rudder assembly. Rudder pedal steering authority is 7° (+2°/-0°) either side of centre corresponding to full rudder pedal deflection.

Operation

The NWS is activated by a two position OFF/ARMED toggle switch fitted on the landing gear control panel. When selected to ARMED, it provides DC power to the SCU and a built-in test (BIT) equipment check is automatically and continuously carried out by the SCU to verify the integrity of the system.

NWS faults are indicated as NOSE STEER FAIL on the EICAS. A fault code to aid fault diagnosis and rectification can be downloaded from the SCU if required.

The following set of conditions are required for the NWS system to operate using either the rudder pedal or the steering handwheel. The nose landing gear should be down and locked, the weight-off-wheel switches should be 'open'[4] and the NWS switch set to the ARMED position. Then, providing the BIT is satisfactory, the SCU energizes a solenoid selector valve and hydraulic pressure from the gear down system is reconfigured to provide steering. When a steering input is received from the rudder pedals or handwheel and summed with the feedback signal, an electrohydraulic servo valve (EHSV) allows pressure to the actuators to rotate the nosewheels towards the required position. As this position is approached, the LVDT feedback signal is received by the SCU which then signals a cessation of movement via the servo valve. Figure 4 shows a schematic of the NWS.

Footnote

[4] The weight-off-wheels switch is described as open in this case meaning the proximity sensor target is out of the sensor range and has signalled the LGECU that the nose landing gear and wheels are on the ground supporting a proportion of the aircraft weight.

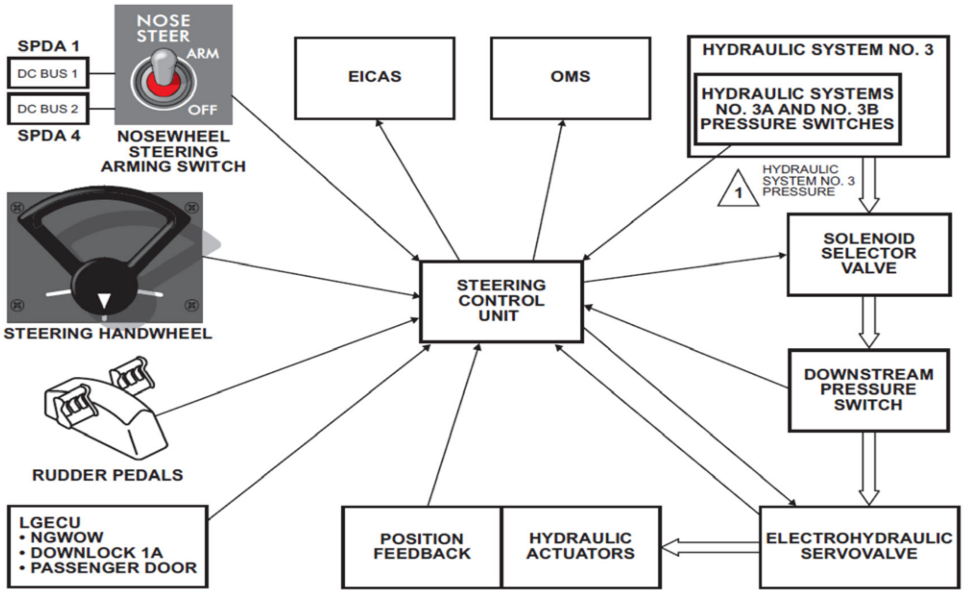

Figure 4
NWS schematic

With NWS selected OFF, or in a failure condition, the nosewheel reverts to free caster. In this condition, hydraulic pressure is blocked to the actuators, but free flow is provided between the actuator supply and return thus allowing unrestricted actuator piston extension and retraction. Nosewheel shimmy damping is provided through a hydraulic compensator that maintains pressure on both sides of the steering actuators when the steering is off.

Wheel brakes

The aircraft is fitted with a brake-by-wire system with each mainwheel fitted with a hydraulically operated carbon fibre disc brake pack. The brake hydraulic system is partitioned with the No 2 hydraulic system supplying the inboard packs and the No 3 hydraulic system supplying the outboard packs.

The integrated brake-by-wire system includes antiskid, autobrake, parking and emergency braking capabilities. There are duplex channels within the control system which normally work collectively but each channel is capable of full brake and antiskid control.

The brakes are applied when the upper part of the rudder pedal is depressed. This mechanical movement is sensed by two pedal position transducers, LVDTs, which produce an electrical signal to the brake control unit (BCU). Pedal displacement is resisted by a pair of springs designed to give feel to indicate to a pilot how hard the brakes are being applied.

The brake control system logic includes a 'dead band' of brake pedal movement within the pedal travel range. It allows 10% of brake pedal movement before any brake pressure is applied. Full maximum pressure braking is achieved at 80% of brake pedal travel, the remaining 20% of travel has no additional effect.

Hydraulic power system

The aircraft is fitted with three hydraulic systems which operate at 3,000 psi. Landing gear extension / retraction and wheel brakes are powered by the No 2 and No 3 systems. The NWS system is powered by the No 3 system from the nose landing extension circuit.

Aircraft examination

Despite departing the paved surface, examination of the aircraft found no pre-existent or resultant damage to the aircraft structure, landing gear, wheels, tyres and brakes. Although there was some evidence of mud spatter on both engine intake leading edges, the engines were undamaged.

The main landing gear's shock absorber extension was correct. The brakes' wear pins showed the brake packs were within limits; tyre wear was unremarkable and consistent with normal usage. The nose landing gear was in good condition and its shock absorber was also correctly extended; the tyres were unworn and correctly inflated.

The CVR and FDR were removed for download. The NWS SCU was removed from the aircraft and its data downloaded for analysis. The EICAS displayed a NOSE WHEEL STEER caution message which the Onboard Maintenance System details as:

> *'Steer by wire system fault 325014DWY – indicates loss of nose wheel steer nose wheel goes to free caster 11Dec2019 0545 – 1 FAULT.'*

Using external electrical power, the hydraulic systems were energised and, with the ground movement pin removed from the NLG torque link, a NWS sense and range check was carried out. During this testing the NWS system operated correctly using the handwheel and the rudder pedals. No additional faults were recorded on the EICAS or on the status display of the SCU.

The rudder and braking systems were also functionally checked. The rudder had full range of movement and operated in the correct sense. The wheel brakes also operated correctly and showed brake pressure correctly in proportion to pedal deflection with either simultaneous or differential braking.

Checks were also carried out to establish the relationship between full rudder pedal displacement and pilots' seat positions, and the potential effect on the brake pedal. This showed that, with the seat adjustment towards the forward end of its travel, there is the possibility that a pilot could inadvertently apply brake pedal movement in excess of the 10% dead band and this would result in brake pressure being applied.

Fatigue

The possibility of fatigue was investigated because the incident occurred during the early morning when the pilots may have been awake for 16 hours or longer. The fatigue investigation considered: sleep and roster history, biomathematical modelling, interviews and the cockpit voice recording.

The co-pilot's history did not suggest any fatigue risk factors. The commander's history and the results of biomathematical modelling[5] suggested the commander may have been affected by fatigue due to reduced sleep duration on the night before the incident, working in the window of circadian low and being 'out of phase' in terms of circadian rhythm and sleeping times. However, although the CVR featured some audible symptoms of fatigue and discussion of the topic during the cruise phase of the flight, from the approach briefing onwards, both pilots sounded alert and engaged. In particular, the commander could be heard actively monitoring and coaching the co-pilot under training.

Organisational information

Neither the pilots Type Rating Course nor the operators recurrent training at the time of the event contained practical experience of steering the aircraft at high speed with the NWS failed. The Flight Crew Operating Manual (FCOM) states:

> *'When the steering system is disarmed or with no WOW signal, the nosewheel steering reverts to free caster and shimmy damping to ensure stability within the nosewheel circuit. In the free caster mode of operation, steering is accomplished only through differential braking and differential thrust'.*

The NOSE STEER FAIL Quick Reference Handbook (QRH) drill (Figure 5) is exercised in the simulator during type rating training but at taxying speeds and only commanders undertake the exercise. The QRH drill has sections for both airborne and on the ground.

NOSE STEER FAIL

Condition: Loss of nose wheel steering. Nose wheel in free–caster mode.

Objective: Rearm nose wheel steering.

During Taxi:

(1) Nose wheel steering tiller ....CENTERED

When the system is re–armed, the nosewheel will immediately move to the commanded tiller position.

(2) NOSE STEER .... OFF then ARMED

– COMPLETE –

In Flight:

(3) NOSE STEER .... OFF then ARMED

(4) NOSE STEER FAIL stays on:

➡ **YES –** Go to (5)

➡ **NO –** No further action required. **End of procedure.**

(5) NOSE STEER FAIL stays on:

(6) NOSE STEER .... OFF

– COMPLETE –

Figure 5

Nose Steer Fail checklist

Footnote

5 The commander's sleep and roster history were assessed using the SAFTE-FAST biomathematical fatigue model. This model considers duration of duties, timing of duties, circadian rhythm, sleep duration and sleep inertia.

The drill is initiated following the appearance of the NOSE STEER FAIL caution on the EICAS. The QRH indicates that, with the caution present, the nosewheel is in free castor mode and the objective of the drill is to re-engage the NWS. The drill does not offer any handling advice nor is it a a memory item. Flight crews would not be expected to consult the QRH in such circumstances as this event. Should the drill fail to recover the system, it states to select the system to OFF. It is permissible to dispatch with the NWS system inoperative under the terms of the Global 6000 MEL[6] and, in such cases, the AFM (Aircraft Flight Manual) Supplement 14 contains handling advice.

Tests and research

Manufacturer's testing

The initial testing revealed no specific failure or malfunction of any individual component within the NWS. Therefore, the following components were removed and returned to the OEM for further testing:

- SCU
- Shock Strut
- Drag Brace
- Manifold Assembly
- EHSV
- LH Steering Actuator (LVDT)
- RH Steering Actuator (LVDT)
- SSV
- Handwheel (Tiller)
- Rudder RDVT

The SCU fault memory contained three specific codes that were likely to be associated with the incident landing: 170 handwheel RVDT, 015 air to ground mode command and 173 left feedback LVDT.

Of the components tested above, two items were found to have faults as indicated by the SCU:

- The handwheel did not pass the null position test but showed a small voltage when returning from 20° CCW which would have resulted in a 0.42° steering offset to the left. In addition, the SCU also detected a 7.5° handwheel offset whilst in the weight-off-wheels condition but this would not have caused the NWS to go into free caster.

Footnote

6 Dispatch with the NWS Inoperative is permitted under transport Canada and EASA Regulations. It is not permitted under FAA Regulations.

- Both steering actuator LVDTs showed insulation resistance values out of the required range. They were found to be 8 megaohm and 63 megaohm respectively when they should have been ≥ 100 megaohm. This was consistent with previous actuator LVDT faults on other aircraft of this type and is known to be caused by the ingress of moisture. It is also known that this failure mode tends to be a gradual degradation and can be intermittent. However, when either steering actuator LVDT is below limits, it is detected by the SCU BIT sequence and so causes the NWS to go to free caster. Moisture ingress has been addressed by improving the LVDT sealing on later build standard steering cylinders.

Simulator testing

The AAIB conducted an exercise in a Global 6000 simulator to examine the pilot tasks and workload in handling the aircraft on the ground following a NWS failure. The exercise was carried out with the assistance of a TRE/TRI from the operator and a CAA Flight Inspector and, before it commenced, the information in the QRH and MEL relating to the NWS was discussed.

The exercise began with normal ground operations to familiarise the AAIB Inspector with the aircraft. The NWS was then “failed” and a number of taxiing exercises carried out. While it is difficult to steer smoothly, the steering task is straightforward and intuitive. Use of pressure on both brakes against applied thrust, with steering by differential braking makes the aircraft motion smoother, although it does increase brake temperature. The exercise included turns on taxiways and 180° turns on the runway. Both the Global pilots present advised that, due to the reduced precision when steering with the NWS OFF, they would not taxi the aircraft into confined parking areas but would elect to be towed.

