AAIB
Air Accidents Investigation Branch

AAIB Bulletin 4/2023

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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

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AAIB Special Bulletins and Interim Reports

This section contains Special Bulletins and Interim Reports that have been published since the last AAIB monthly bulletin.

Farnborough House
Berkshire Copse Road
Aldershot, Hants GU11 2HH

Tel:01252 510300
Fax: 01252 376999
www.aaib.gov.uk

AAIB Air Accidents Investigation Branch

AAIB Bulletin S1/2023 *SPECIAL*

SERIOUS INCIDENT

Aircraft Type and Registration:	Bombardier CL-600-2B16 (604), D-AAAY
No & Type of Engines:	2 General Electric CF34-3B turbofan engines
Year of Manufacture:	2004 (Serial no: 5602)
Date & Time (UTC):	10 August 2022 at 1640 hrs
Location:	In the climb after departing Farnborough Airport, Hampshire
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 7
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damaged contact in number 1 system flap retract relay
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	13,091 hours (of which 5,655 were on type) Last 90 days - 102 hours Last 28 days - 41 hours
Information Source:	AAIB Field Investigation

Introduction

This Special Bulletin provides an update on the progress of the investigation into the uncommanded and unarrested flap extension above the maximum flaps extension speed that occurred on a Bombardier Challenger 604 aircraft, registration D-AAAY, on 10 August 2022. It follows publication of an earlier Special Bulletin[1], which provided preliminary information on the event and included a description of the flap operating system.

Footnote

[1] AAIB Special Bulletin S2/2022 published on 22 September 2022. Bombardier CL-600-2B16 (604 variant), D-AAAY - GOV.UK (www.gov.uk)

The investigation established that a failure in the System 1 retract relay prevented the system from arresting the uncommanded flaps extension. This failure also caused the flaps to retract at half speed during the previous 64 flights recorded on the FDR, without the pilots being aware. A failure of the retract or extend relays on either motor channel would have a similar effect on the flap speed.

Following this serious incident, the aircraft manufacturer issued an Advisory Wire[1] on 26 September 2022 to advise operators of this event, and on 29 December 2022 issued five Service Bulletins[2] (SB) for operators to check the flap system on the Challenger 600 series of aircraft. On 10 February 2023, Transport Canada issued an Airworthiness Directive[3] requiring the initial operational test detailed in the SB to be carried out within 100 flight hours or 15 months.

Summary

While actioning the SB, the operator of D-AAAY identified two further aircraft where the flaps had been operating at half speed over a number of flights. The investigation has established that the cause of the failure was damage to the D contacts in the flap extend relay, which resulted from an unsuppressed back-EMF generated when the flap Brake Detector Unit (BDU) was de-energised. The four flap extend and retract relays form part of the system to arrest an uncommanded flap movement.

Two Safety Recommendations have been made in this Special Bulletin to the Manufacturer to introduce a life policy for the relays, and a modification to protect the contacts from damage caused by the back-EMF. A third Safety Recommendation is made to the Regulator to reassess the safety case for the flap operating system. A Safety Recommendation had previously been made to the Manufacturer on 19 September 2022 to inform operators of the actions to take in the event of an uncommanded flap operation in flight.

Manufacturer's Service Bulletins

Requirement

The manufacturer's SBs recommended an operational test to verify the extension and retraction time of the flaps. They called for an initial action to be carried out within 100 flight hours with a repeat test every 100 flight hours for 600/601 series aircraft, and 400 hours for 604/605/650 series aircraft. This flight hour frequency aligns with existing scheduled maintenance tasks.

Early results from Manufacturer's Service Bulletins

On 9 January 2023 the AAIB was advised by an operator of two Challenger 604 aircraft who, while conducting the SB, found the flaps to be operating at half speed. The AAIB deployed a field team who, with representatives from the aircraft manufacturer, undertook

Footnote

1 Bombardier Wire, AW600-27-2631. Basic issue: September 26,2022.
2 Bombardier Service Bulletins: SB 600-0780, SB601-1112, SB 604-27-040, SB 605-27-011, SB 650-27-004 Basic Issue: Dec 29/2022.
3 Transport Canada. Airworthiness Directive Number CF-2023-07, Effective date 2023, Issue date 10 February 2023.

an examination and test of the flap system. The operator also permitted the examination of a third Challenger 604 aircraft, where the flaps had run at the correct speed while actioning the SB. The aircraft are identified in this report as Aircraft 2, 3 and 4; D-AAAY, on which the failure was first identified, is referenced as Aircraft 1.

Aircraft 2

Aircraft 2 was manufactured in 2006 and had accumulated 10,300 hours and 4,687 flight cycles since new.

On 31 December 2022, the SB was carried out when the aircraft was on scheduled maintenance. The results of the test were as follows:

- The flaps extended at half speed and the retraction speed was normal.
- A 'Break out box' was connected between the aircraft and the Flap Control Unit (FCU) to allow a functional test[4] of the uncommanded movement arrest system to be conducted.
  - During step E3 of the procedure, the system performed as expected; flap movement stopped within the specified limits and a FLAP FAIL message was annunciated in the cockpit as expected.
  - During Step E8 of the procedure, the flaps stopped at 20° without the expected slight overtravel; the expected FLAP FAIL message was not annunciated.

Following extensive testing, the flaps started operating normally without any corrective action having been taken. The cause of the half speed flap operation was believed to be sticking contacts in the No 1 motor extend relay, K1CE.

All four extend / retract relays were replaced as a precaution and to allow further examination by this investigation.

Aircraft 3

Aircraft 3 was manufactured in 2000 and had accumulated 8,915 hours and 4,344 flight cycles since new.

As a result of the findings on Aircraft 2, the operator asked the operating crew of Aircraft 3 to time the flap movement when they returned to their operating base. The crew reported half speed operation on extension, and normal speed on retraction.

A 'Break out box' was connected between the aircraft and the Flap Control Unit to allow a functional test[5] of the uncommanded movement arrest system to be conducted.

Footnote

[4] AMM Task 27-51-04-720-801, *'Functional test of the Flap Control Unit (All drivers ON circuit)'*.

- During Step E3 of the procedure, the flaps stopped at 20° without the expected slight overtravel; the expected FLAP FAIL message was not annunciated.
- During Step E8 of the procedure, the flaps moved past 20° and stopped momentarily at 23° and a FLAP FAIL message was annunciated. This was as expected, but the flaps then retracted, uncommanded, until reaching the UP limit stops and the No 2 motor circuit breaker tripped after a few seconds.

Extensive testing of Aircraft 3 identified that the contacts on the No 2 motor extend relay, K2CE, were stuck in their energised positions. All four extend / retract relays were replaced by the operator as a precautionary measure and the system operated normally.

Aircraft 4

Aircraft 4 was manufactured in 2002 and had accumulated 6,487 hours and 4,241 flight cycles since new.

The SB was carried out and the flaps were found to operate normally. As a precaution, and to provide additional evidence to the safety investigation, the operator replaced the four extend / retract relays so that they could be examined in detail.

Recorded information

The FDR data for Aircraft 2, 3 and 4 were reviewed for evidence of non-normal flap movement speed during extension and retraction. This showed the following:

Aircraft 2: The FDR download contained 260 flights recorded between 22 May 2022 and 30 December 2022. During the most recent 53 flights, which occurred from the 6 October 2022, the flaps extended at half normal speed. During all the recorded flights, the flaps retracted at normal speed.

Aircraft 3: The FDR download contained 34 flights recorded between 22 November 2022 and 11 January 2023. During all the recorded flights, the flaps extended at half normal speed and retracted at normal speed.

Aircraft 4: The FDR download contained 25 flights recorded between 22 December 2022 and 17 January 2023. During all the recorded flights, the flaps extended and retracted at normal speed.

Flap extend and retract relays

Four relays are used to switch electrical power to the two flap drive motors and to release a solenoid operated brake in the BDU fitted in each wing, to allow flap movement. The flap operating system is divided into a No 1 and No 2 System to provide redundancy, and each system has an extend and a retract relay controlling the operation of a motor. Should one system fail, the other system is still capable of operating the flaps, but the operation will be at half speed as only one of the two motors will be operating.

The extend and retract relays are a 4-channel double-pole relay. The component manufacturer's datasheet states that for an inductive[1] load, the relay contacts are specified for 8 amps and a maximum operating cycle life of 20,000 operations.

The schematic layout of the relay pins is shown in Figure 1. When the relay is de-energised:

- Contacts A1, B1, C1 and D1 are OPEN.
- Contacts A2, B2, C2 and D2 are the input to be switched.
- Contacts A3, B3, C3 and D3 are CLOSED.
- Contacts +X1 and -X2 provided electrical power to the operating coil, when energised.

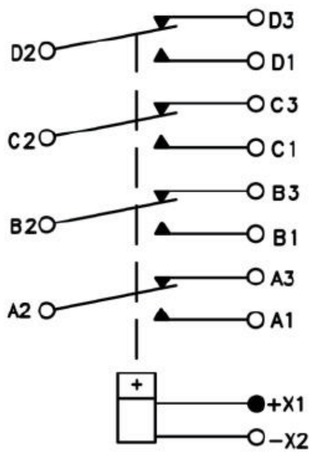


Figure 1

Schematic of relay pin arrangement in the de-energised condition

The D contacts are used to switch the 28 V DC to the BDU brake solenoid coils, the other three sets of contacts (A, B and C) are used to switch each of the three 115 V AC phases to the flap drive motor.

Examination of the relays removed from D-AAAY

Identity of relays

The relays are identified as:

Relay	Description
K1CE	No 1 system extend
K2CE	No 2 system extend
K3CE	No 1 system retract
K4CE	No 2 system retract

Footnote

[1] An inductive load is a part of an electrical circuit that uses magnetic energy to produce work.

Continuity check

An electrical continuity check of all four extend and retract relays removed from D-AAAY was carried out in both the energised and de-energised condition. These checks indicated that the results were as expected in the de-energised condition, but for the K3CE relay in the energised condition, for No 1 system retract, the results were abnormal, Figure 2. O/C refers to open circuit and the measurement values are Ohms (Ω).

Contacts	Relays			
	K1CE	**K2CE**	**K3CE**	**K4CE**
A2 to A3	O/C	O/C	0.2 Ω	O/C
B2 to B3	O/C	O/C	O/C	O/C
C2 to C3	O/C	O/C	0.2 Ω	O/C
D2 to D3	O/C	O/C	O/C	O/C
A2 to A1	0.1 Ω	0.2 Ω	O/C	0.1 Ω
B2 to B1	0.2 Ω	0.2 Ω	O/C	0.1 Ω
C2 to C1	0.1 Ω	0.1 Ω	O/C	0.1 Ω
D2 to D1	0.2 Ω	0.2 Ω	0.1 Ω	0.1 Ω

Figure 2

Results of continuity check in energised condition. Anomalies are highlighted in red

Computerised tomography scanning of the relays

All four of the flap extend and retract relays from D-AAAY were scanned using a computerised tomography (CT) scanner.

The scans identified anomalies with the D contacts of relays K1CE, K2CE and K3CE. The contacts in relay K4CE appeared normal. An example of an image from the K3CE scan is shown in Figure 3.

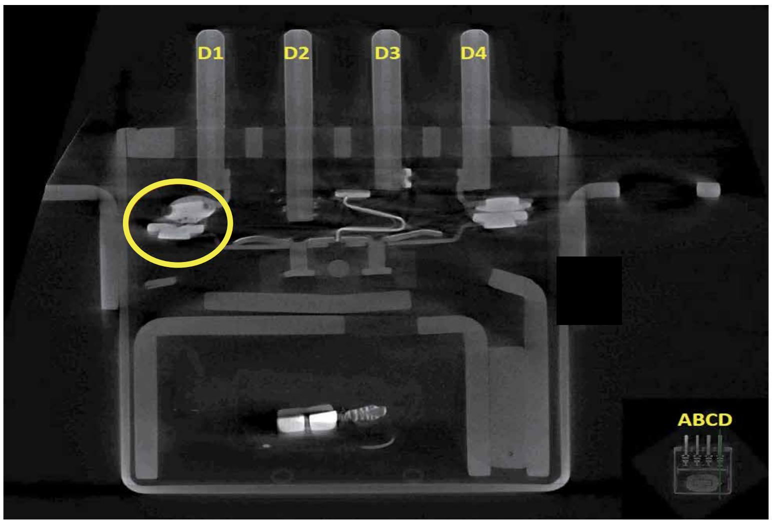


Figure 3

Relay K3CE showing D1 contact damage, circled in yellow

Forensic examination of relays

The relays and the BDU from D-AAAY were taken to a laboratory specialising in forensic examination of electrical components. Before being dismantled for internal inspection, the relays were electrically checked again and the results for relay K3CE in the energised condition was found to differ from the previous test; the other relays conformed to the datasheet specification. The significant differences between the tests are highlighted in red in Figure 4.

Contacts	Relays			
	K1CE	K2CE	K3CE	K4CE
A2 to A3	O/C	O/C	O/C	O/C
B2 to B3	O/C	O/C	O/C	O/C
C2 to C3	O/C	O/C	O/C	O/C
D2 to D3	O/C	O/C	O/C	O/C
A2 to A1	0.1 Ω	0.2 Ω	O/C	0.1 Ω
B2 to B1	0.2 Ω	0.2 Ω	O/C	0.1 Ω
C2 to C1	0.1 Ω	0.1 Ω	O/C	0.1 Ω
D2 to D1	0.2 Ω	0.2 Ω	0.1 Ω	0.1 Ω

Figure 4

Significant differences from previous test in energised condition are highlighted in red

Internal condition of relays

The relays from D-AAAY were dismantled to allow examination of the contacts. All four relays had the same part number; Figure 5 shows the disassembled contacts of relay K3CE.

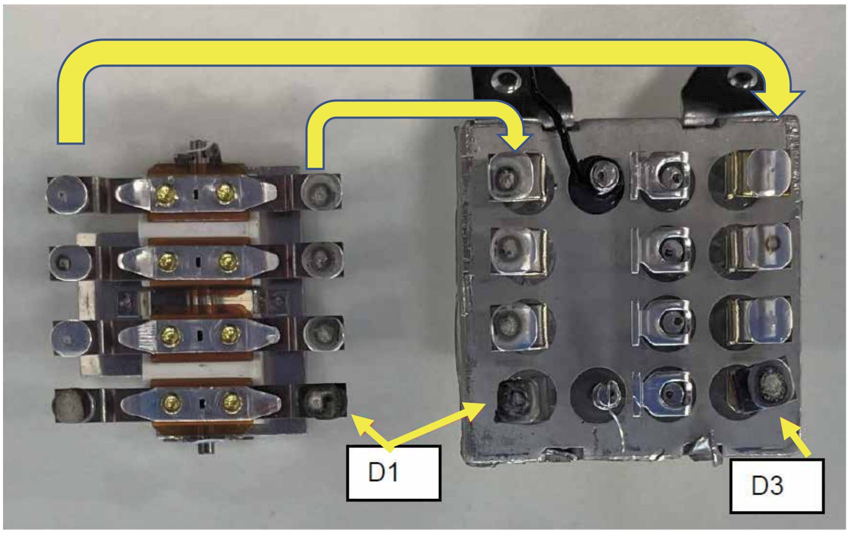


Figure 5

General arrangement of relay contacts, disassembled.
Arrows show how the part on the left connects to the part on the right

Prior to full disassembly, the contacts were examined using an optical microscope and significant damage was found on the D contacts on relays K1CE, K2CE and K3CE. The damage to the D1 contact on relay K3CE is shown in Figure 6.

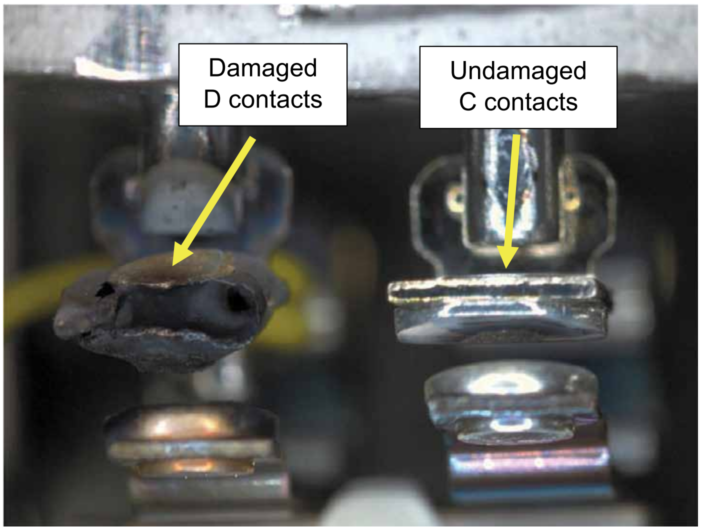


Figure 6

K3CE relay showing contact damage

Scanning Electron Microscopy inspection and Energy Dispersive X-ray analysis was conducted on a selection of contact pads which showed evidence of welding and pulling apart.

Preliminary examination of the relays removed from Aircraft 2, 3 and 4

External condition of relays

The extend and retract relays removed from Aircraft 2, 3 and 4 were visually inspected, and appeared to be in good condition. No anomalies were noted with their connecting pins.

Aircraft 2

Apart from the K2CE relay, the manufacturing date on the relays was consistent with them having been fitted at the time of aircraft manufacture.

The maintenance records for Aircraft 2 showed that the K2CE extend relay had been replaced in April 2018, at 7,596 flight hours and 3,316 flight cycles, after trouble shooting of a defect that caused a FLAP FAIL EICAS message. The trouble shooting found that the BDU brake solenoids were permanently energised. Further investigation found that the K2CE extend relay was not operating normally. Once this relay was replaced, the flap system operated normally.

The K2CE relay, which had not failed, and was replaced in 2018, was CT scanned and the D1 and D2 contacts were found to show signs of erosion and material transfer (Figure 7). This relay had been in-service for approximately 2,700 flight hours and 1,371 flight cycles.

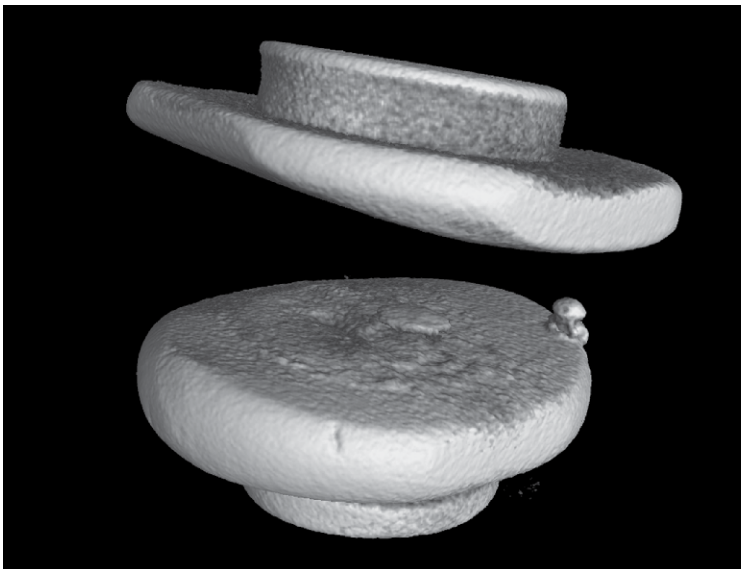


Figure 7

Aircraft 2, relay K2CE, contacts D1 and D2 showing surface degradation and material transfer

Aircraft 3

The K2CE relay from Aircraft 3 was found to have the D1 and D2 contacts welded together. When in the de-energised condition; the contacts should have been open. The D2 and D3 contacts were also closed; this would be their normal position with the relay de-energised (Figure 8). In this condition, if the uncommanded flap movement arrest system was activated, rather than the flap movement being arrested, the flaps would retract.

Figure 8

Aircraft 3, relay K2CE, showing welded D1 and D2 contacts

Aircraft 4

Aircraft 4, which had passed the SB flap movement timing test, also had degraded D1 and D2 contacts on relay K3CE. Figure 9 shows erosion and metal transfer between the contacts.

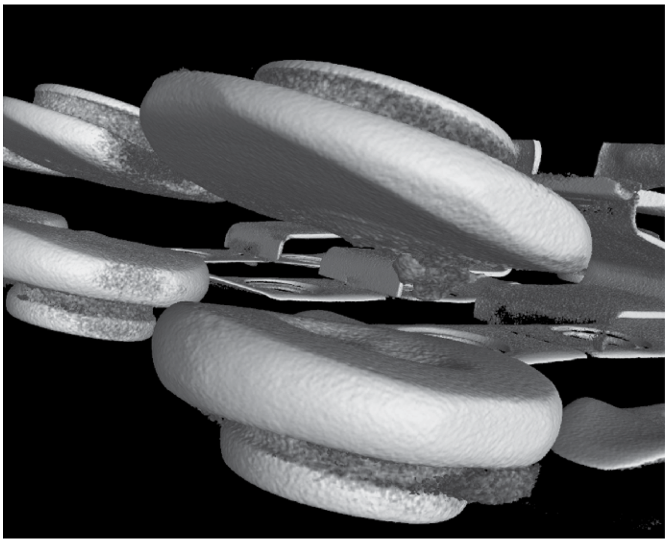


Figure 9

Aircraft 4, relay K3CE, showing erosion and metal transfer on contacts D1 and D2

Summary of damage found on examined relays

In most of the relays examined, metal erosion and metal transfer were visible on the D contacts to varying degrees. Figure 10 shows damage to the D1 and D2 contacts on relay K1CE from Aircraft 2, which did not exhibit any faults during the testing carried out as part of the SB.

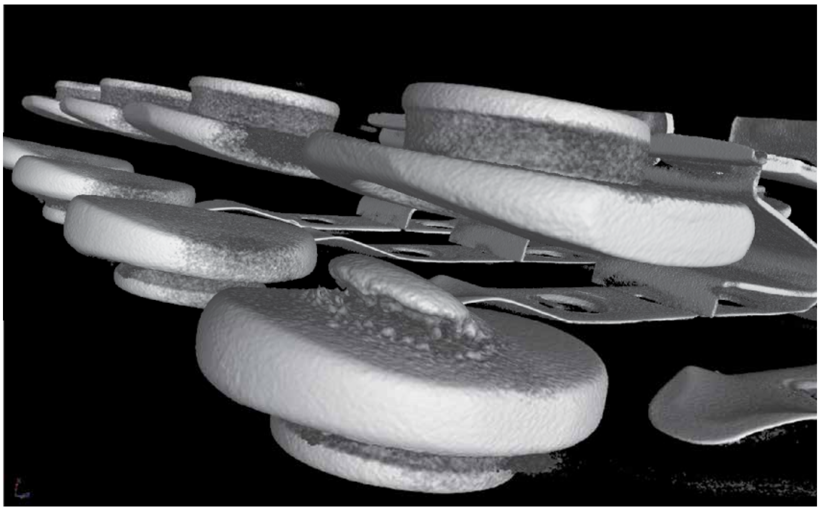


Figure 10

Aircraft 2, relay K1CE, showing erosion and metal transfer on contacts D1 and D2

Examination of the Brake Detector Unit

The aircraft was fitted with two BDU's, one on each wing. Each consists of a 28 V DC solenoid operated brake and a speed sensor detector unit (Figure 11). The investigation considered the effect of the solenoid operated brake on the relay, as their electrical power is switched by the D contacts in each of the four extend and retract relays. To provide redundancy each brake solenoid has two operating coils, one powered by each operating system, and each system powers an operating solenoid in each of the two BDU's; these are connected in parallel. The brake solenoids are energised to release the brake and are de-energised to apply the brake.

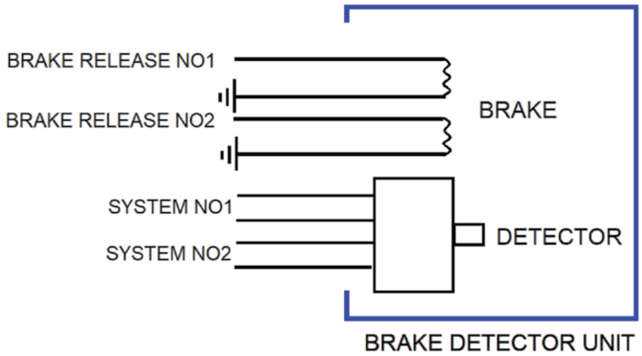


Figure 11

Schematic of BDU Brake Solenoid arrangement

Laboratory testing of the BDU coil resistance indicated they were within specification. The current and voltage during solenoid switching was measured using an oscilloscope (Figure 12). When the solenoid was de-energised a transient voltage spike of up to approximately 300 V was seen, and this spike regularly exceeded 150 V during repeated switching. The voltage spike is likely to be the back electro motive force (EMF) which is a known feature of inductive loads and is caused by the current to the solenoid coil decaying and inducing the EMF after the electrical supply has been switched off. There was no protection or suppression provided within the flap operating system to prevent or reduce this back-EMF.

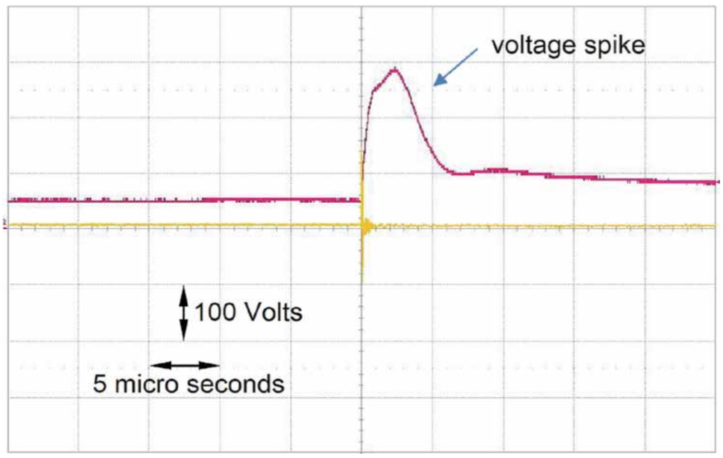


Figure 12

Oscilloscope output showing typical voltage spike after de-energising the BDU coil

Operator's response to the initial findings

Following the uncommanded and unarrested flap extension on D-AAAY, and the finding of damage to the D contacts on the other three Challenger 604 aircraft in their fleet, the operator replaced and introduced their own precautionary life policy for the extend and retract relays.

Certification standard

The Type Certificate[1] for the Challenger 604 aircraft was issued by Transport Canada and, with a number of listed exemptions, is compliant with Title 14 of the Code of Federal Regulations Part 25 (FAR 25).

FAR 25.1309 covers equipment, system and installations and the following sections are applicable to the arrest of an uncommanded flap movement:

> *'(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that -*
>
> > *(1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and*
> >
> > *(2) The occurrence of any other failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable.'*

Analysis

The arrest of an uncommanded flap movement relies on the four extend / retract relays operating correctly to remove electrical power to the flap motors. Evidence from three aircraft inspected by the AAIB shows that these relays can fail and prevent correct operation of the uncommanded flap movement arrest system.

The failure of the relays on these three aircraft was caused by damage to the D contacts which switch electrical power to the BDUs. The damage was consistent with arcing between the contacts, which caused metal transfer and the welding of the contacts. As all the contacts in the relay are mounted on a common shaft, the welding of the D contacts would stop the other three sets of contacts from working properly. Examination of relays provided to the investigation, which had not failed in-service, also had damage to the D contacts showing that the damage had accumulated over a period of time.

During laboratory testing, when the BDU solenoids were de-energised, a transient voltage spike was seen to peak at up to 300 V and regularly exceeded 150 V. This spike is caused by a back-EMF, which could cause arcing across the D contacts. There is no protection within the electrical system to suppress this back-EMF.

Footnote

1 Transport Canada, Type Certificate Data Sheet, Number A-131, Issue 62, Issue Date September 14, 2022.

The relays have an inductive load life of 20,000 operating cycles. During a normal flight there will be four flap extensions and two flap retractions, with each movement energising and deenergising the BDU brake solenoids. This would mean the relays would reach their life after 5,000 flight cycles for the extend relays and 10,000 flight cycles for the retract relays. The three aircraft on which the relays had failed had flown 3,900 (retract), 4,687 (extend) and 4,344 (extend) flight cycles. The only damage seen on the relay contacts was due to arcing, indicating that the lower-than-expected time to failure was probably due to the unsuppressed back-EMF. Therefore, the following Safety Recommendation is made to Bombardier Aviation:

Safety Recommendation 2023-004

It is recommended that Bombardier Aviation introduce a modification on the Challenger 600 series of aircraft to protect the D contacts within the extend and retract relays of the flap operating system from unsuppressed back-EMF electrical arcing.

Airworthiness Directive AD CF-2023-07 requires a timing check on flap movement to be conducted within 100 flight hours or 15 months and, dependent on aircraft variant, repeated every 100 or 400 flight hours. This check will determine if a relay has failed, but it does not assess the condition of the contacts and will not identify a degraded relay that is close to failure.

The rate of accumulating damage on the D contacts is not known. Furthermore, the aircraft maintenance programme does not consider the component manufacturer's life of the relay of 20,000 operating cycles. The maintenance policy is for the relays to remain fitted to the aircraft until a failure is detected; however, detection can be many flight hours after a failure has occurred. The correct function of these relays is required for the operation of the safety critical, uncommanded flap movement arrest system; therefore, the following Safety Recommendation is made to Bombardier Aviation:

Safety Recommendation 2023-005

It is recommended that Bombardier Aviation introduce a life policy for the flap operating system relays on the Challenger 600 series of aircraft, which takes account of the component's specified life and is sufficient to ensure that any in-service damage on the D contacts on the extend and retract relays remains acceptable for continued operation.

The uncommanded, unarrested movement of the flaps is potentially catastrophic and requires two concurrent failures. The original safety case considered this to be extremely improbable. However, this investigation has identified that on at least three different aircraft a relay was in a failed condition for a significant number of flights, and the failure was not detected even though the flaps moved in one direction at half speed. The failure of any one of these relays is a latent failure because it is not annunciated to the operating crew or maintenance staff. The undetected latent failure of these relays suggests that the original safety case for the uncommanded, unarrested flap movement may no longer be valid. This is because the protection offered by the flap brake system is no longer available and a single failure of another part of the system could be sufficient to cause a catastrophic outcome. This possibility is unlikely to satisfy the 'extremely improbable' requirement. At the time of certification, FAR 25.1309 required that the occurrence of any failure condition which would prevent the continued safe flight of the airplane is 'extremely improbable'. To ensure that the Challenger 600 series of aircraft meets this requirement, the following Safety Recommendation is made to Transport Canada:

Safety Recommendation 2023-006

It is recommended that Transport Canada reassess the safety case for the flap operating system on the Challenger 600 series of aircraft to ensure it meets the requirements of Title 14 of the Code of Federal Regulations Part 25.1309.

Further investigation

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

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 Global 6000, LX-NST
No & Type of Engines:	2 Rolls Royce BR700 engines
Year of Manufacture:	2017 (Serial no: 9814)
Date & Time (UTC):	7 April 2022 at 1625 hrs
Location:	London Luton Airport
Type of Flight:	Commercial
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to right wing tip, flap fairing, leading edge slat and aileron
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	7,200 hours (of which 1,350 were on type) Last 90 days - 34 hours Last 28 days - 0 hours
Information Source:	AAIB Field Investigation

Synopsis

On approach to Runway 25 at London Luton Airport in gusty conditions, the right wing of LX-NST made contact with the runway causing damage to the wingtip, flap fairing, aileron and slat. The runway contact occurred during a baulked landing in which the pitch and roll combination was sufficient for the right wing to touch the runway for approximately 18 m.

The risk of wingtip contact is well known in this aircraft type and has been the subject of numerous previous reports including by the AAIB. As a result of this known risk, the manufacturer has taken a number of actions including improving training and publishing new guidance for pilots on techniques for wingtip strike avoidance. Before this serious incident, the manufacturer applied to Transport Canada for approval to make crosswind training a Training Area of Special Emphasis (TASE) for the Global Fleet. This would ensure that all training providers have a standardised approach to crosswind techniques and training, for both initial and recurrent training programs. At the time of publication, the manufacturer was in the midst of on-going discussions with Transport Canada regarding the details of the proposed TASE.

History of the flight

The aircraft departed from Biggin Hill Airport at 1605 hrs for a positioning flight to London Luton Airport. The flight was crewed by two pilots with no other crew members and no passengers on board. The commander was a training captain, and it was the co-pilot's first flight on the aircraft type. The co-pilot was PF.

The aircraft was radar vectored for an approach at Luton on Runway 25. The wind given on the ATIS before the start of the approach was 290/27G38 which gave a crosswind component of 23 kt including the gust. This was below the maximum demonstrated crosswind for the aircraft type. The aircraft was configured and began a stable approach on the ILS. The wind given by Luton ATC when the aircraft was cleared to land was 290/22G36 which gave a crosswind component of 22 kt. At 100 ft radio altitude (RA) the commander recalled that the aircraft began to be affected by what he considered to be turbulence generated by the nearby buildings but, although the aircraft was deviating slightly from the centre of the ILS, he considered it to be well within acceptable boundaries. At the 50 ft RA call, the autothrottle system (ATS) began to retard the throttles as designed. At some point after this the commander described how he suddenly felt the aircraft becoming unstable and beginning to drift to the left. He decided that the aircraft was no longer in a suitable stable state to land and, on taking control from the co-pilot, applied full power by pushing the throttles forward.

The aircraft rolled to the right before the right main gear momentarily touched down. During this, the right wingtip contacted the runway. The commander applied full left controls and the aircraft rolled rapidly to the left. The aircraft climbed away from the runway.

There were no control difficulties after the aircraft climbed away and the subsequent approach and landing was completed without further incident. After shutdown, the commander noticed that there was damage to the right wingtip, flap fairing, leading edge slat and aileron. There was no damage to the left wing.

Accident site

The aircraft had touched down on Runway 25 at Luton around the normal touchdown markers. There were marks visible from the right wing contacting the ground from around 390 m from the threshold of the runway for 18 m as shown in Figure 1.