A series of simulated landings were carried out, initially with the NWS operational and then with it failed. This exercise was conducted with a variety of crosswinds up to 29 kt. In each event it was relatively straightforward to control the aircraft with a combination of rudder and differential braking.

The final exercise was to look at the effect of inadvertent braking. The brake pedals do not need much pressure applied to cause enough movement to result in brake pressure being applied. With full scale rudder pedal deflection applied, the articulation of the opposite foot can apply pressure on the brake pedal and, unless the pilot is conscious of this effect, it is relatively easy to inadvertently apply braking which opposes the sense of the rudder deflection.

For the final series of exercises the aircraft was accelerated to 130 kt on the ground. Then approximately half deflection brake pedal movement was applied to one side and the throttles retarded to idle. During the deceleration, only rudder was used to try and maintain aircraft direction. This was adequate at high speed but, by approximately 80 kt, full scale rudder deflection was insufficient to overcome the effect of the brake.

With the inadvertent braking still applied, the exercise was repeated with the addition of braking applied in the same direction as rudder deflection. Even with the inadvertent braking still applied, the aircraft could be readily controlled on the centreline with rudder and differential brake.

Other information

Other aircraft types produced by the manufacturer and which have similar NWS systems, specifically mention in the QRH and AFM procedures the need to use differential braking to steer in the event of NWS failure. An example of the procedure is at Figure 6.

NWS FAIL

Condition: Loss of nose wheel steering. Nose wheel in free–caster mode.

Objective: Maintain directional control.

(1) Select appropriate status:

➡ **At Normal taxi speeds –** Go to (2)

➡ **In flight –** Go to (7)

▼

Non–normal procedures CH 350 – QRH–I Vol. 2	*Gear / Brakes*

Challenger 350	*GEAR 10-7*
	Rev 16, Dec 18/2017

NWS FAIL (Cont'd)

(2) At Normal Taxi Speeds:

(3) Maintain directional control using differential braking.

(4) NWS .... OFF

(5) Thrust .... IDLE

(6) Brake to a stop.

– COMPLETE –

(7) In flight:

(8) NWS .... OFF

(9) Maintain directional control using differential braking on landing.

– COMPLETE –

Figure 6

NWS Procedure for Challenger 350

The manufacturer agreed that the disparity of information between aircraft types on differential braking was unsatisfactory and has undertaken to amend the QRH and Non-Normal Procedures of the AFM for the Global 6000 to provide direct guidance to flight crew on the use of differential braking.

Analysis

Engineering analysis

The component testing of the NWS and associated components showed that the NWS had gone into free caster, as it was designed to do when a fault is detected. It is most likely the NWS fault was caused by either or both steering actuator LVDTs having low insulation resistance values. The handwheel faults detected on test are not considered to have caused any difficulty in controlling the aircraft and would not have caused the NWS to go into free caster.

Handwheel movement is not recorded separately but did show as an offset fault in the SCU beyond 7.5° which would have occurred during one of the weight on/off/on wheels transitions of the nosewheel during touchdown. The commander did not recall operating the handwheel during the event. However, with the NWS system in free caster, any subsequent movement of the handwheel during the rollout would not have had any effect and so is not relevant to the loss of directional control that occurred during this event.

The BIT detected a fault approximately three seconds after the nosewheels initially contacted the runway. The NWS fault did not inhibit the directional control of the aircraft afforded by either the rudder or differential braking.

Operations analysis

There were some fatigue risk factors for the commander, so the investigation considered whether these influenced the course of events. Despite disruptions to sleep and circadian rhythm that are typical of long-haul pilots working at night, the speed of the commander's reaction to the aircraft's change of direction and a detailed review of the CVR, showed that he was actively engaged in the task and capable of a fast reaction. On balance, it is unlikely that fatigue was a factor in the commander's handling of the situation.

For the approach and landing the co-pilot under training was PF. The approach and landing were uneventful, and the co-pilot retained control for the initial stages of the landing roll. The NOSE STEER FAIL caution illuminated approximately eight secs after touchdown, accompanied by its audio tone, and it was acknowledged by the commander two seconds later. Shortly after this, the commander took control of the aircraft when he noticed it turning right from the runway centreline. This was unexpected, so the commander's posture on the pedals may not have been ideal and he inadvertently applied some right braking, as shown on the recorded data. He instinctively and rapidly applied full left rudder to try and control the aircraft's direction. This was briefly effective but, as the speed decayed, the rudder's effectiveness reduced, and the aircraft continued to turn right due to the effect of the right brake still being applied.

The commander was unaware that he had applied pressure on the right brake pedal. The pedal forces are very light, and it is unlikely the commander would have felt much, if any, feedback from it. His expectation was that rudder pedal movement would control the aircraft's direction. When this did not occur, the commander would have needed to recognise the inadvertent braking and either take his foot off the right brake pedal or start to use differential braking to control the aircraft. The time between the aircraft starting to veer right even though full left rudder was applied and departing the runway was approximately four seconds. He had not trained in the use of differential braking at high speed and thus its use did not immediately occur to him. Relevant training may have afforded the commander a rehearsed response that he might have been able to implement in this limited time. He reacted to the situation he was presented with based on instinct and, with all his attention on trying to keep the aircraft straight, high workload and lack of time prevented him from considering an alternative diagnosis.

Conclusion

As a result of a fault, the NWS went into free caster shortly after touchdown. During the subsequent landing roll, directional control of the aircraft was lost, and the aircraft departed the right side of the runway and onto the grass. The commander, in applying left rudder to try to keep the aircraft straight, had inadvertently applied some right braking. As the aircraft slowed, full left rudder was unable to counteract the effect of this braking.

Safety action

Following the event, the operator took the following safety actions to address the issues of inadvertent brake application and use of differential brake for steering at high speed:

It issued a Safety Alert to all its pilots which included the following:

'*we would like to recommend all pilots, at the first occasion and when on the ground at parking on board of the airplane, to apply FULL rudder deflection. At full rudder deflection one should check if both brakes can be pushed. In addition, notice that the opposite rudder pedal moves physically closer to your body, if you feel the pressure of the closer pedal increasing and if you apply any unwanted brake pressure due to the position of your shoe on the pedal, the pedals/seating position should be adjusted. This should be checked in the normal seating position with the respective shoe position adopted for takeoff and landing.*'

In its Training Syllabus for 2020 the operator has included a failure of the NWS system after landing as a preferred malfunction scenario.

The aircraft manufacturer agreed that the disparity of information on differential braking between its aircraft types was unsatisfactory and also that training for NWS failures at high speeds could be beneficial. As a consequence, the aircraft manufacturer has stated it will:

> Amend the QRH and Non-Normal Procedures of the AFM for the Global 6000 to provide direct guidance on the use of differential braking.
>
> Recommend that appropriate training providers introduce training for takeoff and landing without NWS into the Type Rating and Recurrent Training programmes.
>
> Include information in the FCOM regarding the possibility of inadvertent brake application with rudder pedal deflection and issue a bulletin to all operators to increase awareness of this issue.

Published: 19 November 2020.

All times are UTC

ACCIDENT

Aircraft Type and Registration:	Cessna 172S, G-CBXJ
No & Type of Engines:	1 Lycoming IO-360-L2A Piston engine
Year of Manufacture:	1999 (Serial no: 172S8125)
Date & Time (UTC):	25 November 2019 at 1140 hrs
Location:	Near Puffin Island, Anglesey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	79 years
Commander's Flying Experience:	More than 2,200 hours (hours on type not known)[1] Last 90 days – 4 hours Last 28 days – 1 hour
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was on a local flight when it descended into the sea, killing the pilot. No definitive cause for the accident could be found. There was no evidence of a structural failure leading to the accident and a trial to replicate the final flight profile discounted a full or partial engine failure. The trial concluded that it was likely the aircraft required an input on the controls in order to enter and maintain the recorded final descent path. The pilot had recently been unwell but there was no evidence of medical incapacitation, although this could not be dismissed as a possible cause.

History of the flight

The pilot arrived at Caernarfon Airport at about 0915 hrs on the day of the accident, having booked that morning to fly G-CBXJ with the flying club based at the airport. He planned to complete a local flight from Caernarfon out to Great Orme, a small peninsula about 24 miles along the coastline to the east, returning via Puffin Island off the north-east coast of Anglesey; a flight of about 30 minutes. The pilot checked the weather and booked out with the flying club before going out to the aircraft at about 0925 hrs. The engine, however, would not start.

Footnote

[1] The last record of the pilot's hours was a logbook completed in 2014 recording 2,200 hours total flying time. It is known the pilot had flown regularly since that time, including more recently on G-CBXJ, and flying club records were used to calculate his recent flying experience.

An engineer examined the aircraft and identified the starter motor shear pin had failed. Whilst the engineer worked on the aircraft, the pilot returned to the flying club where he talked to a number of people who described his demeanour as being normal. About an hour later the aircraft had been repaired and the pilot started the engine and taxied for takeoff, departing from Runway 07 at 1115 hrs.

Shortly after becoming airborne the pilot contacted Caernarfon Radio enquiring whether RAF Valley was open. Caernarfon Radio replied that it was and the pilot replied he was changing frequency to RAF Valley. The pilot contacted ATC at RAF Valley at 1126 hrs explaining he was on “a short trip to the Orme and back” asking for a Basic Service. RAF Valley ATC acknowledged his request.

The aircraft flew up the Menai Straits at about 1,400 ft amsl[2] and passed abeam Bangor at about 1130 hrs (Figure 1). The aircraft continued to follow the mainland coastline and climbed to 1,500 ft amsl as it turned left towards Great Orme, before turning left again towards Puffin Island.

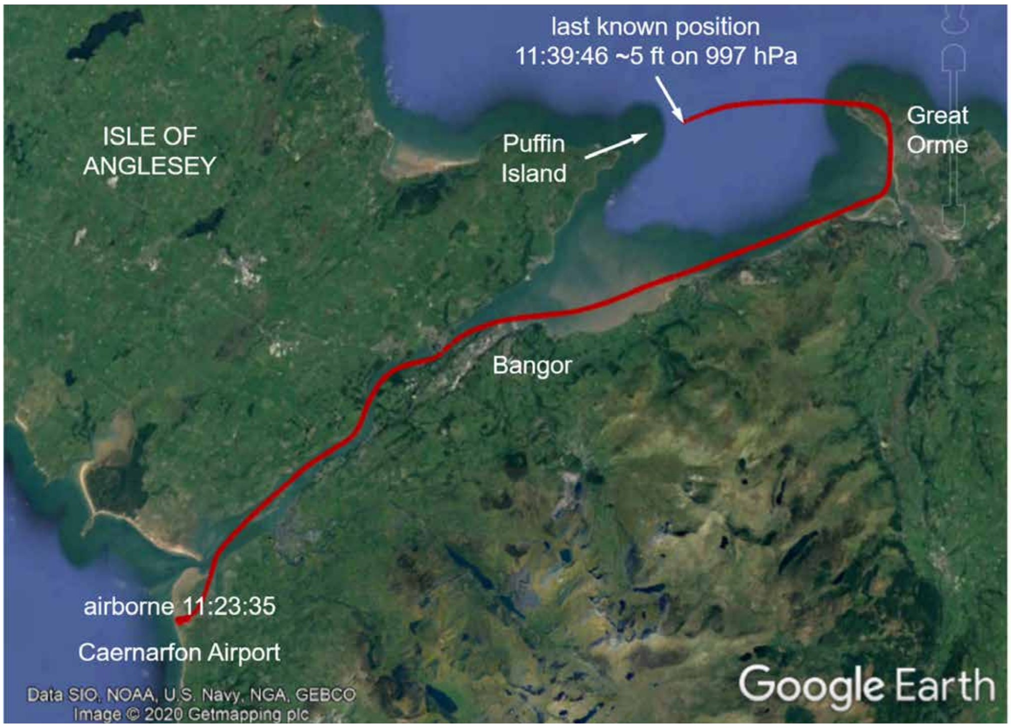

Figure 1

ADS-B[3] track of G-CBXJ

Footnote

2 Aircraft are required to transit the Menai Straits below 1,500 ft on the Holyhead QNH.

3 Automatic Dependent Surveillance—Broadcast (ADS–B) is a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it and other information, enabling it to be tracked.

Personnel at the flying club offices sometimes checked progress of flights using the Flightradar24 app[4] and at about 1205 hrs they looked to check the position of G-CBXJ, but could not see the aircraft on the live feed. They then searched the playback feature on the app which showed the aircraft apparently disappearing in the vicinity of Puffin Island. The flying club staff then asked Caernarfon Radio to put out a call to the pilot, but there was no response. Growing concerned, they phoned RAF Valley ATC which, at 1218 hrs, also tried to contact the pilot. Again, there was no reply and at 1235 hrs RAF Valley notified the Distress and Diversion Centre which initiated overdue action. A search was commenced using lifeboats and a search and rescue helicopter. Debris was found floating in an area north-west of Puffin Island later that afternoon.

Accident site

During the search for the aircraft, a lifeboat crew found the aircraft's right wing (Figure 2), part of the nose landing gear, a first aid kit and some personal effects floating in the sea approximately 3 miles north-west of Puffin Island. The wing was floating with its root up and photographs show that the leading edge had crumpled. An attempt by the lifeboat crew to recover the wing was abandoned when the wing came into contact with the lifeboat, puncturing the side. It was not found again and is thought to have later sunk. The other items were recovered back to shore.

After the immediate search and rescue attempts had been called off, a seabed search for the missing aircraft was commenced using vessels equipped with sonar. The search area was based on the last known ADS-B position, as well as calculations using the known currents and the time and position the floating wreckage was found.

The survey of the area found the wreckage of an aircraft, approximately one mile off the north-east tip of Puffin Island in about 27 m of water. The aircraft was not recovered, but video from a Remotely Operated Vehicle (ROV) subsequently confirmed the wreckage to be that of G-CBXJ.

Figure 2

Inboard end of the right wing found floating in the sea

Footnote

4 A publicly available app using ADS-B technology and other transmissions to provide flight tracking and other information on aircraft.

The strength of the current and limited visibility meant a detailed survey of the wreckage by the ROV was not possible. However, the ROV was able to take video footage of much of the aircraft. This identified that, except for the right wing and engine, the aircraft was intact. The left wing's leading edge and lower surfaces were crumpled, consistent with a high-speed impact, but the aileron was still attached. The elevators were also still attached although the position of the trim tabs could not be established. The passenger compartment was severely disrupted and the engine was found lying detached next to the main wreckage.

Recorded information

The aircraft was not detected by primary or secondary radar as it was shielded from the only radar station in range, Clee Hill 90 miles to the south-west, by the Snowdonia Mountains. The aircraft was, however, fitted with an ADS-B Out capable Mode-S transponder[5] that broadcast the aircraft's identification, position, altitude, groundspeed and other performance data, at approximately 0.5 second intervals. These ADS-B broadcasts were detected and recorded by ground stations, in line of sight of the aircraft during the flight, that form part of the Flightradar24 ground network.

Figure 3 shows the aircraft's altitude (adjusted to the Holyhead QNH of 997 hPa) and groundspeed from the ADS-B Out broadcasts. Also plotted is the calculated true airspeed assuming a 15 kt southerly wind, which shows the aircraft flying at about 100 KTAS as it transited the Menai Straits and followed the coastline to the east.

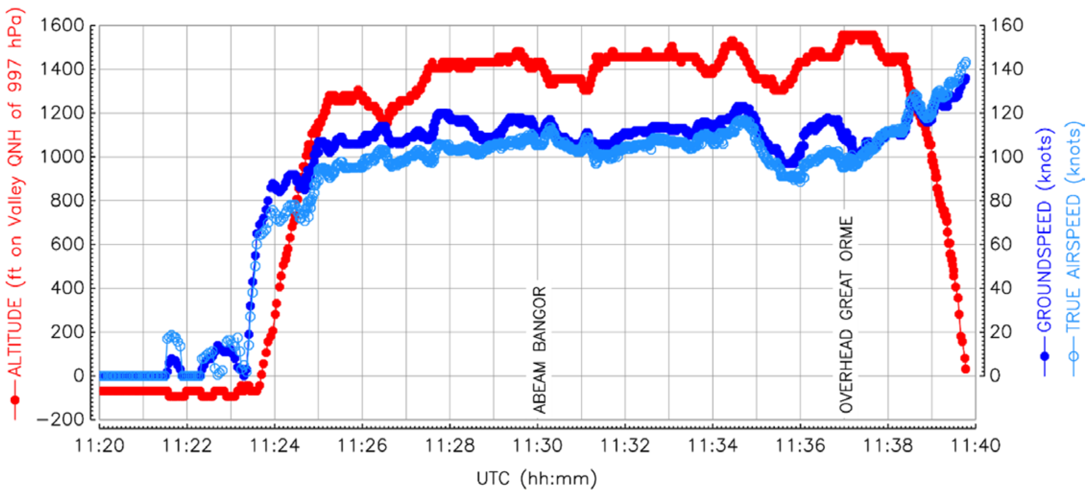

Figure 3

ADS-B data of accident flight

Figure 4 provides an expanded view of the data for the last two minutes of the flight starting as the aircraft crossed the Great Orme coastline heading toward Puffin Island. The aircraft's broadcast heading and climb rate are also plotted. This shows that after it headed west from Great Orme at 1,500 ft and 105 KIAS, the aircraft descended to 1,400 ft and accelerated to 110 KTAS before it turned left through about 7° towards Puffin Island. The

Footnote

5 A transponder capable of transmitting data by ADS-B. In contrast, ADS-B In refers to a suitably equipped aircraft being capable of receiving and interpreting the broadcasts from other aircraft.

aircraft then descended again for about 90 seconds, initially at about 1,000 ft/min, during which it briefly levelling off at 1,200 ft. The last recorded point positioned the aircraft at a height of 5 ft over the sea on the Valley QNH of 997 hPa[6]. The descent profile shows the aircraft's rate of descent steadily increased, but fluctuated, reaching a peak of 1,700 ft/min, with a corresponding airspeed of about 140 KTAS. The data also shows that the aircraft turned slightly to the right by about 20° as it descended through 600 ft onto a final heading of about 245°M.

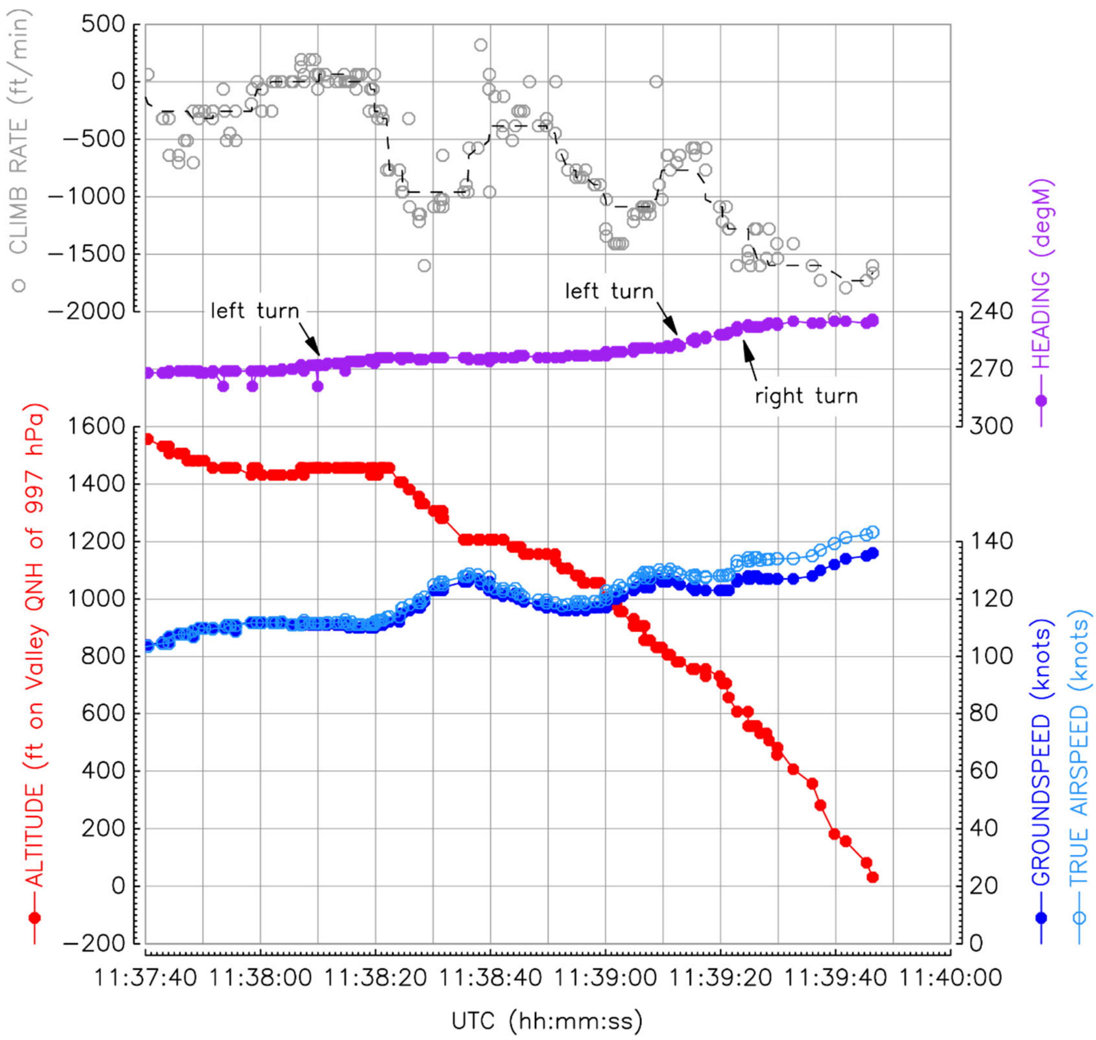

Figure 4

ADS-B data of the aircraft's descent from Great Orme coastline

Footnote

6 ADS-B recorded an altitude for G-CBXJ on the ground at Caernarfon Airport prior to takeoff of -70 ft, when adjusted for the Valley QNH of 997 hPa. Caernarfon Airport has an elevation of 14 ft, giving a difference between actual altitude and recorded altitude of 84 ft. Therefore, the last recorded altitude during the flight could be as much as 89 ft amsl.

Aircraft information

The Cessna 172S[7] is a high-wing, four seat light aircraft powered by a Lycoming IO-360-L2A piston engine. It has a fixed tricycle landing gear and a two-bladed, fixed pitch propeller.

G-CBXJ had been maintained by an approved maintenance organisation in accordance with the manufacturer's service plan. The aircraft had recently undergone a 50-hour interval inspection, during which the directional indicator was replaced. The annual inspection and airworthiness review had taken place on 21 March 2019 and the aircraft had since completed 139 flying hours, having accumulated 6,072 flying hours from new at the time of the accident.

The aircraft was fitted with a manual pitch trim system and a single axis autopilot, although the autopilot was unserviceable at the time of the accident flight; the relevant circuit breaker having been pulled and appropriately placarded. There were no other known defects.

Pilot's background

The pilot had held a private pilot's licence since 1977 and had gained an instrument rating in 1983. He had renewed his instrument rating and completed a proficiency check on 17 August 2019. The pilot had previously owned his own aircraft for several years before selling it, after which he had flown regularly from Caernarfon in G-CBXJ. The route the pilot stated he was to fly was one he was known to have flown many times before.

Medical

The pilot held a valid EASA Class 2 medical certificate with a limitation requiring correction for defective near and distant vision. He had previously suffered from migraine but had not suffered an attack for over ten years. Medical opinion considered the circumstances did not support an incapacitating or distracting return of migraine, or a related condition called Transient Global Amnesia, as aircraft control and communications would likely to be wholly or partially preserved.