Figure 1

Markings on Runway 25 with the arrow indicating the direction of landing

The winglet damage consisted of trailing edge and outboard skin damage. The flap fairing, which was composite construction, had been partly worn away. The outboard leading edge slat outer skin was damaged down to the second inner skin layer, and the aileron trailing edge lower outboard skin had been shaved off. Three of the static discharge wicks on the right aileron also required replacement. The damage is shown in Figure 2.

Figure 2

Damage to LX-NST Clockwise from top left – slat, winglet, aileron, flap fairing

The following parts were replaced:

- Right hand slat assembly
- Right hand aileron including three static dischargers
- Access panel

Repairs were made to the flap fairing and winglet trailing edge.

Recorded information

Closed-circuit television (CCTV)

LX-NST's baulked landing was recorded on the airport's CCTV system. Figure 3 shows the moment the right wing contacted the ground.

Figure 3

Redacted CCTV image of LX-NST's wing contacting the ground

Flight data and anemometry

The recorded data, downloaded from the solid-state FDR fitted to LX-NST, showed that the autopilot was disengaged at 450 ft RA. In the windy conditions, significant activity was recorded on the controls, especially the control wheel position, and, after the autopilot was disengaged, on the rudder pedals. This resulted in larger roll perturbations, but the aircraft's flight path was generally well controlled. At point 'A' on Figure 4, at 50 ft RA, the ATS retarded the throttles towards idle. The wind, sampled four times a second and recorded by the anemometer situated near to the touchdown point of Runway 25, was from 308° at between 17 and 19 kt and varied little over the next 10 seconds – between point 'A' and point 'C'. Three seconds after the ATS had retarded the throttles, at approximately 25 ft RA, a significant nose-left rudder pedal demand and corresponding right-wing-down wheel input was made to de-crab the aircraft and align it with the runway. At approximately 10 ft RA, during the de-crab manoeuvre, the rudder and wheel position were reversed to demand a nose-right and left-wing-down correction, but almost immediately afterwards, at point 'B', the landing was aborted and the throttles were selected to full thrust. However, the aircraft rolled to the right and, before the engines had developed a substantial increase in thrust, reached 10.5° right angle of bank with a pitch attitude of 9.5°. At this point, the right main gear briefly touched down and the wing contacted the ground. The aircraft then began to roll rapidly left to 7.5° angle of bank, which was countered by a large, swift right-wing-down wheel input. Shortly afterwards, at point 'C' – three seconds after the selection of TOGA, the engine thrust began to increase significantly and the aircraft began to climb away.

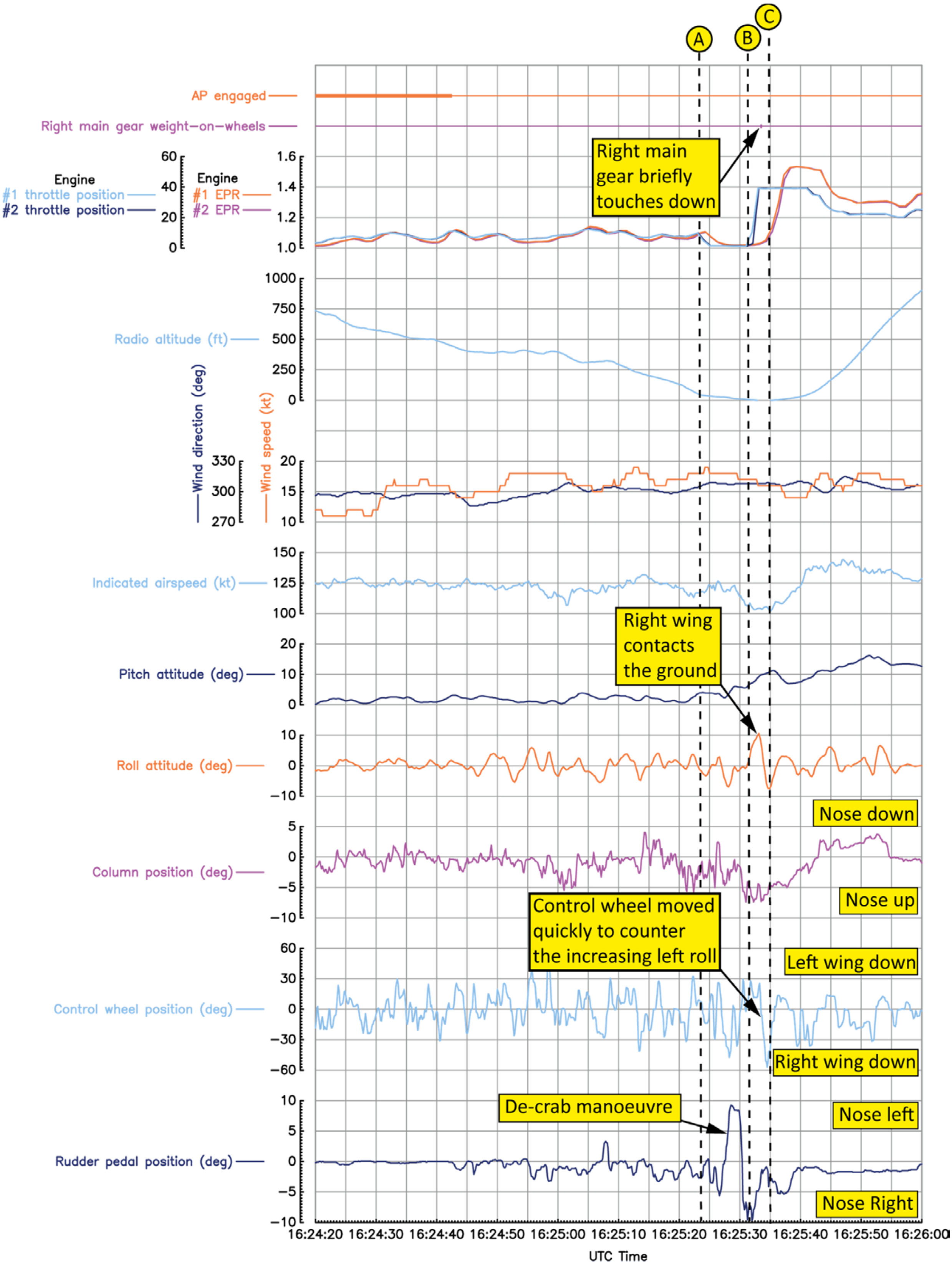


Figure 4

Flight data from LX-NST's approach and baulked landing

Aircraft description

The Bombardier Global Express is an ultra-long-range, high-speed, business/corporate turbofan powered aircraft. The aircraft has mechanically controlled, hydraulically actuated primary flying controls.

Approach speed control

The ATS is designed to manage engine thrust through automatic positioning of the throttle levers over the aircraft's complete flight regime. When the aircraft is on approach and the ATS is engaged, it will aim to maintain a speed appropriate to the configuration of the aircraft and then of the selected approach speed. The approach speed calculation for the aircraft type recommends adding half the gust to V_{REF} in gusty conditions.

The ATS has a retard mode which causes both thrust levers to automatically retard to idle at a fixed rate during the landing flare. The mode activates when the aircraft is in a landing configuration (Slats OUT / Flaps 30, Gear DOWN) and a RA of 50 ft agl is reached. The ATS remains engaged until touchdown to provide go-around thrust should a go−around be selected. If go-around is selected, then the ATS will advance the thrust leavers to the active upper engine rating.

Crosswind technique

The Flight Crew Operations Manual (FCOM) for the aircraft type specifies that pilots are to use the wings-level crab technique until the flare for landing with the aircraft pointing into wind and tracking the extended centreline. The flare is commenced at approximately 30 ft agl when downwind rudder is applied to align the aircraft with the centreline. Opposite aileron is required to maintain wings-level with the aim to touch down as soon as the aircraft is aligned with the runway. The FCOM warns against extending the flare or delaying the touchdown as this usually results in an increasing pitch attitude reducing the wingtip clearance in bank (as shown in Figure 5). For gusty conditions the FCOM recommends a '*deliberate positiv touchdown*'.

The maximum demonstrated crosswind component for takeoff and landing is 29 kt and is not considered limiting for takeoff and landing. The operator did not have an additional crosswind limit for co-pilots or inexperienced pilots beyond that of FCOM.

Go-around technique

The FCOM states that a go-around can be initiated by the pilots until thrust reversers have deployed. The technique requires the selection of maximum thrust and the simultaneous press of the go-around switch. The PF must then increase the pitch attitude smoothly to +10°. The aircraft type demonstrated minimum height for a go-around without touching the ground is 50 ft.

The FCOM also has a procedure for baulked or rejected landings which it defines as '*a missed approach initiated after the aeroplane has entered the low-energy landing regime. It may be before or after the main gear contact with the runway'*. In this low-energy state the engines are usually at or close to idle and they require several seconds to accelerate up to maximum thrust. The procedure requires the pilot to simultaneously select TOGA and advance the thrust levers, maintain the landing flap setting and maintain or slightly increase the pitch attitude. The pilot is warned to expect the aircraft to touch down and to keep the aircraft aligned with the runway with minimum bank angle. Only once the aircraft is safely established in the go-around and there is no further risk of touchdown is the configuration of the aircraft changed.

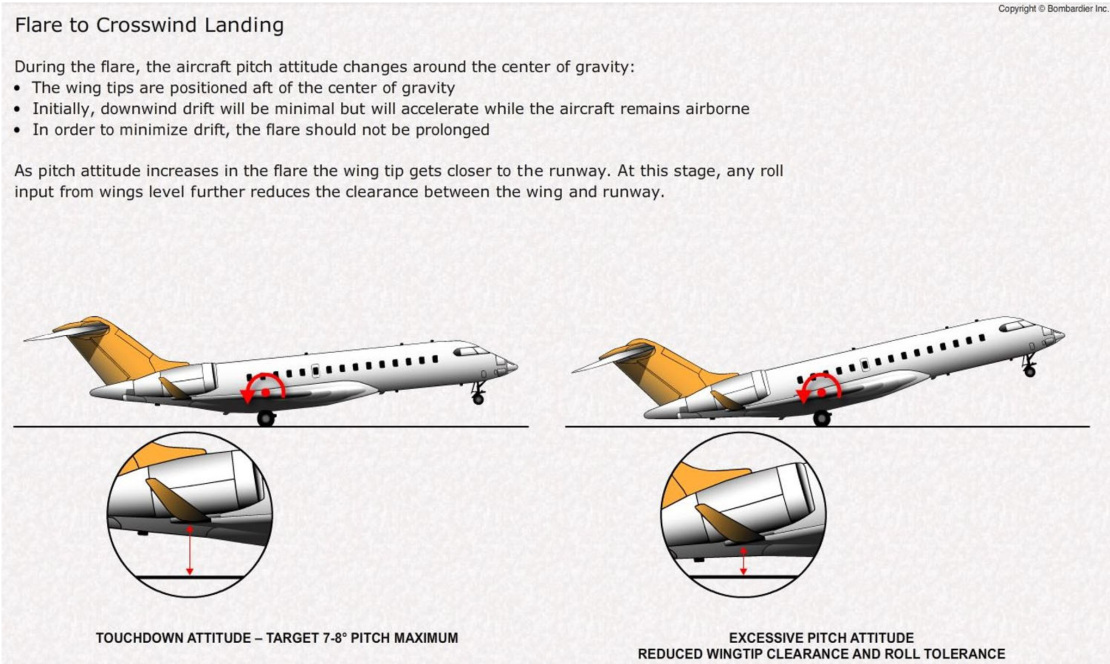


Figure 5

Flare to crosswind landing

Landing attitude and roll control

The aircraft manufacturer provided the following information on the pitch attitude and angle of bank combinations in which the wingtip will contact the runway (Table 1). The JIG figures are for when the wing is under no aerodynamic load (as if in the manufacturing jig) and the FLIGHT figures for a fully loaded wing with the aerodynamics bending the wing upwards. The true figure will lie somewhere between the two depending on many variations such as the aircraft weight, flap position, airspeed, and spoiler activity. The figures are intended to provide the pilots with a good idea of how much they can bank the aircraft with a given pitch angle close to the ground.

PITCH°	Bank Angle JIG° (Wing under no aerodynamic load)	Bank Angle FLIGHT° (Wing under aerodynamic load)
0	10.6	13.5
3	9.6	12.3
6	8.5	11.2
9	7.4	10.1

Table 1

Nose-up pitch attitude and angle of bank at wingtip contact

Previous incidents

The AAIB has conducted several investigations into very similar incidents with this aircraft type, most recently to CS-GLD[1]. This aircraft was operating into Biggin Hill with a crosswind from the right when the right wing contacted the runway. The damage to CS-GLD was almost identical to that on LX-NST. Worldwide, there have been a significant number of similar events; it is a known risk with this aircraft type as it has a relatively low undercarriage height and a long, swept-back wing.

The manufacturer has taken a number of steps to better understand, reduce and/or mitigate the risk of wingtip strikes in the aircraft type. These include completing internal safety studies, providing free online training modules as well as issuing further guidance to pilots setting out the correct technique to be used in a crosswind and its importance in terms of aircraft geometry. The manufacturer also introduced a new section into the FCOM called Recommended Operational Procedures and Techniques (ROPAT). The aim of the ROPAT was to provide a single document for pilots, operators, and training organisations to refer to. The ROPAT includes expanded guidance on the crosswind technique and wingtip strike avoidance.

The manufacturer also worked with a training provider to improve existing initial and recurrent training, ensuring it reflected the FCOM and ROPAT technique. In 2021 they also applied to Transport Canada for approval to make crosswind training a TASE for the Global Fleet. This would ensure that all training providers, both initial and recurrent have a standardised approach to crosswind techniques and training. At the time of publication, the manufacturer was waiting for Transport Canada's assessment of the proposed TASE.

Aircraft performance

When calculating the approach speed required for the aircraft type, pilots must first establish the reference approach speed for the aircraft weight (V_{REF}). This speed at the aircraft weight was 111 kt. They must then make a correction for half of the wind gusts, which in the case of LX-NST added an extra 7 kt, leading to an approach speed (V_{APP}) of 118 kt.

Footnote

[1] https://www.gov.uk/aaib-reports/aaib-investigation-to-bombardier-bd700-1a10-cs-gld [accessed December 2022]

The operator's Operating Manual Part B states that for landings on runways over 4,500 ft (1,372 m) the minimum approach speed is to be V_{REF}+5 kt. The manual does not make clear whether this is additional to any wind correction or is intended to make sure on longer runways the V_{APP} is always equal or greater than V_{REF} + 5 kt regardless of the wind. The commander understood that the 5 kt was in addition to the wind correction figure. During the approach the speed set was 123 kt which was 5 kt over the calculated VAPP.

The manual also states:

> *'Increased airspeeds above VREF may be required upon encountering turbulence, strong crosswinds or gusts. The increased approach speed shall be cross-checked to be compatible with the landing distance requirements. In any cases, during flare, crew shall make sure that the aircraft is not floating to such a point where the speed reduces significantly below VREF'.*

As designed, the ATS entered retard mode at 50 ft agl and the aircraft speed had dropped to 107 kt by 8 ft RA, which was 11 kt below the required, adjusted V_{REF} and 16 kt below the selected airspeed.

Previous incidents in this aircraft type resulted in further research into the control effectiveness at slower speeds. This research showed that roll control was effective down to much lower speeds than LX-NST reached in this approach and therefore full control was available at all times during the flight, touchdown and go-around.

Meteorology

Analysis of the weather show an occlusion holding to the north of the south-east region of the UK with a tight surface pressure gradient across the area. This would suggest that strong winds would be likely across the region. Radar images showed some showers in the area, some heavy. The cloud base at Luton never reduced below 4,300 ft aal during the period that LX-NST was in flight to the airport. It was daylight during the period of both approaches.

The TAF issues at 1103 hrs showed a strong westerly wind with gusts up to 44 kt with the wind becoming more west-north-westerly from 1600 hrs but reducing in strength. The airfield METARs show that the wind did move to a more north-westerly direction but that the reported gusts remained strong. The METARs for 1620 hrs and 1650 hrs are shown below:

METAR EGGW 071620Z 29026G36KT 9999 -SHRA BKN043 10/00 Q0991=

METAR EGGW 071650Z AUTO 30025G43KT 9999 FEW044 09/01 Q0992=

The Luton Airport wind reporting system recorded the wind speed and direction every four seconds. This wind was recorded by the anemometer close to the touchdown zone for Runway 25, south of the runway as shown in Figure 6. The figures from this recording at the time that LX-NST was approaching the runway are shown in Figure 4.

Airfield information

Luton Airport has a single runway orientated 07/25. The airfield sits on a hill at 526 ft amsl. The terminal and associated buildings are to the north of the runway and include a multistorey carpark which is 325 m from the centreline. Figure 6 shows these buildings in relation to the wind from the METAR and area in which the aircraft wing made contact with the runway.

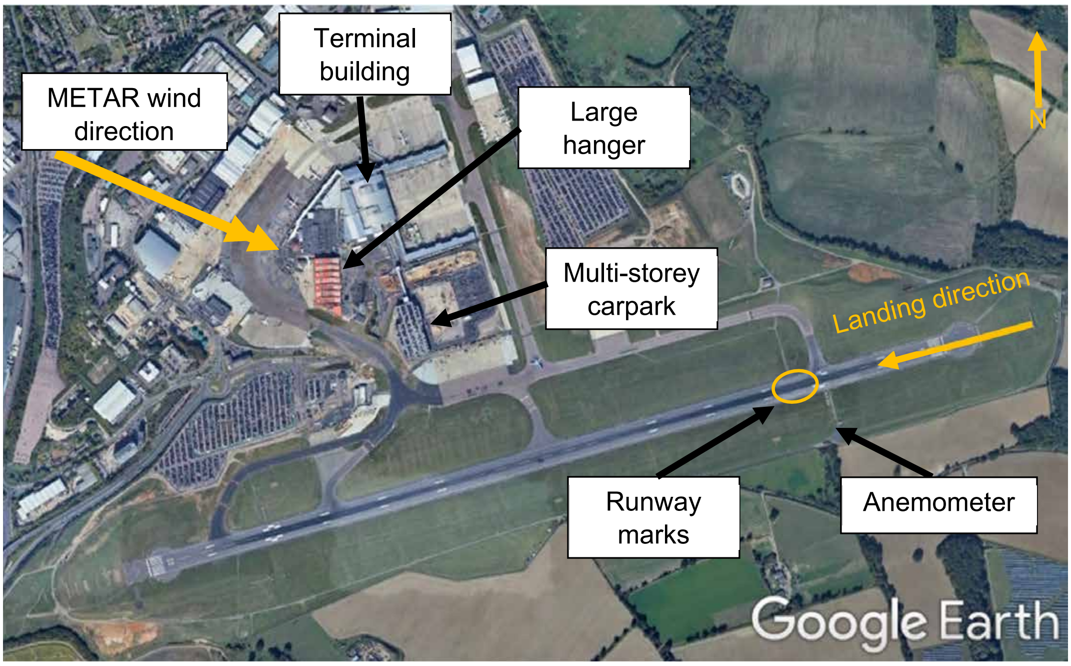


Figure 6
Luton Airport layout

Personnel experience

The co-pilot was on his first flight on type after completing his type rating. The type rating included base training, so the co-pilot had performed a minimum of six landings prior to the flight from Biggin Hill to Luton. He had also spent a considerable amount of time in the simulator supporting the training organisation's recurrent program waiting to begin his training on the aircraft itself. The commander considered that as the flight was so short it would be better for the co-pilot to operate as PF as the duties of the PM would make him extremely busy. The commander was aware that the co-pilot had significant experience of the aircraft type in the simulator and felt that he would benefit from being PF rather than PM for the sector. The commander did intend to remain as PM for the approach and landing at Luton but took control from the co-pilot below 50 ft RA with the ATS engaged in retard mode. The co-pilot stated that he made no further inputs onto the controls.

The commander had been a training captain at a previous employer, completing a Type Rating Instructors course in 2016. He had completed the operator's required training to be a line trainer. The training did not include any practise of taking control close to the ground nor any training in conducting go-arounds from low altitude close to the runway, although he had received training in baulked landings below the approach minima but above 100 ft agl. Although the commander had not flown the aircraft in the previous 28 days, he did not consider this to be unusual in the work pattern of the operator.

Decision making

The commander decided that the co-pilot would be PF for the sector on the basis of his previous experience doing such flights, which are very short and involve a significant amount of ATC frequency changes and mean the PM is working very hard to complete the required tasks during the flight. He felt that the weather was suitable for the co-pilot to operate as PF for the flight although he would review who would fly the final approach and landing at Luton once he had up to date wind information from Luton ATC. Having listened to the ATIS he considered that the crosswind was well below the aircraft limits and that the co-pilot was sufficiently experienced from the simulator that he could continue to act as PF for the approach and landing.

Once on the approach the commander continued to monitor the co-pilot whom he felt was dealing well with the conditions. From the point at 100 ft RA when the commander first sensed the changing wind to when he applied full thrust was approximately 10 seconds. He did not press the go-around switch as he was unsure as to whether it would work with the ATS in retard mode.

Analysis

Decision making

In allocating the roles for the flight the commander had considered his previous experience of the route, the weather forecast for Luton and what he considered would provide the greatest benefit for the co-pilot. The commander considered that the role of PM was more demanding on this route and therefore decided that it was best for the co-pilot to act as PF for the sector. The commander had also considered the weather at Luton, particularly the wind forecast and had decided that he would reassess the situation prior to allowing the co-pilot to fly the approach. There was no reduced crosswind limit for trainees or inexperienced pilots and the wind was within what he considered to be appropriate values for the co-pilot's experience level.

Whilst there was nothing in the operator's procedures to prevent the commander allowing the co-pilot to fly the approach into Luton, subsequent events left him taking control in a position of low-energy, close to the ground. The commander made a prompt and suitable decision to take control when he sensed the aircraft was no longer in a stable position to land, but he was left with little time in a very dynamic situation to decide what to do and action it whilst ensuring that the bank/pitch combination did not reach the critical point where the wingtip would make contact with the runway.

Although the commander had completed some training in initiating go-arounds below procedural minima, these had all been above the height at which he took control in LX-NST. He had received no specific training in taking control and completing a baulked landing despite conducting training in the aircraft with inexperienced pilots.

Wind conditions

The approach was stable with a crosswind from the right which varied in speed and direction. With the aircraft below 100 ft RA the commander suddenly sensed that the aircraft was drifting sideways and took control. He selected full thrust and began a go-around. The crosswind component from 50 ft RA to 20 ft RA was less than 10 kt but as the commander began the go-around he felt that the wind shifted in both direction and strength. With the aircraft in a low-energy state, and an increasing pitch angle, the aircraft touched down momentarily on its right main wheel and the wing tip contacted the runway. The crosswind component did not exceed the maximum demonstrated value during the approach, baulked landing or go-around although the variations in strength and direction made controlling the aircraft close to the ground more challenging than a steady wind.

The layout of Luton Airport has a large multistorey car park, hangars and the terminal building to the northwest of the touchdown zone. This can mean that with a strong north-westerly wind, there can be turbulence and variations in the wind as aircraft land on Runway 25. Although the wind data from Luton does not show a large shift in wind direction or strength during the baulked landing, it is possible that the aircraft was affected by low-level turbulence or wind changes that did not reach the airport anemometer position and therefore are not recorded.

Aircraft operation

The speed the pilots flew on the approach was above that calculated by the manufacturer taking into account the aircraft weight and the wind correction. The pilots added an additional 5 kt above that required by the operating manual. Despite this additional 5 kt, once the ATS entered retard mode at 50 ft RA and the thrust levers moved back to the idle position, the aircraft speed dropped to 16 kt below that selected (V_{REF} -11 kt) by the time the aircraft reached 8 ft RA. Previous research carried on the controllability of this aircraft type at slow speeds showed that full controllability in all axes was available to much lower speeds than LX-NST reached on this approach.

The go-around and subsequent approach were performed without incident, and the pilots were unaware until after they had shutdown that the right wing had contacted the runway.

Aircraft manufacturer

There have been a number of previous incidents on this type, including those previously investigated by the AAIB. The manufacturer took action to ensure that pilots are fully aware of the risks and have received suitable specialist training in handling the aircraft in strong crosswinds. At the time of publication, the manufacturer was working with Transport Canada to approve the TASE for the Global Fleet, which should ensure that the correct and consistent technique is taught in both initial and recurrent training.

Conclusion

The pilots of LX-NST made an approach to Runway 25 at Luton with a strong and gusty crosswind. The co-pilot was flying the approach until the commander sensed the aircraft begin to drift sideways around 100 ft RA. The commander took control and began a go-around during which the pitch of the aircraft increased whilst the aircraft rolled to the right. The combination of the pitch and roll led to the right wingtip making contact with the runway. Wingtip strikes, particularly during crosswind conditions, are a known risk on the aircraft type that the manufacturer continues to address through publications and training.

Whilst the wind data from the airport did not show any large changes in wind speed or direction, it is possible that the aircraft was caught by some low-level turbulence or wind changes that did not reach the anemometer.

The commander was conducting line training for the co-pilot who was new to the aircraft type. Although the operator had no crosswind limitations for inexperienced pilots, and therefore there was nothing to prevent the co-pilot flying the approach, the commander subsequently faced taking control of the aircraft in a low-energy state close to the ground.

Safety actions

The operator completed their own investigation into the incident and took the following safety actions:

- Simulator training to include new scenarios of crosswind landings and low-energy go-arounds
- This event was shared amongst all crews.

A number of other recommendations made in the operator's report are under consideration, including the introduction of a specific threat and error matrix for line training captains to assess the risk level of sectors, and a reduced crosswind limit for trainee pilots until they reach a certain level of experience.

The manufacturer continued to engage with pilots and operators of the aircraft type regarding the correct crosswind technique and the risk of wingtip strikes. They also developed a TASE proposal to further mitigate the risk, which was being assessed by Transport Canada at the time of publication.

Published: 16 March 2023.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-140, G-BCJN
No & Type of Engines:	1 Lycoming O-320-E3D piston engine
Year of Manufacture:	1974 (Serial no: 28-7425350)
Date & Time (UTC):	4 August 2022 at 0935 hrs
Location:	Cotswold Airport, Gloucestershire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Beyond economic repair
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	24 years
Commander's Flying Experience:	526 hours (of which 230 were on type) Last 90 days - 71 hours Last 28 days - 32 hours
Information Source:	AAIB Field Investigation

Synopsis

During an attempted go-around the aircraft veered left from the runway track. The instructor was unable to establish a climb and the aircraft touched down approximately 350 m from the end of the runway, tracking approximately perpendicular to the left of the runway track. As the aircraft touched down it passed between two parked, out of use, airliners and its right wing tip struck the nose landing gear of one of the parked aircraft. The outer portion of the right wing was severed and the aircraft continued across the grass. It passed through the airfield perimeter fence, crossed the A429 road and came to rest in a ditch adjacent to the road.

There had been a confused handover of control between student and instructor that meant the go-around actions were not completed effectively. This resulted in the aircraft flying at very low height at an airspeed that was probably below the minimum power speed, leaving it with insufficient power to climb away.

History of the flight

The intended flight was a circuit training detail for a PPL student. The instructor and student had flown together previously and met in the flying school to discuss the sortie content. The instructor's preference was to conduct circuits at Bristol Airport, where the operator is based, as he felt this would be the most beneficial for the student. However, circuit training at Bristol was not available due to high traffic levels and so the instructor selected Cotswold Airport (Kemble) as an alternate. The plan was to transit to Kemble, join the circuit, then do one circuit to a powered approach before moving to glide circuits.

The student went to the aircraft (Figure 1) and completed the pre-flight checks.

Figure 1
Piper PA-28-140

On arriving at the aircraft, the instructor checked the engine oil level and decided to add an extra quart of oil to ensure there was sufficient for the day's flying.

The student carried out the engine start. On the first attempt the engine immediately cut out as the fuel cock had been left at shut off. The engine started successfully on the second attempt and the subsequent taxi out and power checks were uneventful. The aircraft departed from Runway 27 at 0851 hrs.

During the takeoff the student rotated the aircraft at 52 kt rather than 60 kt and continued to have difficulty with speed control during the climb-out.

The aircraft then flew to Kemble to join for the intended circuit training. For the overhead join the student allowed the aircraft to fly approximately 300 ft below the intended altitude but the instructor decided to allow him to continue. There was another aircraft in the circuit and the student positioned on base leg too close behind it, so the instructor took control and flew a go-around. He then repositioned the aircraft for the student to conduct a powered approach from base leg. During the final approach the student allowed the airspeed to become too low, so the instructor took control, added power and completed the touch and go. On the climb the instructor returned control to the student for another circuit to a powered approach. This approach was successfully carried out, though the student still required some assistance from the instructor.

On the third approach the instructor left more of the workload to the student. The student began his approach right of the centreline and then began to "snake" either side of it. Initially, the aircraft was too high on the approach, but the student recognised this and reduced power to idle to correct. The student then allowed the aircraft to descend below the approach path and added power, but as the aircraft pitched up to recover to the path the airspeed reduced. The aircraft was left of centreline by this point and at approximately 300 ft agl. The instructor considered that the approach was unsatisfactory and again decided to go around.

CCTV from the airport showed that the aircraft continued descending to touch down near the threshold of the runway, then turned sharply left and became airborne again. Once airborne, the aircraft continued to turn left but only climbed to approximately 20 ft agl. It passed over a fence approximately 100 m from the left side of the runway and then continued towards a row of parked airliners on Taxiway C, close to the southern perimeter (Figure 2). The aircraft descended as it approached the line of parked aircraft. It passed under the wing of an Airbus A319 and touched down as it passed between the A319 and an Airbus A321. The right wing tip struck the nose landing gear leg of the A321 severing the outboard section of the right wing. The aircraft then continued across the grass, passed through the aircraft perimeter fence and crossed the A429 road, which runs just outside the airport perimeter. The aircraft encountered no cars as it crossed the road, but struck trees surrounding a vehicle yard and came to rest in a ditch alongside the road.

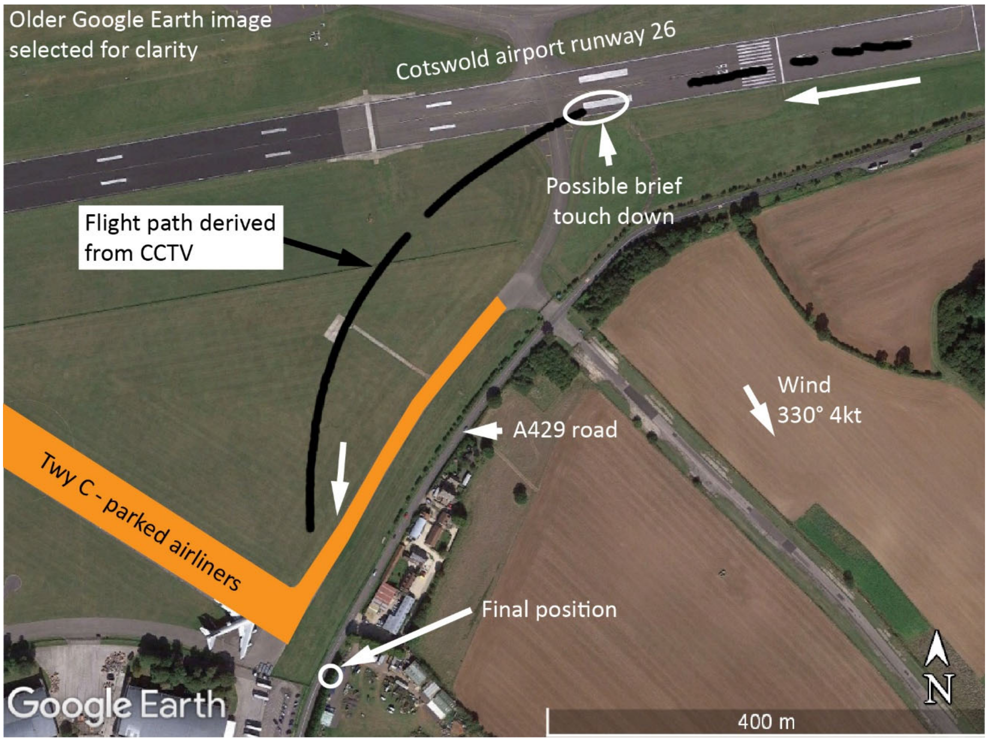


Figure 2
Kemble Airport diagram

Both pilots were assisted from the aircraft by the RFFS, exiting through the broken windshield. Both sustained minor injuries and were taken to hospital for precautionary medical examination, but both were released from hospital on the evening of the accident.

Pilots' recollections

The instructor recalled stating "I have control" at approximately 100 ft agl. The instructor applied full power and retracted the flaps to 25° which is standard for a go-around. At this point the airspeed was approximately 60 kt whereas the planned approach speed was 70 kt.

As the instructor applied power, he recalled the aircraft pitching up more than he expected and rolling left. The instructor noticed that the student was continuing to make control inputs. He described using explicit language to encourage the student to fully relinquish control. The instructor did not recall the student stating “you have control” at any point nor did he recall stating “I have control” a second time.

The instructor described the aircraft’s nose-up attitude as being above a level flight attitude and recalled there being 10 to 15° of left angle of bank. The speed was between 50 and 60 kt. He recalled wondering why the climb was stagnating but then recalled nothing else until the aircraft had stopped in a ditch alongside the A429.

The student recalled the nose being “steeply up” in the go-around which impeded his view ahead. He recalled seeing the parked airliners ahead but did not recall anything else until the aircraft had come to a stop.

Accident site

The accident site was located at the south-east corner of the airfield where several airliners were parked on Taxiway C. The first ground marks were made by the G-BCJN’s left landing gear tyre as it touched the grass under the left wing of the A319 (Figure 3). There was a section of outboard right wing from G-BCJN attached to the nose landing gear of the A321 and several pieces of fairing scattered just beyond. There were ground marks from both G-BCJN’s main landing gear tyres across the grass until the airfield perimeter fence, which had four posts knocked over.