In the week prior to the accident, the pilot had complained of being unwell with a cough and cold for which he had self-medicated and spent 48 hours in bed. He had, however, recovered sufficiently two days before the accident to go out with a family member to watch a rugby match. During the car journey to the match, for which the pilot was a passenger in the car, he had complained of feeling 'strange' when the car had accelerated suddenly at one point during the journey. His family, however, thought he had recovered from his illness by the time he went flying and similarly found nothing unusual in his demeanour.

When the aircraft was located on the seabed, the pilot was found occupying the front left seat, secured by the seat harness. His body was recovered and a post-mortem examination and toxicology tests were carried out. Neither found any evidence of any medical condition which may have caused the pilot to become incapacitated during the flight.

Footnote

7 Also known by its popular name, the Cessna 172 Skyhawk.

Weight and balance

The calculated takeoff weight for the aircraft using available weights for the aircraft, fuel and pilot, was about 2,072 lb, which was within the maximum permitted takeoff weight of 2,550 lb.

Similarly, the CG for the aircraft was calculated to be 39.8 inches aft of datum, this being within the permitted range of 36.4 – 47.3 inches aft.

Meteorology

Both Caernarfon and RAF Valley airfields were reporting generally good weather conditions at the time of the accident with visibility in excess of 10 km and a wind of between 7-11 kt from the south-east. There was broken cloud in the area with a base of 1,600-2,000 ft and showers to the south of Caernarfon, although these did not affect the route flown by the pilot prior to the accident. The temperature at Caernarfon was 12°C with a dew point of 10°C and a QNH for the area of 997 hPa.

Fuel

The aircraft was last refuelled on 17 November 2019 and had since completed three flights without incident. Flying school documents record there were 110 litres of fuel on board at the time it departed; sufficient for about 2 hours 15 minutes of flight.

Tests and research

Radio 'blind spots'

The aircraft operator carried out radio tests shortly after the accident to ensure that there were no radio 'blind spots' along the route flown which may have prevented any radio calls by the pilot being heard by RAF Valley ATC. No such 'blind spots' were found with the test radio transmissions all being heard.

Cessna 172S handling characteristics

As part of the investigation, a flight trial was carried out in another Cessna 172S to assess the likely handling qualities and performance of G-CBXJ and the inputs required to create its final descent profile. The flight was conducted with a similar takeoff weight and CG to G-CBXJ[8] by a qualified test pilot, using standard EASA CS-23[9] test techniques. The assessment specifically looked at the following:

1. *Descent from trimmed cruise* - to establish the force required on the control column (yoke) to make the aircraft descend at 1,000 and 2,000 ft/min from trimmed cruise;

Footnote

[8] The takeoff weight of the test aircraft was 2,300 lbs (estimate for G-CBXJ was 2,072 lbs) and the CG was 41.43 inches aft (estimate for G-CBXJ was 39.8 inches aft). The CG position of the test aircraft would have resulted in a negligible reduction in longitudinal stability over that of G-CBXJ.

[9] CS-23 is the EASA certification specification for normal, utility, aerobatic, and commuter category aeroplanes.

2. *Trimmed descent from cruise* - to establish the change of trim required from the cruise to a descent of 1,000 ft/min;

3. *Longitudinal stability long-period oscillation (phugoid)* - to establish the phugoid damping characteristics when the aircraft controls were released from an out-of-trim condition, and

4. *Lateral stability (lateral, directional and spiral)* - to establish the aircraft's weather-cock stability and response in the cruise when no inputs were made to the controls.

Handling test results

1. Descent from trimmed cruise

The aircraft was set up in the cruise with the engine at 2,500 rpm[10] in straight and level flight giving a speed of 110 KIAS. When trimmed, the trim wheel pointer was adjacent to the base of the letter 'A' in the vertically aligned words 'TAKE OFF' on the trim wheel indications. The aircraft was then put into a gentle dive by pushing the stick forward and a steady state 1,000 ft/min descent was established. A hand-held force gauge was used to measure force required to hold the control column in the required position.

In the descent, the engine rpm increased to 2,650 rpm and the airspeed to 135 KIAS, and a small push of about 2 kilogrammes force (kgf) was required to maintain the dive (this could be easily achieved by pushing on the yoke with a single thumb). When the descent was steepened to achieve 2,000 ft/min, the engine rpm increased further and the throttle had to be closed slightly to maintain 2,700 rpm, and the required push force increased to about 3.5 kgf.

2. Trimmed descent from cruise

When in the 1,000 ft/min descent, the 2 kgf force on the yoke could be trimmed out by moving the trim wheel (in a nose-down sense) so that the pointer moved from the base of the 'A' to midway through the 'A'. This corresponded to about 2 mm movement in the trim tab on the right-hand elevator trailing edge.

3. The longitudinal stability long-period oscillation (phugoid)

When the un-trimmed 2 kgf described above was released the aircraft's longitudinal stability caused the aircraft to pitch up and slow down. This pitch up excited the phugoid. The oscillation was allowed to continue for two full cycles and observed to be heavily damped with a period of 35-40 seconds (which is typical of this type of stable training aircraft).

Footnote

[10] The aircraft flight manual states a normal engine operating range (green arc) of 2,100-2,500 rpm and a maximum engine speed of 2,700 rpm.

Figure 5 plots the recorded data from the test aircraft for the phugoid. It shows that the vertical speed peaked at ±2,500 ft/min during the first oscillation with a corresponding change in altitude of ±300 ft. The airspeed varied ±25 KIAS and engine speed by about ±1,500 rpm.

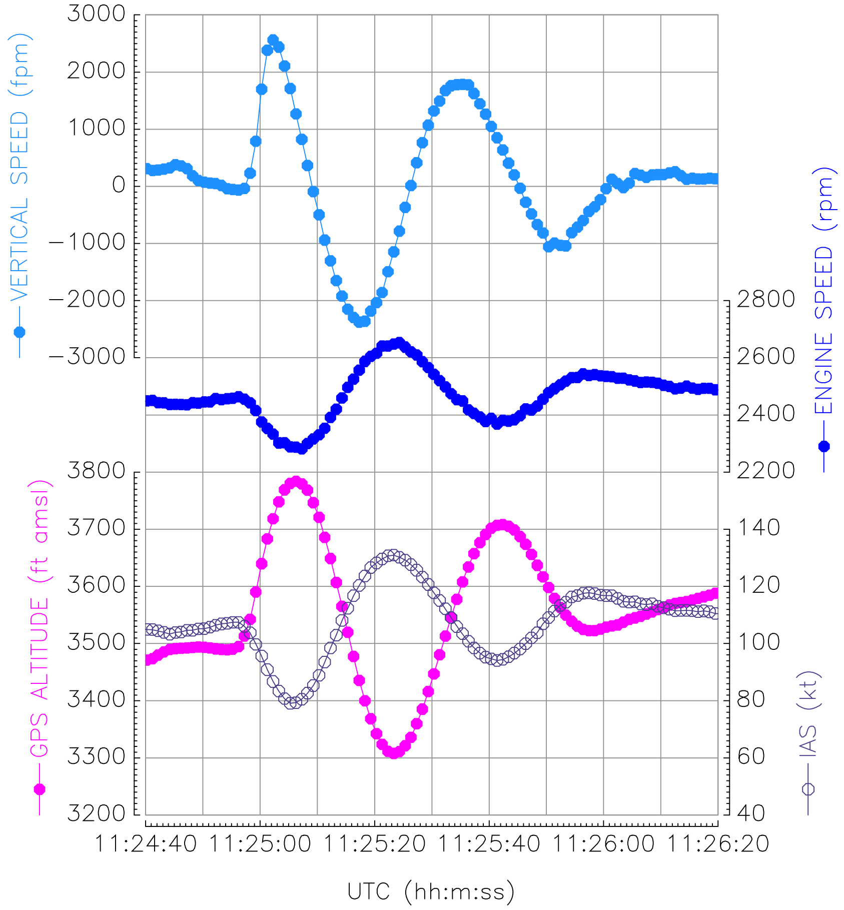

Figure 5

Test aircraft phugoid characteristics

4. The aircraft's lateral stability (lateral, directional and spiral):

Aileron only turns were flown in which the slip ball remained centred, indicating strong lateral stability (due to the wing dihedral). Equally, after initiating a rudder only turn, the aircraft rolled away from this sideslip condition, indicating strong directional (weather cock) stability.

When the aircraft was flown in the cruise stick free (hands off), the aircraft was reluctant to depart from wings-level flight. When encouraged by a small (2 cm) right rudder pedal input to simulate an out-of-trim condition or some turbulence, the aircraft began to roll slowly to the right. As the roll amplitude increased, the nose dropped and the airspeed progressively increased, resulting in a spiral dive within 10 to 15 seconds.

The results of the tests were supported by information provided by the aircraft manufacturer. This confirmed that the Cessna 172S is a stable aircraft design, but that the aircraft would tend to bank slightly to the right from straight and level flight if the controls were to be released. Should this occur then the aircraft would also start to descend and enter a spiral dive.

The manufacturer also reported that should the elevator have become disconnected, the CG would have caused the aircraft to enter a descent, but at a faster rate than that recorded.

Analysis

The review of the aircraft's maintenance records did not reveal any significant issues. The work carried out during the recent service and the repair to the starter motor just prior to the flight are unlikely to have resulted in any problems leading to a loss of power or inability to control the aircraft.

The flight trial also determined that the parameters required to recreate the final flight profile for the accident flight were consistent with the power being at a normal cruise power setting just prior to descent. The setting remaining unaltered for the subsequent descent, allowing the aircraft to accelerate and the rpm to increase due to the accelerating airflow through the propeller. This also indicates that the descent was not caused by a full or partial engine failure.

Whilst the right wing was found detached from the aircraft, the similar damage to both wing leading edges indicate that the aircraft was intact at the time it struck the water. The nature of the crumpling and buckling is consistent with the aircraft striking the water at high speed, with sufficient force to cause the right wing to detach. The separation of the nose landing gear from the airframe indicates that it was subject to significant force and it is considered the aircraft was pitched nose down with the wings approximately level when it hit the water.

Although the entire airframe could not be examined in detail by the ROV, from the available video it appeared that all the control surfaces were still attached. It would have been highly unlikely that the linkage to any of them would have become detached in flight. Had this happened it is expected the final flight path would have showed the aircraft maintaining a less stable flight path during its final descent.

The post-mortem and toxicology tests did not reveal any indication that the pilot had become incapacitated, although it is still possible that this had occurred. The pilot had been unwell in the days before the flight and his complaint of feeling uncomfortable when the car he had been travelling in had accelerated was unusual. His family had however considered he was well again at the time he went flying and saw nothing unusual in his behaviour.

Had the pilot become incapacitated during the flight it is likely he would have released the controls. The flight test demonstrated that the aircraft should then have entered a spiral dive rather than the near constant track descent seen on the ADS-B data.

Of note, it is probable that had a technical problem occurred, or the pilot suffered some kind of incapacitation such as a sudden migraine attack, the pilot would have attempted to notify ATC by radio.

Finally, the flight trial demonstrated that the aircraft's longitudinal stability resulted in a tendency to pitch up with increasing airspeed, requiring a small push force on the controls to achieve and maintain the descent as the aircraft accelerated. If the force was not held, the trim wheel would have had to be rotated slightly to increase the selected nose-down trim. The peak vertical speeds of ±2,500 ft/min of the phugoid during the trial flight varied only by ±250 ft/min from those seen during the accident flight descent, indicating that any phugoid motion would have been supressed by the pilot, either voluntarily or involuntarily. In assessing these results the test pilot concluded: "It is difficult to imagine a scenario where the trim could have been adjusted accidently or such a constant push force applied to the control column for 90 seconds or so without some deliberate action", and that "a lack of attention or pilot incapacitation would be very unlikely to lead to a wings level constant heading dive but would almost certainly lead to a spiral dive".

Conclusion

It has not been possible to identify a definitive cause of the accident. Whilst only a remote visual examination of the aircraft was possible, there was no indication of structural failure and the flight trial conducted indicated an engine failure had not occurred. The stability of the aircraft and evidence from the flight trial points to the need for an input on the controls, if only slight, to both enter and maintain a descent along a nearly constant track, as well as turning the aircraft left and then right towards the end of the descent. There was no evidence of medical incapacitation of the pilot, however, his recent illness and the fact that causes of incapacitation are not always evident means that this cannot be excluded.