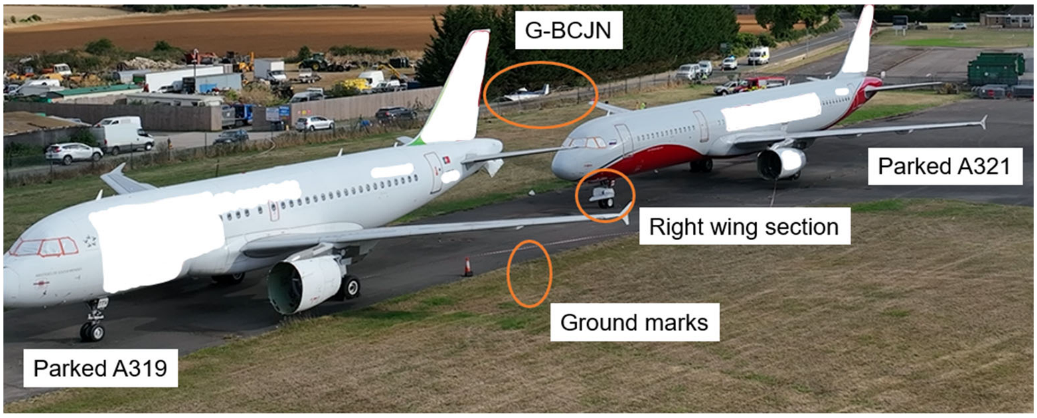


Figure 3
Accident site

The wire link fence was lying over towards the A429 road and there was evidence of fuel from the left fuel tank of G-BCJN across the road surface (Figure 4). G-BCJN had come to rest in a drainage ditch on the far side of the road with its right wing bent upwards and its left wing pointing forwards. There were marks on the tall fir trees from an impact with the nose of the aircraft.

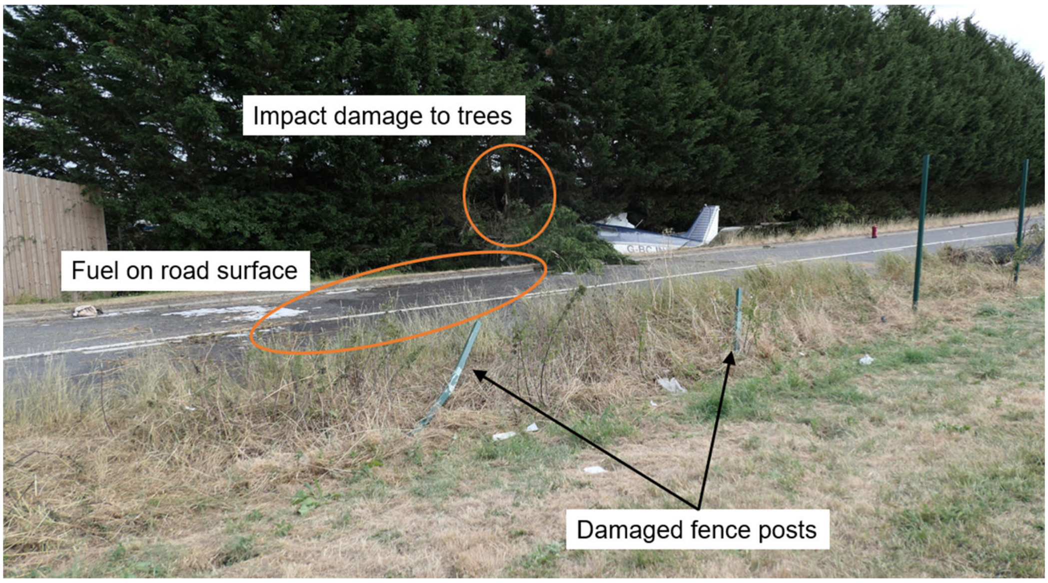


Figure 4
Accident site

Recorded information

The aircraft was not fitted with any devices that record aircraft position. An aviation app was being used on a mobile phone that records position, but this stopped tracking the aircraft before the accident landing. External tracking of the aircraft provided an overview of flight path information but no detail close to the ground.

A number of airfield CCTV cameras captured various stages of the approach, landing and attempted go-around. This was the best available source of information to track the aircraft movements from just prior to touch down through to the final aircraft position. The aircraft was small and pixelated in the CCTV recordings and suffered from video compression processes; this meant it was not always possible to track the aircraft accurately. CCTV recordings of the aircraft from different locations on the airfield enabled photogrammetry techniques to be used to determine the flight path and ground speed of the aircraft (Figure 2), albeit with errors and breaks in the data due to the quality issues. The altitude and groundspeed associated with this period are shown in Figure 5.

The recordings gave an impression of pitch attitude and heading but would not support calculation of orientation without significant errors. Figure 6 shows a significant change in heading over the space of 6 seconds. This period possibly included a brief touch down. After that, the pitch appears to have been held relatively high.

A CCTV recording was provided from a business situated across the A429 road from the airport. Figure 7 shows the aircraft touching down close to the parked A319 on Taxiway C, striking the nose landing gear of the A321 parked behind the A319, and crossing the road.

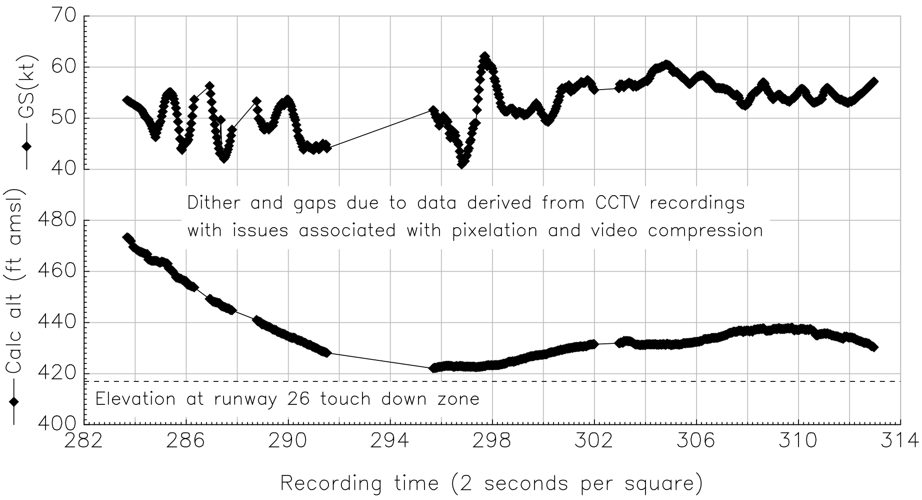


Figure 5

Altitude and ground speed derived from CCTV recordings

Figure 6

Four cropped CCTV images, two seconds apart, overlaid to show change in heading

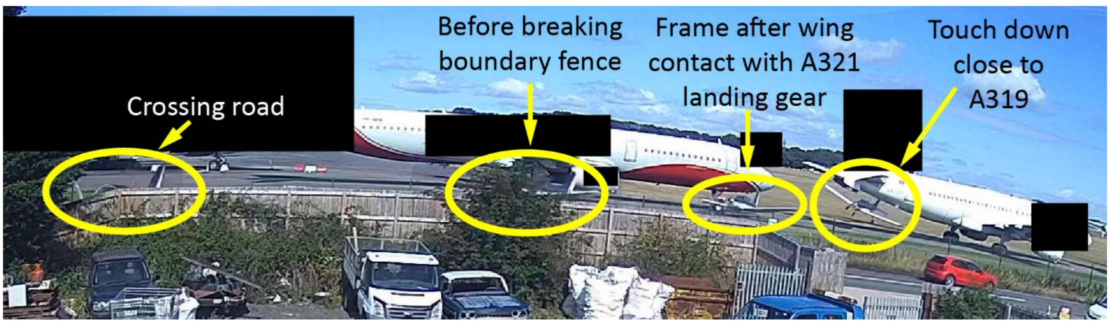


Figure 7

Four cropped CCTV images, one second apart, overlaid to show the final touch down, contact with a parked aircraft and the crossing of the A429 road

Aircraft information

G-BCJN was a 48-year-old Piper PA-28-140 powered by a Lycoming O-320-E3D engine. The aircraft is a conventional aluminium construction low wing aircraft with capacity for four people, and it has tricycle landing gear. The wing outboard trailing edge is equipped with an aileron and the inboard with a flap which can be deployed to 10°, 25° and 40°.

Airspeed indications

The student had flown the accident aircraft three times previously, but it is fitted with a different ASI to the other aircraft he had flown in his limited experience. The aircraft's ASI (Figure 8) has two concentric scales with mph on the outer scale and kt on the much smaller inner scale.

Figure 8
G-BCJN ASI

The student had difficulty with speed control in a previous sortie and had discussed this with the instructor, who had suggested that the student was focusing his attention on the outer scale and thus using speeds which were too low.

Aircraft examination

The aircraft was recovered to the AAIB facilities and examined for control continuity and engine performance. The investigation determined that before the impact there were no pre-existing defects that would have affected normal performance of the aircraft.

Aerodrome information

Cotswold Airport is a private general aviation airport, near the village of Kemble in Gloucestershire. Located 4.5 nm (8.3 km) southwest of Cirencester, it is used by flying schools, clubs, and industry as well as for the storage and recycling of retired airliners. The accident aircraft was operating on the asphalt Runway 26 which is 2,009 m long.

Weight and balance

The aircraft departed Bristol with a fuel load of 50 US gallons. The weight and CG position were calculated for takeoff and for the time of the accident (Figure 9). The aircraft was within the CG envelope throughout the flight.

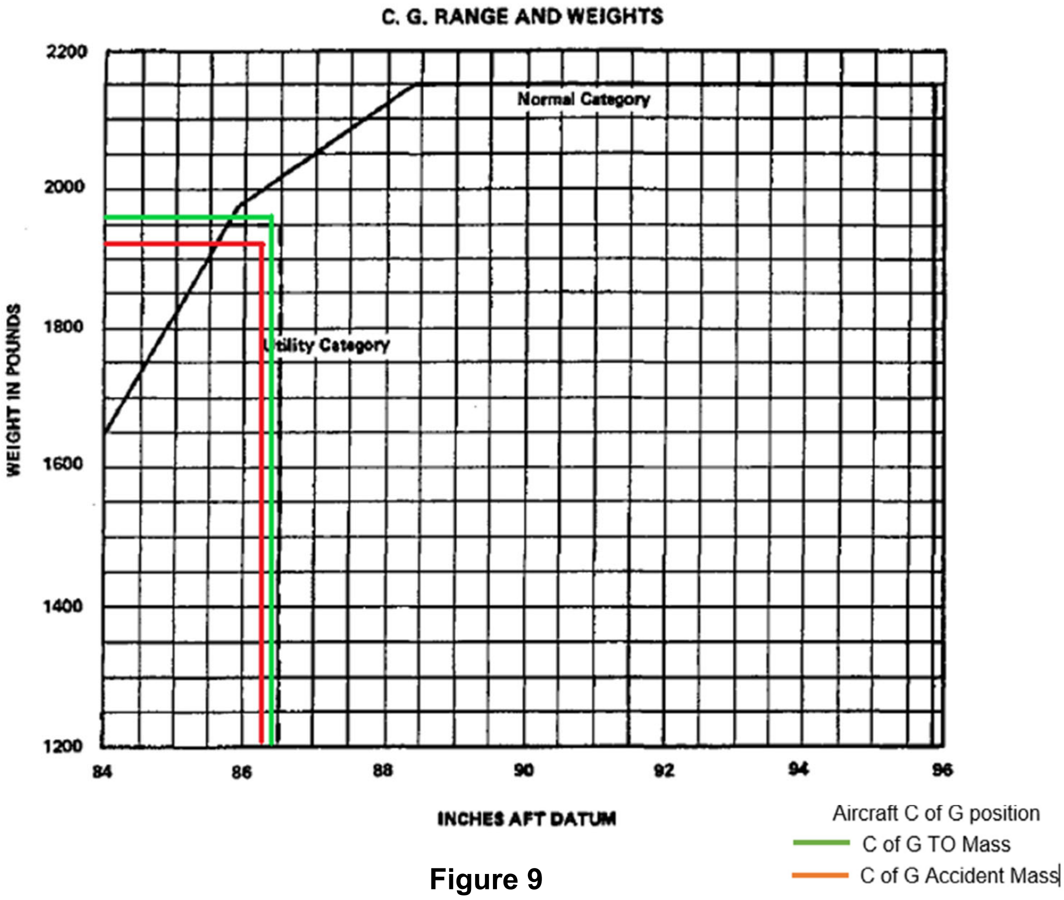


Figure 9

Aircraft weight and balance diagram

Meteorology

The last weather report generated by the control tower at Kemble before the accident was at 0900 hrs, and it stated that the wind was from 340° at 6 kt, visibility was greater than 10 km, there were 1-2 oktas of cloud at 800 ft and 3 to 4 oktas of cloud at 4,000 ft. As the aircraft was operating on Runway 26 there was a crosswind from the right. When the aircraft reported "Final" to ATC the responding RTF call gave a surface wind of 330° at 4 kt.

The closest airfield which generates a TAF is RAF Brize Norton and the details are as follows:

> For the period 0900 hrs on 4 August until 0900 hrs on 5 August the wind was forecast to be from 300° at 8 kt and the cloud was expected to be 2 to 4 oktas at 4,500 ft.

Personnel

The student had begun his flying with a different operator but had difficulty in finding consistent instruction and felt he was not making good progress. He therefore transferred to the accident operator in an effort to improve his progress. However, despite an improvement in the continuity of instruction, his progress remained slow. The student had repeated difficulties in the circuit with control of the approach and landing. He found managing ATC and RTF a challenge and this distracted him from key operational tasks. He had set a financial budget for PPL training and was concerned that his progress was insufficient to reach the required PPL standard within that budget.

The week before the accident the student had a discussion with his instructor and the operator's Chief Flying Instructor (CFI). At the meeting the CFI shared his view that it was unlikely that the student would reach the required standard for issue of a licence within his budget. The student had taken a view that he wished to continue flying to enjoy the experience if in the knowledge it would be unlikely to lead to the issue of a PPL. The accident sortie was the last instructional sortie before the student moved to more experiential content.

Other information

The operator used the Pooleys Instructor manuals as a source of briefing material. The handover/takeover is expressed in a standard exchange, with the instructor saying: "I have control", the student response being to relinquish control and respond "you have control". Should there be no response from the student then the instructor should repeat his order. In this event the instructor recalls making the "I have control" instruction, but the student does not recall hearing it. He did feel the instructors' inputs on the controls but uncertain of what was intended he continued to make control inputs in the belief he was assisting the instructor. The instructor does not recall repeating the "I have control" order and was confused with regard to the actions of the student. He did ask what the student was doing but the situation was not satisfactorily resolved and so there was uncertainty between the pilots as to what actions were being taken.

Drag curve

The aerodynamic drag on an aircraft is made up of components of zero lift drag and lift dependant drag. Both components vary with airspeed and a typical total drag diagram is shown in Figure 10. Minimum drag speed is the point at which the lowest total drag is achieved. It coincides with the speed for best lift/drag ratio.

If an aircraft slows below minimum drag speed, then the total drag on the aircraft is increasing. The shaded area is the minimum product of drag and airspeed at any point on the total drag curve, and it occurs at the minimum power speed. If the aircraft slows below this speed, then the power required to remain in level flight will increase. The minimum power speed for a PA-28 is not identified in the Pilots Operating Handbook. When the power required to remain in level flight equates to the maximum power available the aircraft will not be able to accelerate without descending to increase airspeed.

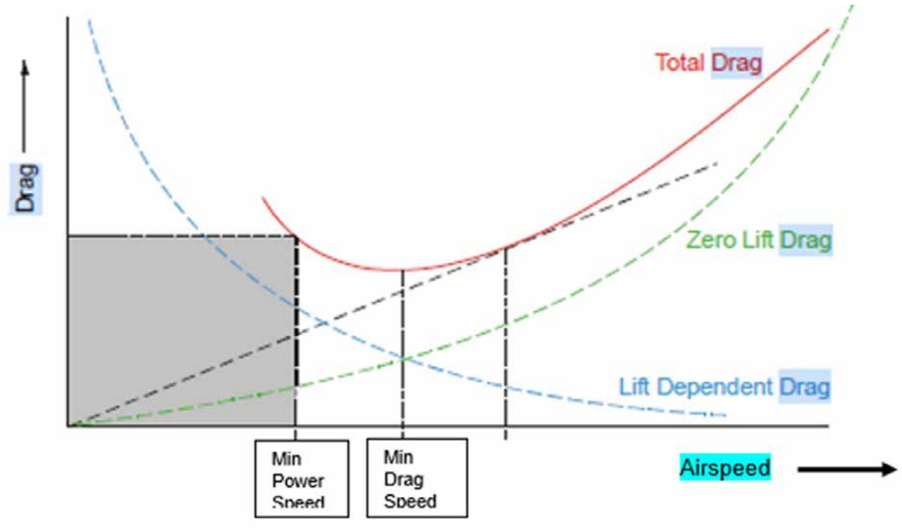


Figure 10

Typical Drag diagram

Engine overhaul

The aircraft was subject to a maintenance programme developed to comply with the requirements of Part-ML. The programme contained inspections at 50 hours, 100 hours and annual intervals. The engine maintenance programme was to be completed in accordance with the engine manufacturer's published instructions. The aircraft owner had contracted a Part-CAO organisation to manage the aircraft's continuing airworthiness and maintenance programme and to perform the required maintenance.

The engine manufacturer had published Service Instruction 1009 '*Time between overhaul (TBO) schedules*' which contains the standard overhaul time and any applicable extensions. The standard TBO for the O-320-E3D engine is 2,000 hours or 12 years, whichever is the sooner. If the engine is a new engine from the manufacturer, overhauled by the manufacturer or by an overhaul organisation using approved parts then an additional 200-hour extension can be granted. A further 200 hours can be applied if the engine is *'in frequent use accumulating 40 hours or more per month and has been so operated consistently since being placed in service'.* The engine fitted to G-BCJN had accumulated 2,366 hours at the time of the accident.

A review of the engine logbook revealed that it had been zero-hour overhauled in 2014 by an overhaul organisation using approved parts, but in only 20% of the 95 months the engine had been in service had it accumulated more than 40 hours of running time. Therefore, the engine had only qualified for a 200-hour extension.

The maintenance organisation reviewed its procedures and put in place more stringent checks regarding operating hours and the granting of life extensions.

Analysis

During a circuit training detail, the instructor was not satisfied with the student's handling of an approach. He recalls directing a go-around, but this order was not acknowledged by the student and nor did the instructor repeat his order when he did not receive the correct response from the student. Both pilots felt the other continue to make control inputs and there was confusion between them as to what actions were being taken. As a consequence, the go-around was not effectively instigated. The instructor believed the go-around actions of applying full throttle and retracting one stage of flap were carried out at 100 ft agl but the actual point of application is unclear. The CCTV images show that the aircraft descended and briefly touched the runway before lifting off again. It is therefore likely that full throttle was applied much lower than recalled by the instructor.

The aircraft touched the runway left wheel first causing it to yaw left. As the left wheel exited the runway onto the grass, the drag on the wheel caused the aircraft to yaw further left. It then became airborne at low speed and continued to fly across the grass at low speed and low height in a significantly nose-up attitude. With the flaps at 25° and at very low airspeed the aircraft was likely below the minimum power speed and therefore did not have sufficient performance to either accelerate or to climb.

The aircraft continued across the grass in a shallow bank to the left, increasing the divergence of heading from the runway. As the aircraft approached the line of parked airliners it descended and touched down just as it passed between two of them. Neither pilot recalls taking any action to avoid a direct impact with the parked aircraft and it is likely that this was the result of an instinctive action.

As the aircraft passed between the two airliners, its right wing struck the nose landing gear leg of one of them, the A321. The outer portion of G-BCJN's right wing was severed but the aircraft continued across the grass, running on its wheels. Neither pilot recalled closing the throttle and it is likely that the aircraft remained under power at this point. The aircraft's speed was nonetheless quite low, and it was further reduced by the collision with the airfield perimeter fence. As a result, the energy of the collision with the trees surrounding the vehicle yard was quite low and allowed the pilots to escape with only minor injuries. It was fortuitous that the aircraft encountered no traffic as it crossed the road.

Conclusion

A go-around was mishandled as a result of a confused handover of control between student and instructor. The go-around actions were not effectively instigated, and the aircraft diverged from the runway at low height and speed. The aircraft had insufficient performance to climb away, struck a parked airliner, exited the airfield, crossed a public road and collided with some trees.

Published: 23 March 2023.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna FRA150M, G-BDNR
No & Type of Engines:	1 Rolls Royce O-240-E piston engine
Year of Manufacture:	1976 (Serial no: 284)
Date & Time (UTC):	1 August 2021 at 1426 hrs
Location:	Approx 4 miles NNE of Retford Gamston Airport, Nottinghamshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - 1 (Minor)
Nature of Damage:	Nose leg collapsed, prop bent and engine cowling damaged. Subsequent engineering inspection found number 3 cylinder and piston had detached in flight
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	21 years
Commander's Flying Experience:	534 hours (of which 300 were on type) Last 90 days - 223 hours Last 28 days - 59 hours
Information Source:	AAIB Field Investigation

Synopsis

The number 3 cylinder and piston broke free from the engine causing engine failure during flight. A forced landing was carried out in a field resulting in significant damage to the aircraft but only minor injury to the passenger.

Examination of the engine crankcase found that the number 3 cylinder's base studs had all failed in fatigue due to crack progression. When cylinder studs were replaced with new items on other engines of this type during overhaul or maintenance, some of the studs' threads stripped before the required torque values could be achieved. Analysis revealed that the nuts used to fasten the cylinders were distorting and stripping the threads of the studs before reaching their required torque value or were failing at values just above the published maximum, leaving only a small safety margin. The investigation revealed that there was a mismatch of tensile strength between the nuts and studs.

Safety actions have been taken by the Type Certificate Holder to introduce a Service Bulletin to replace cylinder base studs during RR O-240 engine overhaul and carry out repetitive torque checks following their replacement. The cylinder base studs will be replaced with compatible alternative base studs which achieve consistent torque values above the maximum stated within the engine manuals.

History of the flight

On the return leg from a training flight to the Humber Bridge, the aircraft's engine started to "run 'rough" around 5 nm from Retford Gamston Airport (Gamston). A carburettor heat check was carried out at which point the pilot noticed that part of the right engine cowling was protruding outwards. Shortly afterwards, "control of engine power was lost" and the engine stopped. A MAYDAY call was transmitted on Gamston's radio frequency and a forced landing was made in a field 4.5 nm NNE of the airport. The aircraft touched down a quarter of the way into the field, but the aircraft could not be stopped before it hit a hedge at the edge of the field. The aircraft came to rest upside down (Figure1). Both occupants climbed out of the aircraft without assistance, although the passenger had sustained a minor leg injury.

Figure 1

After hitting a hedge, the aircraft came to rest upside down

Aircraft information

The Aircraft Renewal Certificate Part ML[1] was valid until 6 November 2021 and the aircraft's last maintenance check was a 50-hours servicing completed 5 July 2021. There were no faults recorded prior to the accident flight relating to the Rolls Royce (RR) produced O-240 engine fitted to the aircraft.

The aircraft had flown 233 hours since the engine, serial number 40R-079, had been overhauled on 7 October 2020.

Footnote

[1] EASA Part ML is a continuing airworthiness standard that dictates which maintenance must be performed on the aircraft and who can certify it.

Engine manufacturer and Type Certificate Holder

The RR O-240 four-cylinder piston engines were produced approximately 50 years ago before the FAA transferred ownership of the engine Type Certificates to Continental Aerospace Technologies (now the Type Certificate Holder - TCH) on 12 December 1983[2]. The O-240 engine Instructions for Continued Airworthiness (ICAs) and parts catalogue have been maintained at the last revision published by Rolls Royce in 1979. There has been no equivalent engine produced by the TCH in the intervening years.

Engine crankcase examination

During the initial examination of the aircraft, it was evident that the number 3 cylinder and piston had broken free from the crankcase and been ejected through the engine cowling during the flight. They were not recovered.

After removing the engine from the aircraft, examination of the engine crankcase revealed that the six engine cylinder base studs and two crankcase through-studs which attach the number 3 cylinder to the crankcase had failed (Figure 2).

Closer inspection of the fractured ends of the studs revealed crack growth marks and fatigue failures. The engine crankcase was sent for metallurgical and fatigue analysis including comparison to the manufacturer's material specifications. A second engine crankcase, serial number 40R-116, which was unrelated to G-BDNR but with a similar failure mode to cylinder 3 was also sent for comparative analysis.

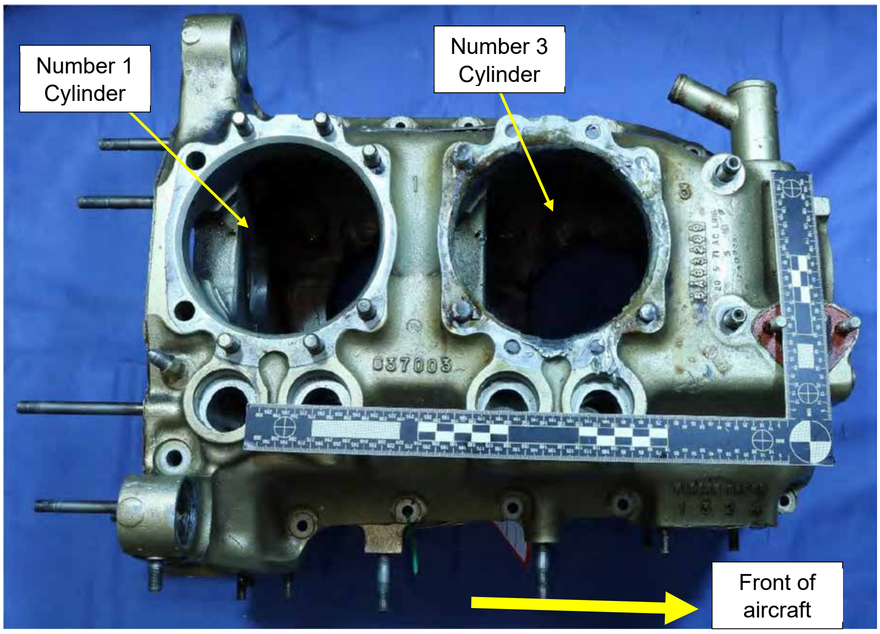


Figure 2

Crankcase right side showing numbers 1 (intact) and 3 (failed) cylinder studs

Footnote

2 Continental Service Bulletin SB00-12A.

History of engine cylinder stud failures

Research into similar engine failures revealed further accidents where the number 3 cylinder's base studs had failed while the engines were in use:

Aircraft G-PHUN: cylinder number 3, six base stud failures on engine serial number 40R-356 after 1,074 hours in service. The engine was overhauled on 16 May 2015. The engine was replaced with an overhauled unit.

Aircraft G-BDNR: cylinder number 3, six base studs plus two through studs had failed on engine serial number 40R-079 after 233 hours in service. The engine was overhauled on 7 October 2020. The crankcase was beyond economical repair.

Aircraft G-BDRD: cylinder number 3, six base studs and two through studs failed on engine serial number 40R-116 after approximately 900 hours since overhaul. The engine crankcase was beyond economical repair.

Aircraft G-BBEO: cylinder number 3, one cylinder base stud failed on engine serial number 40R-373 after 1,734 hours in service. The engine was overhauled on 19 December 2014. The failed stud was replaced.

Aircraft G-PPFS: cylinder number 3, one cylinder base stud failed on engine serial number 40R-347 after 1,214 hours in service. The engine had been overhauled on 16 July 2018. The base studs were replaced with studs from a new batch shortly after the accident to G-BDNR revealed legacy stud failures. When a 50-hours check was carried out, the lower front base stud on cylinder number 3 had sheared off and two of the front upper base studs had stretched and lost torque. Further examination found that the threads had deformed on the two upper studs.

Replacement stud issues

Following this accident and during the overhaul of an unrelated engine, the overhaul company decided to replace all the engine cylinder base studs with new studs and nuts 'on-spec'. When the engine cylinders were re-installed and the nuts on the studs torqued to between 34 and 36 ft/lbs in accordance with the engine overhaul manual, some of the studs failed before achieving the required torque. The threads on the studs appeared to have stripped during the torque process. The failures occurred despite using the manufacturer's supplied studs and nuts which were sourced from different batches and from various suppliers. Samples of the replacement studs were sent with the two damaged crankcases[3] for materials analysis and comparison with some of the legacy studs still installed in the crankcases. The legacy studs that had failed had done so after many hours of use rather than during initial installation.

Footnote

[3] Crankcases 40R-079 and 40R-116.

Further inquiries with two other engine overhaul companies revealed that issues with replacement studs failing during RR O-240 engine rebuilds was not uncommon. The cylinder base studs and nuts had simply been replaced and no action was taken to determine the cause.

Fatigue failure analysis of installed studs

For ease of reference, the cylinder 3 crankcase base studs from G-BDNR's engine, 40R-079, were arbitrarily numbered #1 to #8 (Figure 3).

Studs #2, #5 and #6 had failed just above the cylinder mounting face. The remaining studs had failed just beneath the cylinder mounting face. Studs #5 and #6 were through studs to help bolt the two halves of the crankcase together.

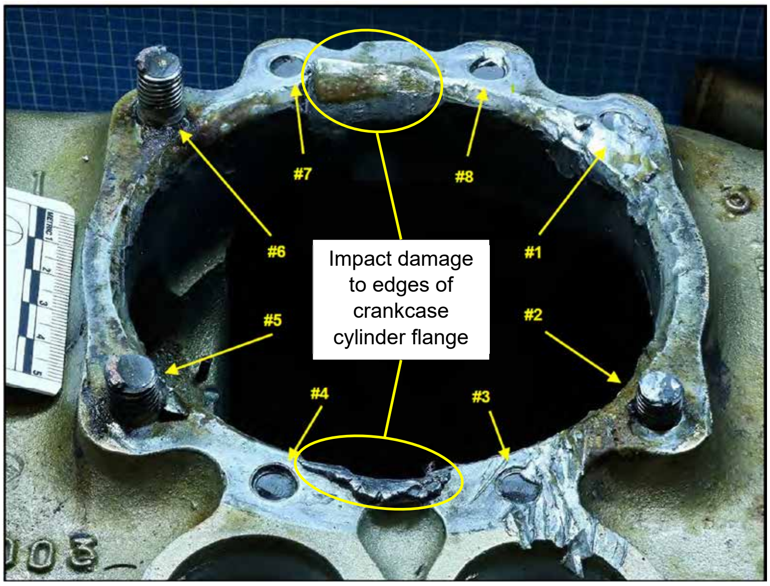


Figure 3

Close inspection of number 3 cylinder mounting surface

Hardness testing

Table 1[4] shows the hardness test results were within the Rockwell Hardness Rating C (HRC) specification (spec).

Some of the six fractured studs fitted to each of the two crankcases achieved hardness test results that were slightly above spec which, due to potential precision bias, would still be deemed acceptable. None of the samples from the three batches of replacement studs were out of spec.

Footnote

4 Through Studs #5 and #6 were not included in the hardness analysis.

	Stud #1	Stud #2	Stud #3	Stud #4	Stud #7	Stud #8
Engine 40R-079	32.1	32.6	30.1	29.1	30.3	31.8
Engine 40R-116	31.5	32.0	33.9	28.7	33.3	32.5
Batch GR063178	31.4	30.5				
Batch GR063924	30.3	29.6				
Batch GR13318	31.6	31.0				

Table 1

Rockwell Hardness Rating stud test results

Material composition testing

Results from material composition testing showed that both the fractured studs in the crankcases and the replacement stud batches were mostly aligned with the manufacturer's spec, with only slight deviations that would not have caused the problems experienced by the overhaul company.

Crankcase stud failure results

Closer views of the in-situ stud fracture surfaces show signs of post fracture damage (Figure 4). Crack progression markings on each of the fracture surfaces appear to show fatigue failures. The directions and extent of stable fatigue crack growth are shown in Figure 5.

On studs #1 and #2, fatigue cracks had propagated across almost the entire stud diameter, with only a small region of static fracture. This was consistent with a relatively low magnitude of stress repeated for a high number of cycles. In comparison, the remaining studs show larger regions of static fracture consistent with a greater magnitude of stress, repeated for fewer cycles. These findings indicate that the fatigue cracks on studs #1 and #2 had initiated first and would have accelerated the remaining stud failures. In each case, the fatigue crack fronts had initiated from multiple sites within the inside edge of the thread roots nearest the cylinder and propagated outwards.

Evidence from the scanning electron microscope revealed that fatigue striations could just be resolved in places around the edges of the studs. Their fine spacing was consistent with a high frequency vibration load spectrum. There was no evidence of corrosion pitting or pre-existing material or mechanical defects associated with crack initiation.