Published: 29 October 2020.

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:	Boeing 737-86N, G-DRTN
No & Type of Engines:	2 CFM CFM56-7B26 turbofan engines
Year of Manufacture:	2002 (Serial no: 32735)
Date & Time (UTC):	9 February 2020 at 1122 hrs
Location:	East Midlands Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers -193
Injuries:	Crew - None Passengers - None
Nature of Damage:	No 4 brake unit and wheel deformed due to brake heating
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	45 years
Commander's Flying Experience:	12,300 hours (of which 893 were on type) Last 90 days – 75 hours Last 28 days – 13 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

In very gusty conditions, the aircraft experienced a significant loss of airspeed due to windshear as it approached V_1 on takeoff. The strong crosswind led to a loss of directional control so the takeoff was rejected after reaching V_1. The aircraft stopped about 600 m from the end of the runway. The No 4 wheel and brake unit suffered heat damage from the high temperatures caused by full brake application during the rejected takeoff.

History of the flight

On the day of the event the weather at East Midlands Airport (EMA) was experiencing strong, gusty winds and squalls, resulting from Storm Ciara. The forecast indicated a wind of 200º at 32 kt with gusts to 45 kt. The crew arrived early for the briefing and the pilots discussed the weather situation at some length. The commander's initial decision was that he would conduct the takeoff from EMA due to the severe weather. The runway surface was wet, and the aircraft was therefore limited to a 25 kt crosswind component for departure. The co-pilot, during their discussions, informed the commander that as a Senior First Officer (SFO) he was permitted by the operator to use the same weather limits as the commander.

In addition to the weather considerations for the aircraft, the airport had stopped using high lift vehicles, which transport Persons of Reduced Mobility (PRM) and catering to the aircraft. The commander anticipated that there would be many difficulties that would consume his attention in the lead up to departure and these were also discussed at the brief. On reflection, he decided that the co-pilot would prepare for and conduct the takeoff, allowing him to focus on the other matters.

Once at the aircraft the commander conducted the walkaround checks while the co-pilot prepared the cockpit for takeoff. As expected, the commander spent a considerable amount of time dealing with the airport ground staff and the operator's HQ as he tried to resolve several issues related to the strong winds.

During the cockpit brief the crew refreshed the actions for the Windshear Escape Manoeuvre and a Rejected Takeoff (RTO). The calculated performance figures for the departure were V_1 134 kt, V_R 149 kt, V_{RMAX}[1] 158 kt and V_2 156 kt. Actions in the event of windshear at various stages of the takeoff were discussed along with the implications of windshear performance calculations. The aircraft had fuel loaded in excess of the planned requirement, so the crew decided to start and taxi to the departure end of the runway to await a suitable weather opportunity for takeoff. They had seen similar aircraft from other operators departing. The wind direction was relatively steady, and the pilots had calculated the maximum wind speed and direction that would give a crosswind component of 25 kt, which was 210º at 29 kt. They passed this figure to ATC.

As the aircraft approached the A1 holding point for Runway 27, the pilots were cleared for takeoff and were passed a wind of 220º at 32 kt. The pilots confirmed that this was in limit by referring to their Electronic Flight Bag (EFB). The aircraft lined up on the runway without stopping and takeoff thrust was selected.

At approximately 120 kt, the commander recalled a transitory reduction in airspeed of between 10 and 15 kt. He called this to the co-pilot but, as the acceleration resumed, decided to continue. The commander stated that approaching V_1 (134 kt) the aircraft deviated dramatically from the centreline to the right. He estimated the deviation was between 20° and 30° of heading. The commander saw a large downtrend on his airspeed indication and felt that the co-pilot's attempts to control the heading were ineffective. He stated to the investigation, "as PM, my instant snapshot was that indicated airspeed was reducing and we were below V_1, so I called Stop." During this sequence of events both pilots recalled hearing the automated V_1 callout. The commander took control in accordance with Standard Operating Procedures (SOP), the RTO actions were carried out and the aircraft stopped on the runway centreline between M and H taxiways (Figure 1), with approximately 600 m remaining.

Once the aircraft stopped, the commander made a public address announcement to alert the cabin crew, and the pilots had a brief discussion regarding subsequent actions. They decided that they were able to vacate the runway and informed ATC of that decision, while also suggesting a runway inspection because the commander was concerned the aircraft may have struck runway edge lights. ATC did not deploy the airport fire service and the pilots did not ask for such assistance. The pilots decided to return to stand and were

Footnote

[1] See later section *Aircraft performance* for an explanation of V_{RMAX}.

cleared by ATC to do so. After the RTO, the commander was concerned about the co-pilot, who appeared to be preoccupied about what had happened during the takeoff. During the taxi in the commander believed that at least one brake was "binding" and that greater than normal thrust was required to taxi.

On the stand the aircraft was shut down as normal with the exception that, as soon as a tug and towbar were connected, the commander released the parking brake. He liaised with the cabin crew, company operations and the duty Pilot Base Manager, and the decision was taken to disembark the passengers because company engineering advised it would require a wait of one hour before they could commence work on the wheels. An engineering investigation revealed damage to the No 4 wheel and brake unit. The damaged brake unit was replaced, as were all wheels and tyres in accordance with the operator's maintenance manual.

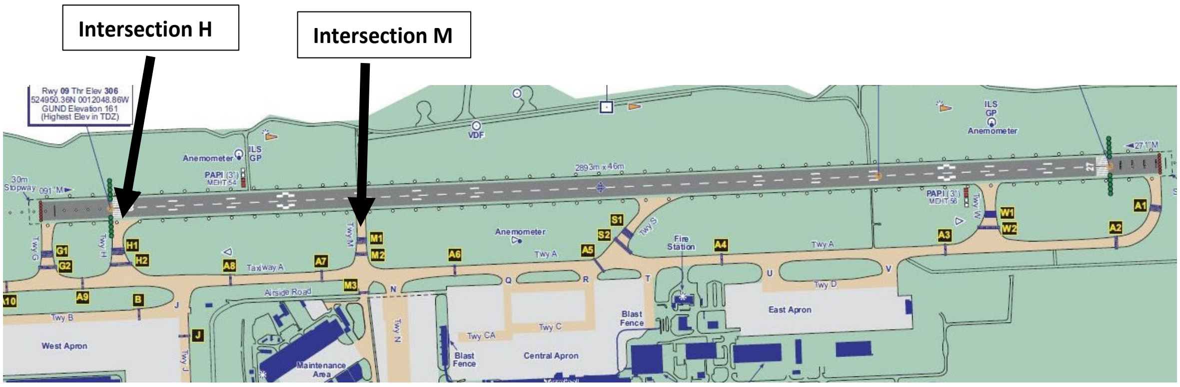

Figure 1

East Midlands Airport Diagram

Recorded information

No FDR or CVR information was recovered for the event, but the Quick Access Recorder (QAR) recorded information which was available to the investigation through the operator's Flight Data Monitoring (FDM) system. An extract of the data is at Figure 2.

A brief reduction in airspeed before V_1, as described by the commander, is shown in the trace. The indicated airspeed reduced briefly from 131 kt to 118 kt before recovering. V_1 and the initiation of the V_1 auto callout are highlighted by the second dashed line on the chart. Almost immediately after this point there was a reduction in airspeed from 142 kt to 129 kt over approximately 1.5 seconds and the aircraft heading changed to the right. There was a significant left pedal input and, between five and six seconds after V_1, both brake pressures increased to 3,000 psi indicating autobrake RTO action. This is indicated by the third dashed line in Figure 2. The autobrake RTO mode is triggered by retardation of the thrust levers to idle. The RTO was initiated at an airspeed of approximately 149 kt but, because no CVR information was recovered, it was not possible to ascertain when the commander called "Stop" in this sequence of events.

Between V_1 and the start of the RTO the aircraft turned right by approximately 8°. Once the RTO was initiated, the aircraft responded to the left pedal input and turned rapidly left through approximately 14° before recovering to the centreline of the runway. Around the start of the RTO there were substantial changes in lateral g commensurate with the rapid changes in heading.

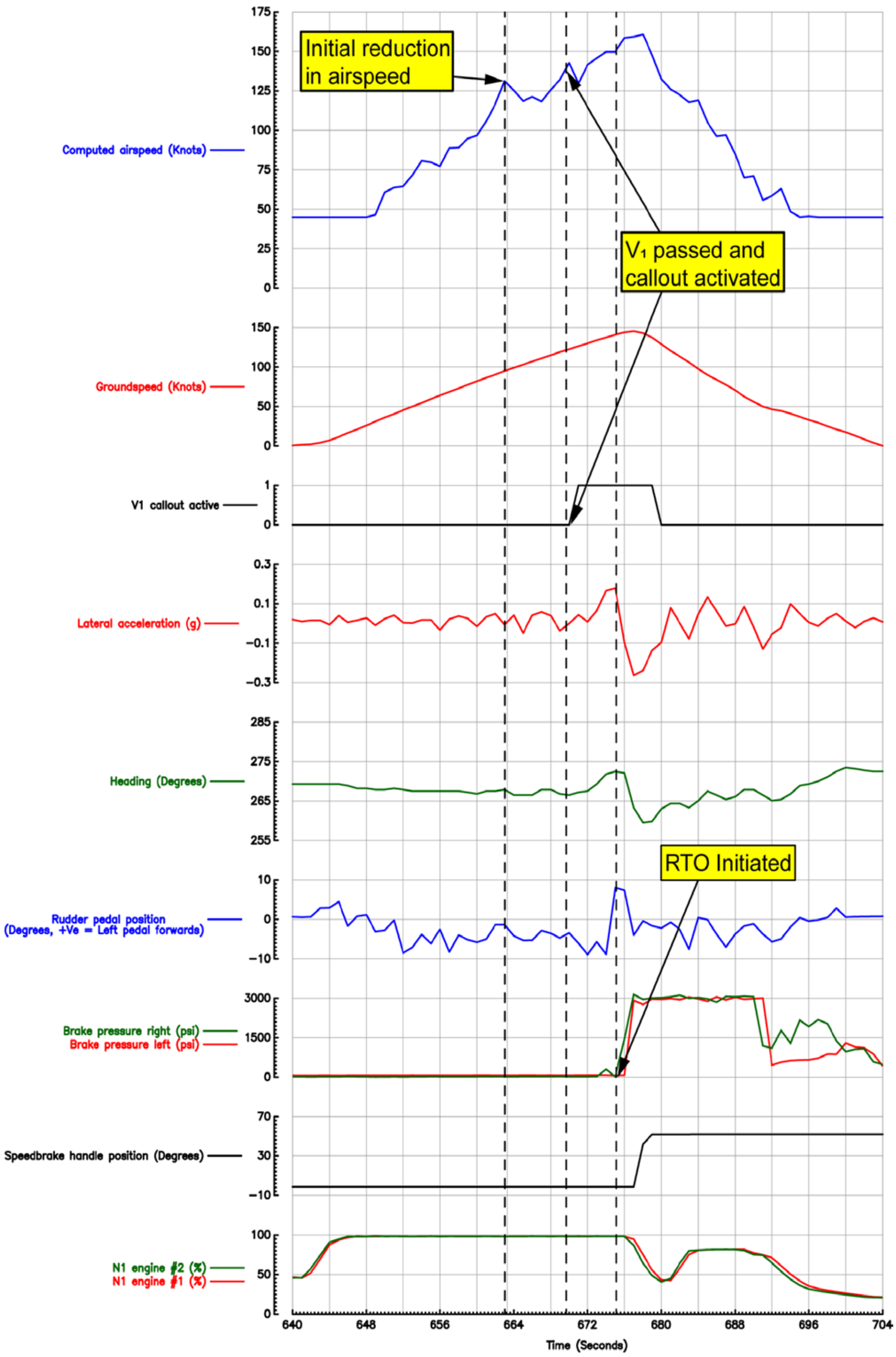

Figure 2

Flight Data Monitoring Extract

Commander's workload issues

The restrictions on the high lift vehicles meant that the aircraft galley carts could not be loaded. The planned sector to Tenerife was long and the commander was trying to ensure there would be as much customer service as possible. He reported that dealing with these ground handling issues was time consuming and was a factor in his decision to allow the co-pilot to operate.