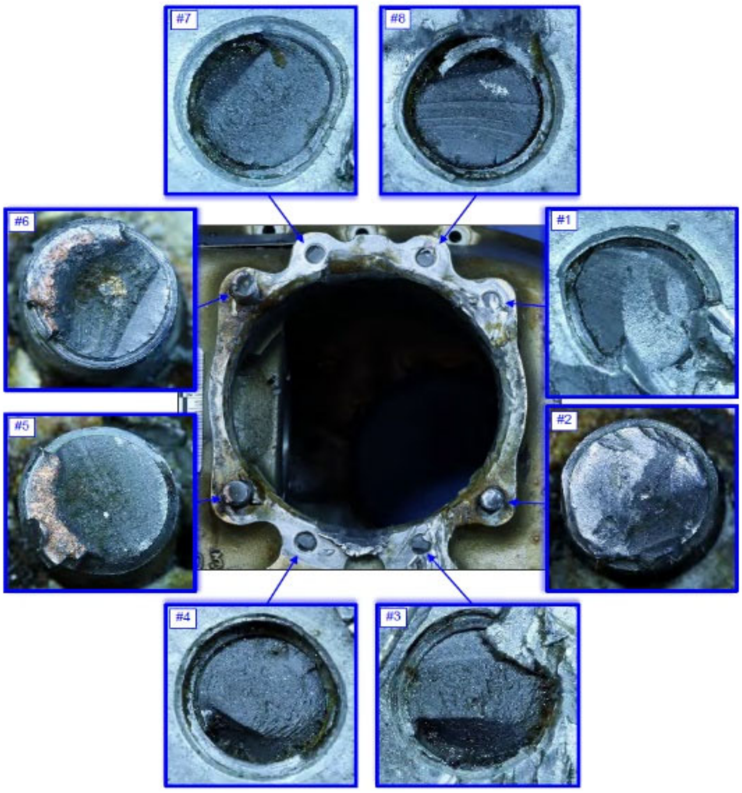


Figure 4

A closer view of the in-situ stud fracture surfaces

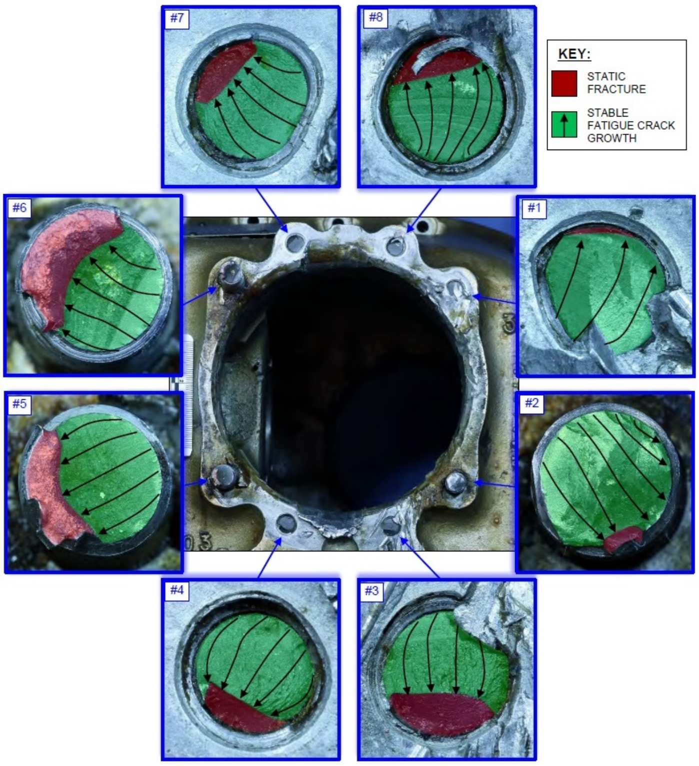


Figure 5

Directions and extent of fatigue crack growth

Failure of replacement studs and nuts

Comparing the results from the materials analysis and hardness testing did not reveal any significant differences between the legacy studs and the new stud samples from the three different batches, potentially ruling out the studs as the cause of the failures. As a result, attention turned to the replacement nuts. A series of torque tests were undertaken using combinations of nuts and studs from the engine TCH and nuts from an alternative engine manufacturer (AM)[5]. As the failure torque was often inconsistent, three studs and nuts were used in each of the 11 tests shown in Table 2 in order to draw statistically meaningful conclusions from the results.

	New Continental Stud (PN 401977)	New AM* Stud (PN 38-13)	Legacy Continental Stud (PN 633181)	High tensile Bolts (With luricant)	High tensile Bolts (Dry, no lubricant)
New Continental Nuts (PN 652421)	36-33-33 Ft/Lbs (T3) Nuts stripped thread	40-40-38 Ft/Lbs (T6) Studs failed in tension	38-37-35 Ft/Lbs (T8) 2 x failed in tension, 1 x stripped	46-48-44 Ft/Lbs (T7) Stud and nut threads stripped	54-50-52 Ft/Lbs (T9) Stud and nut threads stripped
New AM* Nuts (PN 383B)	68-65-60 Ft/Lbs (T5) Studs failed in tension	57-56-56 Ft/Lbs (T1) Studs failed in tension	57-56-56 Ft/Lbs (T2) Studs failed in tension	83+ Ft/Lbs Tensile failure	120-100-110 Ft/Lbs (T10) 2 x Tensile, 1 x thread failures
Legacy Continental Nuts (PN 652421)	38-38-42 Ft/Lbs (T4) Nuts stripped thread				

*Alternative Manufacturer

Torque values in O-240 engine overhaul manual for the cylinders are 34 - 36 Ft/Lbs.

The three numbers represent torque values from the results of 3 samples per test.

NB: T1 - T10 indicates test sequence, ie Test 1, Test 2 etc.

Note, all studs lubricated iaw Continental Manual except High tensile bolts (Dry, no lubricant).

All lubrication iaw Continental's Standard Practices Maintenance Manual M-0 which differs from the Engine Overhaul Manual (no lubrication).

Table 2

Torque test results using different combinations of nuts and studs

To eliminate the studs as a factor in the investigation, high tensile steel bolts were used in place of the studs on four of the tests to determine what effect the nuts had on the bolts when torqued to failure. The results showed a marked difference between the TCH nuts and the AM nuts. In addition, there was a difference in failure torque depending on the application of lubrication.

In general, the TCH supplied nuts and studs either failed at or below the required maximum 36 ft/lbs torque value in the engine overhaul manual, or at a maximum value of 40 ft/lbs (11% above the maximum torque value). By contrast, the AM nuts failed at a minimum of 56 ft/lbs, 55% above the 36 ft/lbs maximum torque value. The tests were carried out with all studs lubricated except in tests 9 and 10 (T9 and T10).

Footnote

5 Note that the AM nuts were not approved by the TCH for use on the RR O-240 engine – as they had similar dimensions to the TCH nuts they were used for comparison purposes.

Thread damage

Studs

Closer examination of the threaded and damaged sections of the studs revealed that the threads had been stripped. The crests of the threads appeared to have been progressively fractured by the nut as it was torqued, and the fractured crests pushed into the thread roots. This created a flat region around the circumference of the stud causing the nut to lose torque. There was also some evidence of stripped spiral thread material which could be remains from the nut thread (Figure 6).

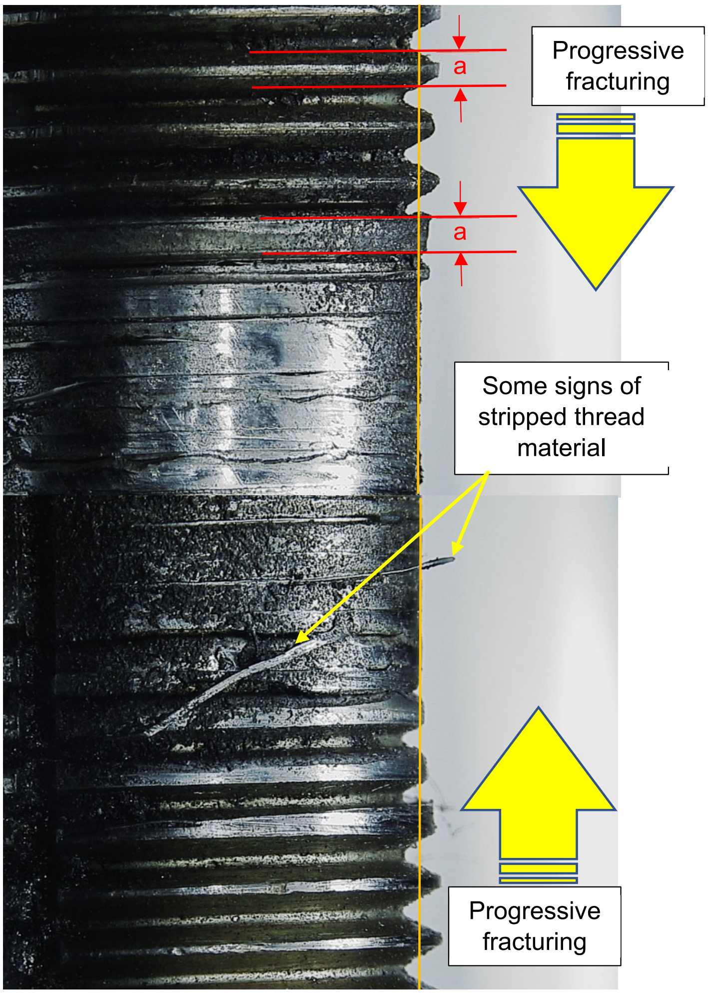


Figure 6

Test 3 - Stud with progressively fractured thread crests (a) and flattened section to half the depth of the intact threads

Nut design

Two types of TCH nuts were used during the tests; one of the samples from Test 3 used a nut employing Spiralock[6] technology (Figure 7) where a 30° ramp had been manufactured between the thread roots which was designed to resist loosening (See Spiralock section below).

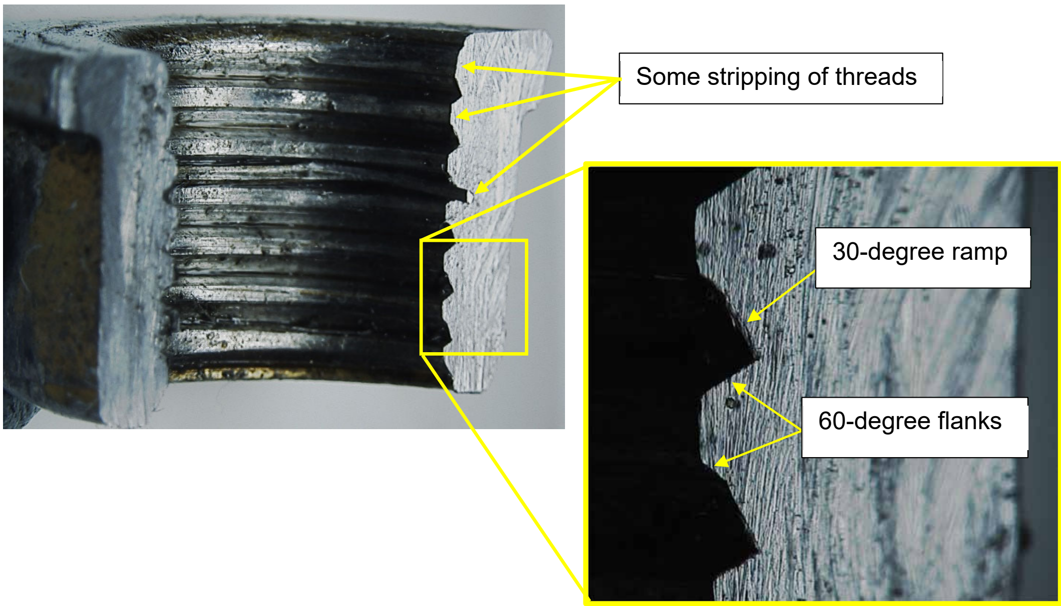


Figure 7

Test 3 - Section of Continental Spiralock nut showing stripped threads (left) and 30° Spiralock ramp (right)

Test 4 used legacy nuts from an old RR O-240 engine which had a standard 60° thread profile (Figure 8). All TCH nut types tested resulted in similar stud failures when torqued.

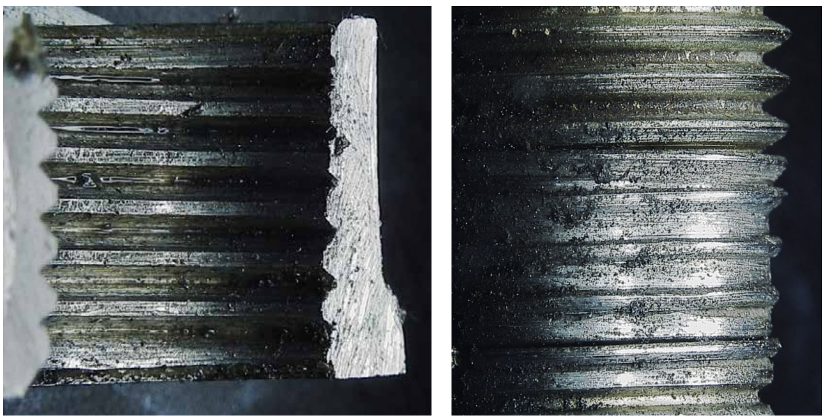


Figure 8

Test 4 - Section of Continental legacy nut showing some thread stripping (left) and distorted threads on the associated stud (right)

Footnote

6 Spiralock is a registered Trademark.

Spiralock technology

During the tests of the different combinations of nuts and studs in Table 2, it was noted that the majority of the new TCH nuts were stamped with the letters 'SPL,' indicating that they employed Spiralock[7] technology. Spiralock is an anti-vibration technology which uses a 30° wedge ramp at the root of internal threads (Figure 9).

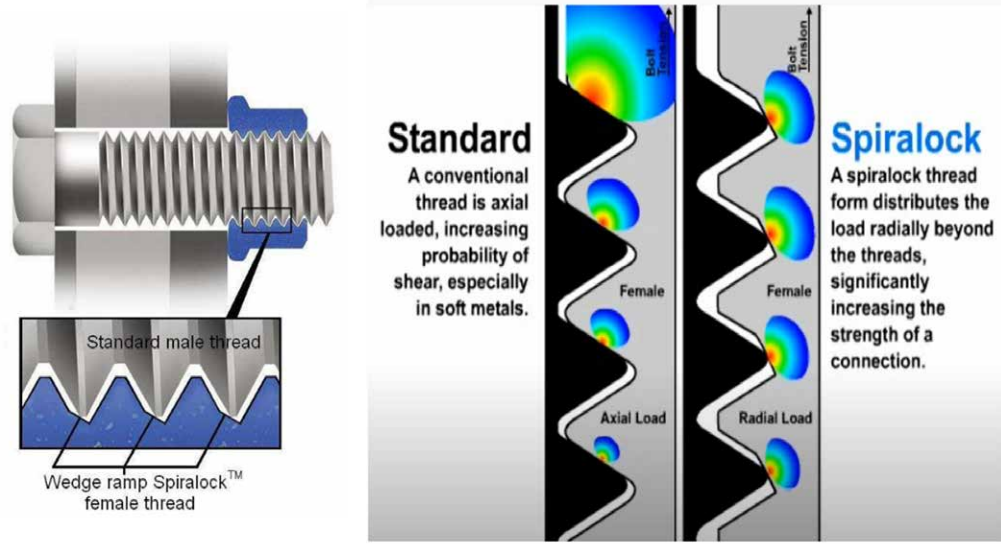


Figure 9

Spiralock anti-vibration thread
Images used with permission

When the clamp load is applied to the nut thread, the crest of the bolt thread is drawn tightly against the wedge giving a continuous spiral line of contact along the length of the engaged threads.

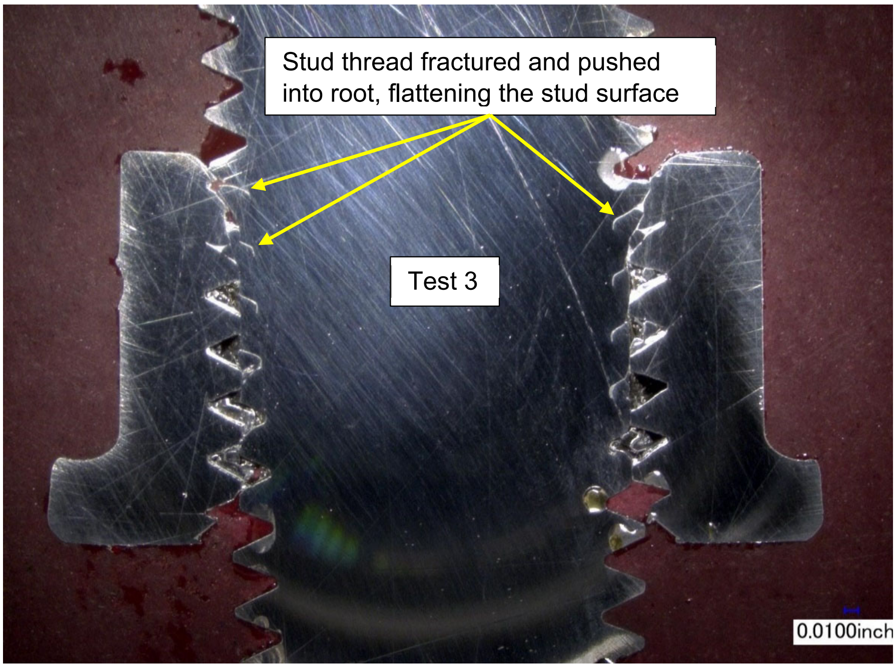
As the clamp load increases, the wedge eliminates the radial clearance that allows fasteners to loosen under vibration. This spreads the clamp load more evenly and allows a lower torque requirement than conventional threads.

The ramp profile at the root of the threads changes the load path on the in-contact thread from an axial direction, which increases the probability of shearing, to a radial load on the crest of the threads. This is designed to eliminate the requirement for secondary locking devices and to allow repeated use of the nuts. The AM nuts used conventional 0.375-24 UNF[8] threads.

Footnote

7 https://www.stanleyengineeredfastening.com/en/brands/optia/spiralock [accessed 12 February 2023].
8 0.375 inches or 3/8 of an inch width - 24 threads per inch Unified Fine Thread (UNF).