Aircraft performance

The pilot's briefing covered the crosswind limitations for the takeoff, the prospect of windshear and the use of windshear performance calculations from the operator's EFB.

The windshear calculation for takeoff uses full thrust and, in addition to the usual calculated speeds of V_1, V_R and V_2, it also generates a V_{RMAX}. This is defined as the lowest of: the rotate speed for the maximum allowable weight for the runway and weather conditions; and the rotate speed for the actual weight plus 20 kt. The operator's Company Operating Procedures give the following advice for use of V_{RMAX}:

> *'When using Maximum Vr*
>
> - *Set calculated V speeds for the 'Windshear' solution.*
> - *Call 'rotate' at the V_{RMAX} speed.*
> - *Clearly brief and agree the call that will be made by PM.*
> - *If windshear is encountered at or beyond the actual gross weight Vr, rotate immediately, do not accelerate to V_{RMAX} speed but rotate without hesitation.'*

Meteorology

The airfield was affected by Storm Ciara and so the wind conditions were severe, with strong gusts. Actual weather reports from EMA are below:

09 Feb 2020 11:20	21037G48KT 9999 -RA BKN016 12/10 Q0980
09 Feb 2020 10:50	21040G56KT 9000 -RA BKN016 13/10 Q0981

Personnel

The commander had 12,300 hours total flying time of which 890 hours were on the Boeing 737 (B737). He began flying with the operator in March 2019 and had flown six departures from EMA in B737 aircraft. The co-pilot had 3,200 hours total time, of which 2,500 hours were on type, and had been with the operator for several years. He had been promoted to SFO in April 2019. The pilots had not met prior to this event.

Organisational information

The operator's Operations Manual advice on crosswind limits is shown in Figure 3.

Maximum Crosswind Components

General

The quoted crosswind limits are based on steady wind (no gust) conditions and include all engines operating. These are Company limits based on demonstrated information and Boeing guidelines. Gust effects were evaluated and tend to increase pilot workload without significantly affecting the stated limits.

The crosswind limits are valid for runway widths of 30 m and greater.

In operations approaching the crosswind limits the Captain must take account of experience on type, experience of airfield characteristics, wind/gust behaviour, runway width and runway surface conditions when establishing whether to commence an approach or which crew member should operate as Pilot Flying.

Second or First Officers (when not flying with a Training Captain) are limited to:

Second and First Officer Crosswind Limit	Dry Runway	Wet Runway
	20 Knots	15 Knots

Take Off Limits

Runway Surface Category	DS Runway Surface Condition	Crosswind Limit (kts) Non-winglet/Winglet
Dry	Dry	36/33
Wet	Wet	25

Figure 3

Operator's Crosswind Guidance

The runway at EMA is 45 m so these limits were valid for the airfield. To upgrade to SFO, co-pilots required in excess of 2,000 hours and six months of service with the operator post completion of training and to be assessed as suitable by the operator's training department. The operator stated that the intention of allowing SFOs to operate to the same limits as commanders is to give them relevant operational experience in challenging conditions before upgrading to command.

Quick Reference Handbook (QRH)

Rejected Takeoff

The aircraft manufacturer lists within the QRH the events for which a pilot should consider rejecting the takeoff. The list provides clear guidance to crews to assist them making what may have to be a very rapid assessment of an event during the takeoff roll. The takeoff is divided into low and high speed regimes for the purposes of the RTO, with the high speed regime defined as above 80 kt. The manufacturer states that, above 80 kt, a takeoff should be rejected only for:

- *fire or fire warning*
- *engine failure*
- *predictive windshear warning*
- *if the airplane is unsafe or unable to fly.*

Windshear information

Windshear is a large change in wind speed or direction over a relatively small distance (where the distance can be vertical or horizontal) and is considered a serious threat.

G-DRTN is fitted with a predictive windshear detection system, which is active whenever the aircraft is below 2,300 ft agl. The system can generate warnings and cautions which are displayed to the pilots and trigger an aural alert in the flight deck. Predictive windshear warnings are enabled during the takeoff until the aircraft reaches 100 kt, when they are disabled until the aircraft reaches 50 ft agl. Cautions are enabled from 0 kt to 80 kt, at which point they are inhibited until the aircraft reaches 400 ft agl. The crew did not receive a predictive windshear warning or caution during the takeoff at EMA.

G-DRTN is also fitted with a reactive windshear system, which only becomes active when the aircraft rotates to lift off.

The Non-Normal Manoeuvres section of the B737-800 QRH contains the following guidance for pilots who encounter windshear during the takeoff roll:

> *'If windshear is encountered before V_1, there may not be sufficient runway remaining to stop if an RTO is initiated at V_1. At V_R, rotate at a normal rate toward a 15 degree pitch attitude. Once airborne, perform the Windshear Escape Maneuver. If windshear is encountered near the normal rotation speed and airspeed suddenly decreases, there may not be sufficient runway left to accelerate back to normal takeoff speed. If there is insufficient runway left to stop, initiate a normal rotation at least 2,000 feet before the end of the runway, even if airspeed is low. Higher than normal attitudes may be needed to lift off in the remaining runway. Ensure maximum thrust is set.'*

The manufacturer was asked for comment in relation to the text above and stated:

> *'The … text … does not imply that stopping could be initiated after V_1. On the contrary, a windshear during takeoff roll can result in groundspeed greater than indicated airspeed due to the tailwind effect of the windshear. Because of the higher ground speed, performance data for stopping on a field length limited runway (a short runway) may not be accurate, resulting in a runway excursion even though the airspeed indicates V_1 or less at the start of the RTO.'*
>
> *'If windshear is encountered before V_1, takeoff performance may be degraded and the planned runway stopping distance may not be available. If the Captain determines that a safe rejected takeoff (RTO) cannot be made, the flight crew should continue accelerating to V_R and rotate normally. When airborne, perform the Windshear Escape Maneuver.'*
>
> '[The] *guidance* [is] *based on industry consensus and event data. Successful outcomes of windshear and other emergency events during takeoff have been more likely if takeoff is continued than if takeoff is rejected late or without sufficient stopping distance. However, guidance cannot be given for every possible set of*

takeoff and windshear conditions. The Captain must assess each situation to determine the safest course of action.'

'The commander has the sole responsibility for the decision to reject or continue a takeoff in a windshear emergency. The commander must determine the safest course of action based on airspeed, airspeed trend, runway remaining, braking capability, and other indications of airplane performance.'

After an RTO event, the QRH directs pilots to consider the need for remote parking and to release the parking brake unless passenger evacuation is necessary.

Operator's report into the RTO

The operator noted that the call of V_1 was omitted by the crew in what was an '*undoubtable increase in workload'*. The call of V_1 is the cue for pilots to remove their hand from the thrust levers, and the operator considered that, without that cue, the pilot's hand might have remained on the thrust levers, '*which lends itself to a rejection'*.

Other Information

The Takeoff Safety Training Aid[2], published by the Federal Aviation Administration in 1993, contains extensive information on RTO events, RTO decision making and analysis of RTO accidents and trends. Section 2, the Pilot Guide to Takeoff Safety was updated in 2004.

Analysis

The weather conditions during the event were severe and the aircraft was being operated to the limits in the operator's documentation. The operator's guidance states that the commander should take account of wind/gust conditions, pilot experience, runway width and surface conditions in deciding who should operate. In this case the co-pilot had three times more hours on type than the commander, was more familiar with EMA, and was permitted to operate to the same limits as the commander. The commander considered that allowing the co-pilot to operate the aircraft was within the operator's guidance and would allow him to focus more of his attention on managing the preparation for departure.

During the aircraft's takeoff roll, there was a 13 kt reduction in airspeed prior to V_1. The commander noted the reduction and informed the co-pilot. It was short lived and as the acceleration in airspeed resumed the commander decided to continue. At this stage of the takeoff, windshear is not one of the manufacturer's RTO criteria and neither predictive nor reactive windshear warnings or cautions would be expected.

As the aircraft passed V_1 the automated callout sounded, but immediately thereafter the airspeed decayed, the aircraft yawed rapidly right away from the centreline and there was a noticeable change in the lateral g. The commander was concerned the aircraft could exit the runway and considered the situation to be unsafe. He had seen the reduced airspeed with the associated downward trend indication, which occurred approximately five seconds

Footnote

[2] https://www.skybrary.aero/index.php/FAA_Takeoff_Safety_Training_Aid [Accessed August 2020].

before V_1, and called "Stop" to reject the takeoff. The RTO actions were promptly and correctly carried out along with rapid control inputs to return the aircraft to the centreline.

There are many factors to be considered by crews in deciding whether to continue or reject a takeoff in windshear conditions, but the manufacturer's comments show that successful outcomes are more likely when the takeoff is continued rather than rejected. Windshear causes the relationship between airspeed and distance travelled along the runway to be altered unpredictably leading to doubt about the continued validity of performance calculations.

In this case, in addition to windshear, the commander had to contend with the fact, and the startling effect, of the aircraft swinging off the centreline immediately after V_1. Both pilots recalled hearing the V_1 auto callout, but they did not call it themselves, and the operator wondered whether the lack of a spoken cue might have meant the pilot's hand remained on the thrust levers. Removing the physical connection to the thrust levers at V_1 is intended to remove the possibility that pilots will instinctively or impulsively close the levers in response to an adverse event. If the pilot did keep his hand on the thrust levers, it might have made it more likely that he would take the option to reject the takeoff.

The manufacturer commented that the commander has sole responsibility for a decision to reject or continue a takeoff and must determine the safest course of action based on many factors. It was also stressed that guidance in the QRH was not intended to imply that *'stopping could be initiated above V_1'.* In this case, however, although the RTO commenced above V_1, the commander brought the aircraft under control and stopped on the runway with 600 m remaining.

Following the RTO, the brakes would have been in the caution band for temperature. In these circumstances, the QRH Non-Normal Manoeuvres section contains guidance for pilots, such as to review the brake cooling schedule and consider whether there is a need for remote parking. In the event, however, this information was not considered, and the aircraft taxied to a normal stand despite there being slight binding in the brakes. It appeared likely that preoccupation with what had just happened and concerns for the co-pilot's wellbeing distracted the commander from considering the QRH guidance.

Conclusion

The commander had a high workload managing the departure and, to give himself time, decided that the co-pilot should fly the take off. In very gusty wind conditions, the aircraft encountered a windshear event near V_1 which caused a 13 kt reduction in airspeed. Additionally, the strength of the crosswind during takeoff caused the aircraft to veer right. Concerned that the aircraft might leave the runway, and considering the situation to be unsafe, the commander initiated an RTO five seconds after V_1. The crew had not called V_1, although the automatic callout had sounded. The SOP is to continue a takeoff when V_1 has been reached because, as the manufacturer commented, successful outcomes are more likely when a takeoff is continued rather than rejected. In this case, the aircraft stopped on the runway with 600 m of runway remaining.

The No 4 wheel and brake unit suffered heat damage from the full braking being applied during the RTO.

ACCIDENT

Aircraft Type and Registration:	Cirrus SR22, N374SR
No & Type of Engines:	1 Continental IO550 piston engine
Year of Manufacture:	2007 (Serial no: 2734)
Date & Time (UTC):	26 May 2020 at 1400 hrs
Location:	Fairoaks Airport, Surrey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to both wings, propeller, fuselage and landing gear
Commander's Licence:	Private Pilot's Licence
Commander's Age:	65 years
Commander's Flying Experience:	451 hours (of which 144 were on type) Last 90 days - 5 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After landing on Runway 24 at Fairoaks Airport, the pilot was unable to stop the aircraft in the distance remaining. N374SR left the paved surface of the runway, went through the airfield boundary fence and crossed a public footpath before colliding with trees. The pilot was uninjured and able to extricate himself from the cockpit without assistance. The runway overrun likely resulted from the combination of a high engine idle speed, little or no headwind and continuing with a deep landing rather than going around.

History of the flight

Witnesses reported that it was a hot day with good weather and a light and variable north-westerly breeze. Having flown from Gloucester Airport the pilot followed an aircraft ahead and positioned to land on Runway 24 at Fairoaks. He stated that the approach was uneventful and that he crossed the runway threshold as normal before flaring at a standard approach speed. Despite the selection of idle power, N374SR did not settle onto the runway as expected. The aircraft continued to float and eventually touched down at what an eyewitness described as "a considerable distance along the runway". By the time the pilot realised there was insufficient runway remaining in which to stop, he judged that, with trees in the overshoot flightpath, it was too late to safely go around.

Despite the application of full braking, the aircraft overran the runway, went through the airfield boundary fence and crossed a public footpath before colliding with trees (Figure 1). N374SR sustained significant damage to wings and fuselage, but the pilot was able to vacate unaided and uninjured.

Figure 1

N374SR after colliding with trees in the runway overshoot
(photograph ©Surrey Police)

Aircraft information

The pilot reported that when he selected idle in the flare the engine stabilised at approximately 1,000 rpm which was higher than he expected. After reviewing N374SR's technical logs, he noted that in preceding months the engine idle speed had been consistently at or above 960 rpm during power checks. He stated that a normal idle speed would be in the range 625 to 650 rpm. The pilot also reflected that at Gloucester Airport his landing roll had been longer than expected and more frequent braking than normal was needed to keep the taxying speed under control.

Airfield information

Public footpaths cross through the undershoot at either end of Runway 06/24 at Fairoaks. Signs are positioned next to the paths to alert passers-by to the potential hazard posed by aircraft taking off and landing as they walk through the extended centreline of the runway.

Additional information

Variable landing performance considerations, such as aircraft weight, runway surface conditions and the observed wind components can significantly affect the landing ground roll required to bring an aircraft to a halt. Deep landings, those achieved beyond the normal touchdown zone, can quickly lead to situations where the braking distance required exceeds the remaining runway available ahead. As a precaution against runway overruns, in Safety Sense Leaflet 1[1], *Good Airmanship*, the CAA recommends that pilots should go around if not '*solidly 'on' in the first third of the runway.*' While other factors, such as minimising

Footnote

[1] Available at http://publicapps.caa.co.uk/modalapplication.aspx?catid=1&pagetype=65&appid=11&mode=detail&id=1156 accessed 2 October 2020.

runway occupancy on very long runways, might also need to be taken into consideration, establishing a landing cut-off point before starting an approach makes the subsequent 'touchdown or go around' decision making process easier.

Analysis

The runway overrun occurred because the aircraft landed too far down the runway for it to be stopped in the landing distance remaining. It is possible that a higher than normal engine idle speed contributed to the aircraft floating rather than achieving a positive touchdown. Additionally, the north-westerly wind gave little or no headwind component to reduce the aircraft's groundspeed relative to its approach speed. A decision to go around would likely have been successful if made before the trees in the overshoot became a limiting consideration.

Comment

Runway overruns resulting from deep landings are a known hazard in aviation. Pilots can mitigate this risk with an awareness of their aircraft's landing performance capabilities and the runway's physical characteristics and by factoring the expected environmental conditions into their threat and error management considerations. It is good airmanship to decide on a 'touchdown or go-around' decision point before committing to an approach. Where obstacles could compromise a go-around flightpath, they should also be factored into the decision point selection process.

ACCIDENT

Aircraft Type and Registration:	Groppo Trail Mk 2, G-RJIT	
No & Type of Engines:	1 Sauer S 2400 UL piston engine	
Year of Manufacture:	2017 (Serial no: LAA 372-15355)	
Date & Time (UTC):	2 August 2020 at 1430 hrs	
Location:	Roche Airfield, Cornwall	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Damaged beyond repair	
Commander's Licence:	Light Aircraft Pilot's Licence	
Commander's Age:	51 years	
Commander's Flying Experience:	152 hours (of which 4 were on type) Last 90 days - 4 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries made by the AAIB	

Synopsis

The aircraft experienced a sudden loss of height from 30 ft agl during the approach to land at Roche Airfield. The aircraft landed heavily, short of the runway and rolled into a gate causing substantial damage. The pilot suffered a minor injury.

History of the flight

Four flights were undertaken on the day of the accident. The first two were type familiarisation flights with an LAA instructor. The third flight was solo to refuel the aircraft at Bodmin Airfield and the accident flight was the return to Roche Airfield.

The weather was dry with visibility in excess of 6 km, light cloud, a temperature of 17°C and a 13 kt wind from 280°. The pilot selected Runway 29, which is a 310 m long, 20 m wide grass strip with a slight up-slope. On the approach to Runway 29 is an 8-10 ft high hedge and a metal farm gate positioned approximately 60 ft from the threshold of the landing strip.

The pilot positioned the aircraft for the approach and configured the flaps for landing. At 30 ft agl and with the engine at idle, the pilot reported that the aircraft dropped sharply and he was unable to react in time to arrest the sudden loss of height. The aircraft struck the ground in a flat attitude with a ground speed of approximately 60 mph and rolled into the open gateway.

The left wing tip struck the gate, whilst the right wing was bent backwards by the impact with the gate-post and hedge. The landing gear, forward fuselage and wings absorbed most of the impact and sustained substantial damage (Figure 1). The pilot suffered a minor injury but was able to climb out of the aircraft unaided.

Figure 1

Final position of the aircraft showing significant damage to the fuselage and wings

Analysis

The pilot hadn’t flown for approximately nine months prior to the accident because of poor weather over the winter period followed by the restrictions for public health due to the COVID-19 pandemic. He considered his lack of currency was a factor.

Although he was familiar with tailwheel aircraft, he only had four hours on type and additional familiarisation flights may have helped him to react quicker to the aircraft’s sudden loss of height. The pilot had flown out of Roche Airfield for approximately two years but had only used Runway 29 a handful of times.

ACCIDENT

Aircraft Type and Registration:	Rans S6-ES, G-YTLY
No & Type of Engines:	1 Jabiru 2200A piston engine
Year of Manufacture:	2011 (Serial no: LAA 204-14925)
Date & Time (UTC):	26 April 2020 at 1530 hrs
Location:	Longside Airfield, Glendaveny, Peterhead Aberdeenshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nosewheel leg, propeller and cockpit structure
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	72 years
Commander's Flying Experience:	260 hours (of which 183 were on type) Last 90 days - 8 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot reported that he planned to carry out a local flight from Longside Airfield near Aberdeen. He took off in a light westerly wind using Runway 28 and at 1,000 ft encountered turbulence. He decided not to continue with the flight and returned to the airfield; however, by this time the surface wind conditions had changed making Runway 10 more suitable for landing.

The pilot said he encountered no difficulty during the approach, with the speed and attitude appearing normal. However, as he flared the aircraft, it descended rapidly, landed hard and bounced before coming to a standstill. The impact broke the nosewheel leg, which collapsed and resulted in damage to the cockpit structure and propeller.

ACCIDENT

Aircraft Type and Registration:	Savannah VG Jabiru(1), G-DOTW
No & Type of Engines:	1 Jabiru 2200A piston engine
Year of Manufacture:	2008 (Serial no: BMAA/HB/575)
Date & Time (UTC):	7 July 2020 at 1204 hrs
Location:	Barville Farm, near Dover, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Severe damage to the engine and airframe
Commander's Licence:	None
Commander's Age:	66 years
Commander's Flying Experience:	126 hours (of which 24 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

An unlicensed student pilot was operating the aircraft from the left seat while a friend who was a pilot with a NPPL[1] sat in the right. During the flare before touchdown, the aircraft experienced turbulence and maximum power was applied to go around. The left wing lifted and the right wing struck the ground, causing the aircraft to rotate to the right and come to rest facing the way it had come.

History of the flight

The owner of the aircraft had not yet gained his pilot's licence and had asked a friend, who was licensed to fly the aircraft, to fly with him. The purpose of the flight was to test a recently fitted transponder before returning to Clipgate Farm. The owner 'booked out' on the airfield Flight Log and gave the friend's name as the 'Pilot'.

The weather was good with a southerly wind of 10 to 15 kt, visibility in excess of 10 km, some scattered clouds, OAT 21° and QNH 1019 hPa. The owner understood that he would fly the aircraft with his friend available to take control if necessary. The friend understood that this would be a short flight to test a recently installed transponder and that he would assist with the radio. After starting the engine the friend discovered that, as well as the uncalibrated transponder, the intercom system was unserviceable, but as they could understand each

Footnote

[1] NPPL: National Private Pilot's Licence.

other above the engine noise, the friend agreed to continue the flight and make the radio transmissions. The friend also noted that there were no toe brakes on his side of the aircraft and other controls, such as the trimmer, were difficult to reach.

The aircraft departed Clipgate and the owner decided that they would carry out a circuit at Boyes Hill, a nearby training grass strip. The flight there was uneventful in smooth flying conditions, and the owner joined for a left-hand circuit, turning onto the final approach for the strip heading of 210°, with full flap selected at an approach IAS of 50 mph. The approach was normal but, in the last 30 ft, there was significant turbulence from the wind passing over a wood on the left of the runway (there was no windsock to indicate the wind direction and strength). The aircraft touchdown was heavier than normal but not severe. They stopped the engine, got out to inspect the landing gear and did not see any signs of damage, both agreeing that the aircraft was safe to fly. They backtracked the runway and then took off to fly another circuit at Boyes Hill. On the second approach, they again encountered the turbulence and a go-around was performed.

The description of events by the owner and his friend differed from this point as to who was flying the aircraft. A third circuit and approach was flown but again they encountered the turbulence. The aircraft was flared and again maximum power was applied to go around. The left wing lifted due to the wind and the right wing struck the ground, yawing the aircraft to the right such that it came to rest facing towards the Runway 21 threshold.

Neither occupant was injured, and they switched off the fuel and electrical systems before vacating the aircraft.

Comments

The CAA stated that the pilot operating an aircraft such as this would normally be expected to sit in the left seat but would be permitted to operate from the right seat provided they had full access to all controls. The aircraft was fitted with toe operated wheel brakes on the left side of the cockpit which could only be operated from the left pilot's seat.

A non-licence holder can only handle the controls when under the instruction of a Flight Instructor during flying training, including solo flying training, for the granting or renewal of a pilot's licence or the inclusion or variation of any rating or certificate in a pilot's licence.

A fuller description of the relevant legislation can be found in the AAIB report on an accident involving a Robin DR400 aircraft, G-ETIV, on 7 December 2016[2].

Conclusion

During the final approach to land, the aircraft experienced turbulence caused by wind passing over a wood to the left of the runway. The increase in wind from the left lifted the left wing, causing the right wing to lower sufficiently to strike the ground.

Footnote

2 https://assets.publishing.service.gov.uk/media/59d21d6040f0b6107da9784a/Robin_DR400_180_Regent_G-ETIV_07-17.pdf (Accessed 27/10/2020).

ACCIDENT

Aircraft Type and Registration:	Team Minimax 91, G-MZPJ
No & Type of Engines:	1 Rotax 503 piston engine
Year of Manufacture:	1993 (Serial no: PFA 186-12277)
Date & Time (UTC):	11 August 2020 at 1215 hrs
Location:	Gatton Bottom, Redhill, Surrey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	218 hours (of which 176 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During a private cross-country flight, the microlight's engine stopped, forcing the pilot to make an emergency landing. The landing resulted in significant damage to the aircraft and serious injury to the pilot after the landing gear clipped an obstacle close to the ground, most likely rough vegetation. The subsequent investigation identified that the aircraft had probably run out of fuel.

History of the flight

The aircraft was based at Fairoaks Airfield. On the morning of the flight, the pilot refuelled the aircraft with 40 litres of fuel and began the pre-flight checks. He reported starting the engine at 0930 hrs and conducted some extended ground checks, prior to taking off and departing the airfield around 1000 hrs. He then flew south east towards the south coast, before turning north-east, just north of Brighton. He flew as far as Royal Tunbridge Wells, before turning west and flying till he was overhead the M23 motorway. He then flew north until he saw the M25 and followed it westward with the intention of returning to Fairoaks to land. However, just north of Reigate, at a height of approximately 1,300 ft, the engine stopped. The pilot made a mayday call, which was logged at 1210 hrs. The pilot reported he circled to find an area suitable for a forced landing, before making his approach. As the aircraft reached the touch down point, the pilot believed the left landing gear clipped something, causing the aircraft to turn 90 degrees to the left and hit the ground. This was broadly corroborated by a nearby eyewitness. The aircraft broke up as a result of the impact with the ground and the pilot was knocked unconscious, suffering serious facial injuries.

Accident site

The accident site was in an area of parkland next to Hop Garden Pond, within the grounds of Gratton Park National Trust. The area was covered with large trees and rough vegetation, particularly around the location of the wreckage.

Aircraft information

The Team Minimax 91 is a fixed wing microlight with a 300 kg maximum takeoff weight. G-MZPJ was amateur built and was powered by a two cylinder, two-stroke, Rotax 503 engine, which ran on MOGAS. The manufacturer quoted a fuel consumption rate for the engine in its Operators Manual of 25 l/h at takeoff performance and 15 l/h at 75% continuous performance.

Aircraft examination

The front of the aircraft was significantly damaged by the impact with the ground. Fire and Rescue first responders stated that they attempted to defuel the aircraft in order to make it safe but did not find any fuel present. The pilot reported that he did some basic checks on the engine after the wreckage was recovered but no mechanical issues were identified.

Analysis

The duration of the accident flight from the time the engine was started to the MAYDAY call was 2 hours and 40 minutes. The pilot reported that he refuelled the aircraft with 40 litres of fuel. Using the manufacturer's fuel consumption rate of 15 l/hr, this gives an endurance of 2 hours and 40 minutes. Allowing for a reduced consumption rate at idle power and increased fuel consumption at takeoff power, the timing of the engine stopping is consistent with the aircraft running out of fuel. This analysis is supported by the lack of fuel observed by the Emergency Services who attended the scene and was acknowledged by the pilot as the most likely cause in his accident report form.

Conclusion

The pilot performed a forced landing after the engine stopped due to fuel starvation, when the aircraft ran out of fuel. As the aircraft touched down the landing gear clipped something, most likely rough vegetation, causing the aircraft to turn 90 degrees and hit the ground. This resulted in significant damage to the front of the aircraft and a serious facial injury for the pilot.

ACCIDENT

Aircraft Type and Registration:	Parrot Anafi (UAS, registration, n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	Not Known (Serial no: H002349)
Date & Time (UTC):	17 July 2020 at 0245 hrs
Location:	Green Lane, Yeadon, West Yorkshire
Type of Flight:	Emergency Services Operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	2 propeller blades and battery damaged. Minor damage to roof covering
Commander's Licence:	Other
Commander's Age:	37 years
Commander's Flying Experience:	40 hours (of which 36 were on type) Last 90 days - 5 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

The operator was conducting a night search of roof tops. About 15 minutes after takeoff, when the UA was at about 50 agl, the pilot noticed the control screen flicker and heard the speed of the UA's motors increase without any input from him. The UA then started to turn and, despite inputs from the pilot, was unresponsive. He attempted to descend the UA to conduct an emergency landing and then selected the '*Return to Home'* function, but it did not respond. The UA then entered an uncontrolled descent onto the roof, where it came to rest.

The UA was recovered with damage to its two front left propellers and battery. There was also minor damage to the roof covering.

The pilot believed that, given the clean fractures on the propellers and the way the motors reacted, the UA had suffered a failure of the two propellers.

The AAIB published another reported failure of propellers on a Parrot Anafi in its 9/2020 Bulletin[1].

Footnote

[1] https://assets.publishing.service.gov.uk/media/5f3cf90a8fa8f51744ded02b/Parrot_Anafi_Thermal__reg_na__09-20.pdf [Accessed October 2020]

Safety actions

Previously the operator would only replace damaged propellers but, as a result of the safety action taken in the published event, they will now also change the propellers every 5 hours flight time. They will also make a video recording of all pre- and post-flight safety checks.

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 investigations reviewed September - October 2020

01-Jul-20 **Vans RV-4** **G-BXRV** Defford Croft Airfield, Worcestershire

The pilot applied power with the brakes on prior to a short field takeoff. As he was about to release the brakes, the tail lifted and the aircraft pitched over resulting in a propeller strike. The propeller and airframe were damaged.

12-Jul-20 **Denney Kitfox MK2** **G-BTTY** Eggesford Airfield, Devon

The pilot encountered significant turbulence on final approach. The main wheels touched down first and then the pilot lowered the tailwheel to improve directional control. The aircraft started to weathervane to the right and despite multiple opposing rudder inputs, the aircraft veered towards the runway edge and pitched nose down. The pilot pulled the stick fully back but was unable to prevent the propeller striking the ground and the aircraft becoming inverted.

14-Jul-20 **Piper PA-24-250** **N7348P** Temple Bruer private strip, Lincolnshire

The pilot omitted to select the gear down prior to landing, causing damage to the fuselage and propeller on touchdown. He heard the gear warning horn as he closed the throttle but mistook it for the stall warning, which has a similar sound and often operates just prior to touchdown.

18-Jul-20 **Jodel D9** **G-BGFJ** Kingstanding Airfield, near Ascott under Wychwood, Oxfordshire

The pilot took off in a crosswind and encountered sink. He successfully avoided a tree on the extended centre line, however the aircraft did not climb and landed in a field, and then rolled over.

20-Jul-20 **Jodel D140E** **G-JRME** Cornwall Airport Newquay

The aircraft ground looped on landing and the main landing gear collapsed. The pilot report that he experienced a strong gust of wind during landing.

06-Aug-20 **Mainair Blade 912** **G-OYES** East Fortune, East Lothian

The pilot misjudged the strength of the crosswind which resulted in a heavy landing and landing gear damage.

08-Aug-20 **Vans RV-6A** **G-CKTF** Holmbeck Farm, Leighton Buzzard, Bedfordshire

The aircraft descended rapidly just prior to touchdown which caused the nose landing gear to dig in and subsequently collapse, and the aircraft turned over.

Record-only investigations reviewed September - October 2020 cont

11-Aug-20 **Champion 8KCAB** **G-DDGJ** Frensham Pond Airstrip, Surrey

During the landing roll on a grass runway the aircraft started to oscillate in pitch. The pilot moved the control column forward to counter this instability, but the aircraft's nose pitched down more rapidly than he expected. This resulted in a propeller strike. The pilot reported that, with hindsight, he should have initiated a go around when the oscillations began.

23-Aug-20 **Grob G115** **G-BPKF** Nottingham Airport

The aircraft bounced twice during landing so the solo student pilot elected to go around. He was informed that the nose landing gear leg had detached and was advised to keep the nose up after touchdown. The pilot was able to land safely; it was his second bounce that had caused the nose leg to detach.

24-Aug-20 **Skyranger Swift 912(1)** **G-CLLA** Sywell Aerodrome, Northamptonshire

After what seemed like a normal touchdown, the nose of the aircraft began to pitch up. The pilot attempted to stop the nose-up pitch but the result was a heavy landing and the aircraft came to rest inverted.

29-Aug-20 **Maule MXT-7-180** **G-BVIL** Lower Lyde Court Farm, Hereford

As the aircraft approached the runway, the speed increased suddenly possibly due to a gust of wind. The aircraft touched down heavily and became airborne again, and on the second bounce the nose wheel contacted the runway first and sheared off. This resulted in the nose digging in and the aircraft inverting onto its roof.

31-Aug-20 **Glos-Airtourer Super 150** **G-AZBE** Peterlee (Shotton) Airfield, Durham

On landing the nosewheel dug into the soft ground and the nose undercarriage leg broke off. The airfield had been affected by heavy rain in the week preceding the event.

05-Sep-20 **Piper PA-28-161** **G-WARU** Wellesbourne Airfield, Warwickshire

While landing in a slight crosswind, the aircraft drifted to the left edge of the runway and, on command from the instructor, the student began a go-around. Believing the go-around would not be successful, the instructor took control and closed the throttle. On touchdown, the aircraft yawed sharply left and the aircraft came to a halt in a maize crop.

06-Sep-20 **Sherwood KUB** **G-TLEE** Egerton, Ashford, Kent

The pilot carried out a forced landing in a field after confusing aerodynamic stall for reoccurrence of a flight control system problem. The landing resulted in the aircraft hitting a hedge.

Record-only investigations reviewed September - October 2020 cont

15-Sep-20	**Tecnam P92-EA Echo**	**G-BZWT**	Manor Farm Airfield, Bicester, Oxfordshire

The aircraft bounced after touchdown and the nose gear subsequently collapsed.

16-Sep-20	**Piper J5A**	**G-BTKA**	Finmere Aerodrome, Buckinghamshire

This was the second flight of a tailwheel conversion course. The student applied right rudder and, probably, right brake, to counter a drift to the left of the centreline on landing. The tailwheel 'broke away', the aircraft ground-looped and then struck a fence post damaging the left elevator.

20-Sep-20	**Skyranger Swift 912(1)**	**G-CLNN**	Desborough Airfield, Northamptonshire

The pilot elected to land half-way along the available landing strip to avoid a ditch that crossed its midpoint. On landing, the aircraft bounced and the pilot made a nose down pitch input, causing damage to the nosewheel on the subsequent touchdown. He was unable to stop the aircraft before a hedgerow at the end of the field, causing damage to the right wing, engine cowling and propeller. The pilot was not injured. He believed the wind may have veered creating a tailwind on landing.

27-Sep-20	**Vans RV-7**	**G-CKMX**	City of Derry Airport, Londonderry

The aircraft bounced on landing from a higher-than-normal approach speed. It bounced again and, on the next touchdown, sustained damage to both spats, the right landing gear leg and the left wing tip. The pilot carried out a go-around and landed safely.

29-Sep-20	**EV-97 TeamEurostar UK**	**G-CDJR**	Eddsfield Airfield, near Driffield, East Yorkshire

While landing on an uphill runway in light wind conditions, the aircraft bounced and became briefly airborne after the initial touchdown. As the aircraft touched down for a second time the nosewheel leg collapsed and folded backwards. The aircraft came to rest on its mainwheels and nose.

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 CORRECTION

Aircraft Type and Registration:	Airbus A321-231, G-WUKJ
Date & Time (UTC):	16 June 2020 at 1038 hrs
Location:	Doncaster Airport
Information Source:	Aircraft Accident Report Form

AAIB Bulletin No 11/20, page 73 refers

Prior to publication, it was noted that the aircraft registration was incorrectly stated as G-WUJK instead of G-WUKJ in the history of the flight and in the recorded information sections of the report.

This was corrected online prior to publication on 12 November 2020.

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

3/2014 Agusta A109E, G-CRST
Near Vauxhall Bridge,
Central London
on 16 January 2013.

Published September 2014.

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.

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
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European 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)
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth's gravity
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
mb	millibar(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
PM	Pilot Monitoring
POH	Pilot's Operating Handbook
PPL	Private Pilot's Licence
psi	pounds per square inch
QFE	altimeter pressure setting to indicate height above aerodrome
QNH	altimeter pressure setting to indicate elevation amsl
RA	Resolution Advisory
RFFS	Rescue and Fire Fighting Service
rpm	revolutions per minute
RTF	radiotelephony
RVR	Runway Visual Range
SAR	Search and Rescue
SB	Service Bulletin
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TAF	Terminal Aerodrome Forecast
TAS	true airspeed
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TODA	Takeoff Distance Available
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
USG	US gallons
UTC	Co-ordinated Universal Time (GMT)
V	Volt(s)
V_1	Takeoff decision speed
V_2	Takeoff safety speed
V_R	Rotation speed
V_{REF}	Reference airspeed (approach)
V_{NE}	Never Exceed airspeed
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional radio Range

AAIB
Air Accidents Investigation Branch