Test results from the manufacturer



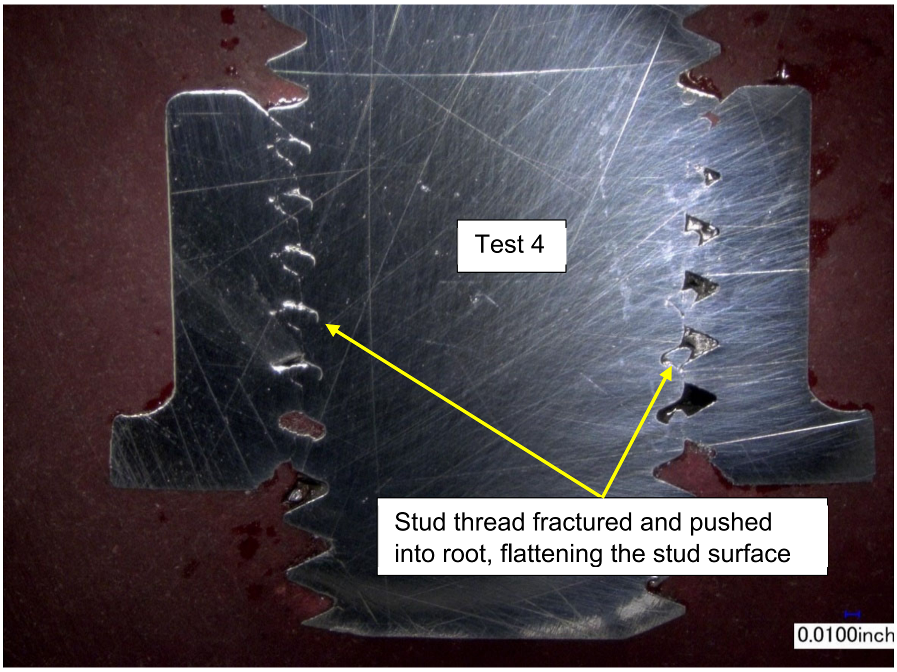


Figure 10

Sectioned samples from Tests 3 and 4 showing failure mechanism
Images used with permission

The manufacturer sectioned and examined some of the failed nuts and studs from Table 2 (Test samples 3 and 4), and the results can be seen in Figure 10. They show the stud threads had been damaged by the nuts in both samples. The broken thread crowns were pushed into their roots creating a flat section around the stud's circumference which caused the nuts to lose torque. Note both samples sectioned had not used Spiralock nuts.

Figure 11 shows that the crowns of the nut threads do not appear to extend fully into the roots of the stud. As a result, only approximately half the flank of the nut threads is in contact with the flanks of the stud threads. With only half the flanks in contact, the shear load is effectively increased which may have contributed significantly to the thread stripping. In addition, it is possible that with nut threads that fully engage with the stud thread flanks, the stud is more likely to fail in tension at high torque values than to strip the threads, as observed when the AM nuts were used.

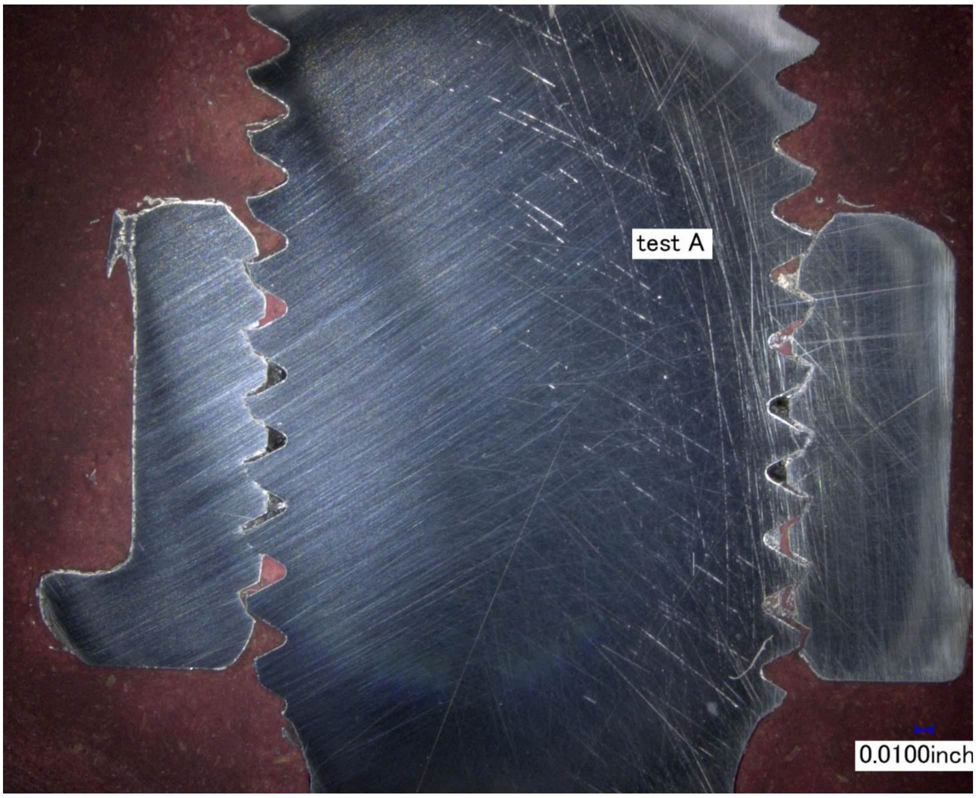


Figure 11

AM stud with matching tensile strength to Spiralock nut
Image used with permission

The manufacturer found that the base nuts had a higher tensile strength of 180 Ksi[9] than the studs, 140 Ksi. This mismatch of tensile strength allowed the nuts to fracture the crown of the stud threads creating a flat surface around the circumference, which probably contributed significantly to the torque failures. When an AM stud was used with a matching tensile strength to the nut, the nut torqued up to 55 ft/lbs before failure, 53% above the maximum torque value (Figure 11).

In this example, the nut threads do not extend fully into the roots of the stud threads which increases the axial shear forces for a given surface area of thread contact.

Footnote

[9] Ksi – Thousands of pounds per square inch.

Alternative cylinder base studs for RR O-240 engines

The TCH proposed the introduction of new base studs that more closely matched the tensile strength of the current cylinder base nuts. They stated that the new studs should be more resistant to thread stripping and have higher failure torque values. The replacement studs part numbers were 643651-1 for RR O-240 engines serial numbers 40R-200 onwards, and 643651-2 for engine serial numbers 40R-001 to 199. The test results in Tables 3 and 4 show that all the proposed replacement studs tested achieved the maximum torque value detailed in the respective engine overhaul manual and, when torqued to failure, they failed in tension with no thread stripping. Table 3 shows the results from the first batch of testing, Table 4 the second batch with each series of tests taking place at different workshops. A slight change was made to the torque technique for the second batch in Table 4 with the nuts slackened between incremental torque increases until failure.

	Continental Nut (PN 652421)							
	T1*		T2*		T3**		T4**	
Proposed New Continental Stud - Long (PN 643651-1)	Achieved 36 ft/lbs Y	Failure torque? 38 Ft/lbs	Achieved 36 ft/lbs Y	Failure torque? 37 Ft/lbs	Achieved 36 ft/lbs Y	Failure torque? 37 Ft/lbs	Achieved 36 ft/lbs Y	Failure torque? 37 Ft/lbs
Failure mode?	Tension		Tension		Tension		Tension	
Proposed new Coninental Stud - Short (PN 643651-2)	Achieved 36 ft/lbs Y	Failure torque? 44 Ft/lbs	Achieved 36 ft/lbs Y	Failure torque? 42 Ft/lbs	Achieved 36 ft/lbs Y	Failure torque? 54 Ft/lbs	Achieved 36 ft/lbs Y	Failure torque? 52 Ft/lbs
Failure mode?	Tension		Tension		Tension		Tension	

*Batch of Nuts supplied by Air Parts ** Batch of Nuts supplied by Multiflight

Torque values in O-240 engine overhaul manual for the cylinders are 34 - 36 Ft/Lbs.
NB: T1 - 5 indicates test sequence, ie Test 1, Test 2 etc.
Note, all studs lubricated iaw Continental Standard Practices Manual M-0.

Table 3

Torque test batch 1 results using proposed replacement studs

	Continental Nut (PN 652421)									
	T1		T2*		T3*		T4*			
Proposed New Continental Stud - Long (PN 643651-1)	Achieved 36 ft/lbs Y	Failure torque? 44	Achieved 36 ft/lbs Y	Failure torque? 56	Achieved 36 ft/lbs Y	Failure torque? 48	Achieved 36 ft/lbs Y	Failure torque? 47		
Failure mode?	Tension		Tension		Tension		Tension		T5	
Proposed new Coninental Stud - Short (PN 643651-2)	Achieved 36 ft/lbs Y	Failure torque? 52	Achieved 36 ft/lbs Y	Failure torque? 48	Achieved 36 ft/lbs Y	Failure torque? 51	Achieved 36 ft/lbs Y	Failure torque? 48	Achieved 36 ft/lbs Y	Failure torque? 51
Failure mode?	Tension		Tension		Tension		Tension		Tension	

*After T1, nuts slackened between each incremental increase in torque.

Torque values in O-240 engine overhaul manual for the cylinders are 34 - 36 Ft/Lbs.
NB: T1 - 5 indicates test sequence, ie Test 1, Test 2 etc.
Note, all studs lubricated iaw Continental Standard Practices Manual M-0.

Table 4

Torque test batch 2 results

Analysis

Fatigue failures

Metallurgical analysis revealed that the installed studs in the two RR O-240 engine crankcases had failed due to crack progression in high cycle fatigue. There was no evidence of corrosion pitting or pre-existing mechanical defects. As the nuts and studs fitted to the RR O-240 engine cylinders are not tracked items, it was not possible to determine when they had been replaced or their operational life.

The result of these high cycle fatigue failures was that two RR O-240 engines failed in flight leading to forced landings and exposing the pilots and passengers to significant safety hazards. Both aircraft were substantially damaged and both engines were beyond economical repair. As there was no way to determine how long engine cylinder base studs and nuts had been fitted to these engines when they failed, the engine studs and nuts should be replaced. Therefore, the following Safety Actions have been taken by the manufacturer:

Safety action taken

The Type Certificate Holder will issue a Service Bulletin to replace engine cylinder base studs for the RR O-240 engine series during their next overhaul.

The Type Certificate Holder will issue a Service Bulletin to introduce a repetitive torque check of engine cylinder base nuts following engine overhaul or replacement of any of the RR O-240 engine series cylinder base studs or nuts

Failure of replacement studs

When all the cylinder base studs were replaced with current TCH studs on the engine fitted to G-PFFS, one stud failed, two studs stretched and their respective nuts were found to have lost torque after only 50 engine running hours.

Noting the failure modes of the studs in Table 2, those fitted with AM nuts failed in tension once their maximum torque value was reached and provided a good margin of safety. The current TCH nuts with Spiralock technology did cause stud failure at slightly higher torque values, (close to the recommended values in the engine overhaul manual). Although the failure torque of the studs was inconsistent, when the TCH nuts did achieve their recommended maximum torque value, the margin before failure was no more than 11%.

The TCH's analysis found there was a tensile strength mismatch between the current replacement cylinder base studs and nuts. The higher tensile strength nuts stripped the threads of some studs during installation which resulted in a loss of torque. Two potential alternative cylinder base studs were tested which had closely matching tensile strength with the current nuts. The results resolved the issue of thread stripping, and failure torque values were above the maximum stated in the respective engine overhaul manuals.

As the cylinder base studs needed to be replaced due to the potential fatigue failure risk, the mismatch between the studs and nuts could be resolved by introducing compatible higher tensile studs already in use on other engine types. Accordingly, the TCH decided that standardising production components by replacing the studs was the best solution for the RR O-240 engine series. Therefore, the following Safety Action has been taken by the TCH:

Safety action taken

The Type Certificate Holder will issue a Service Bulletin to replace the current cylinder base studs in RR O-204 engines, with studs which achieve consistent torque values above the maximum stated in their engine manuals when using the current nuts.

Conclusions

Multiple failures of cylinder base studs on the RR O-240 engine type have been recorded since 2014, but unless they resulted in engine failure in flight, they were not reported to the manufacturer. Two of the three RR O-240 engine failures listed in this report resulted in in-flight failures but in all three cases, the stud failures were caused by crack progression in high cycle fatigue.

Some engine maintenance workshops had been aware that new, replacement studs could fail during initial installation. These occurrences were not reportable and the studs were simply replaced. When new studs were tested, some of them would not achieve their required torque values, and those that did failed at values just above the maximum stated in their respective engine overhaul and maintenance manuals. Further testing and analysis revealed that the nuts were causing the threads of the studs to strip.

Safety actions have been taken by the manufacturer to introduce a Service Bulletin to replace cylinder base studs during RR O-240 engine overhaul and carry out repetitive torque checks following their replacement. Suitable alternative base studs have been identified which achieve consistent torque values above the maximum stated in the engine manuals.

Published: 16 March 2023.

AAIB Correspondence Reports

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

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

The accuracy of the information provided cannot be assured.

ACCIDENT

Aircraft Type and Registration:	Extra EA 300/L, G-ZXEL
No & Type of Engines:	1 Lycoming AEIO-540-L1B5 piston engine
Year of Manufacture:	2006 (Serial no: 1224)
Date & Time (UTC):	19 June 2022 at 1555 hrs
Location:	Near Duxford Airfield, Cambridgeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to vertical tail, rudder and elevator
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	4,641 hours (of which 524 were on type) Last 90 days - 39 hours Last 28 days - 22 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

During a formation display routine the aircraft's elevator trim tab detached at its hinges. The tab was still attached to the aircraft via control cables, and this caused it to flap in the slipstream causing the elevator to move up and down and causing a loud banging noise as it repeatedly struck the side of the rudder. The pilot was able to control the aircraft and make a successful landing.

The elevator trim tab had detached due to a combination of the wrong hinge type being fitted (with only one third of the glue bonding area compared to the type of hinge that should have been fitted) and insufficient glue having been applied. Other aircraft with cracked hinge tabs were found which indicated that insufficient glue had also been applied between the hinges and the tab structure. The aircraft manufacturer has since published a Service Bulletin to mandate more frequent visual detailed inspections of the trim tab hinge areas and has advised the trim tab manufacturer to ensure that sufficient glue is used when bonding the hinges.

History of the flight

The pilot had departed from Duxford Airfield to conduct a public aerobatic display routine in a formation with three other Extra aircraft. About seven minutes into the routine, as the aircraft started to pull up into a formation loop, the pilot heard a loud banging noise from the rear, and his aircraft started to oscillate in pitch by about ± 20°. The control stick was being moved fore and aft without the pilot's input, in sync with the pitch oscillations. The control forces were sufficiently low that he was able to control the stick and to manoeuvre the aircraft away from the rest of the formation. The pilot stated that he was alarmed by the banging noise, and it got progressively worse. The pilot suspected a structural failure of some part of the elevator control system, but he could not see the elevator. He put the aircraft into a climb and manoeuvred away from the display site in anticipation of a loss of control and needing to bail out.

About 25 to 30 seconds after the incident had started, the banging and the pitch oscillations stopped. The pilot requested that one of the other Extra pilots inspect his aircraft and they reported that the elevator trim tab had detached and had embedded itself into the right side of the rudder. They also reported damage to the rudder and vertical tail.

The pilot carried out a low-speed handling check at 4,000 feet and found that the aircraft was fully controllable at normal approach speeds, so he positioned for a long straight in final approach to Duxford and landed without further incident.

Aircraft examination

The elevator trim tab of the Extra 300 is attached to the inboard trailing edge of the right elevator with two hinges. The trim tab is actuated via two control cables attached to a pitch horn on the lower side of the trim tab (Figure 1).

Figure 1
Intact elevator trim tab shown in the full up position

The elevator trim tab on G-ZXEL was found to have detached from the elevator at the hinge points, but it was still attached to the aircraft via the cables; this had allowed the tab to flap in the slipstream, repeatedly strike the side of the rudder, and pull the elevator up and down. The flapping stopped when the trim tab tip became lodged in the side of the rudder (Figures 2 and 3).

Figure 2

G-ZXEL lower side of right elevator showing trim tab detached at the hinge points but still connected via the control cables

Figure 3

G-ZXEL damage to the rudder and vertical tail

The top half of the trim tab had detached in flight and was not recovered. The inboard hinge had de-bonded from the wooden tab structure, while the outboard hinge had snapped and was not recovered.

The trim tab and the inboard hinge were sent to the aircraft manufacturer for examination. They determined that the inboard hinge was the incorrect size, with only one third of the glue bonding area compared to the type of hinge that should have been fitted (Figure 4). The correct hinge has part number EA-33203.1. The fitted hinge could not be identified. The aircraft manufacturer stated that it was not a part used in any of their aircraft.

Figure 4

Left: inboard hinge found on G-ZXEL. Right: correct size and shape hinge

The inboard hinge bonding surface revealed the remains of the glue that had been bonded to the incorrect sized hinge, but it also revealed the presence of glue on either side which showed that the correct sized hinge had been previously fitted (Figure 5). There was also evidence of dirt or soot in the bonding surfaces.

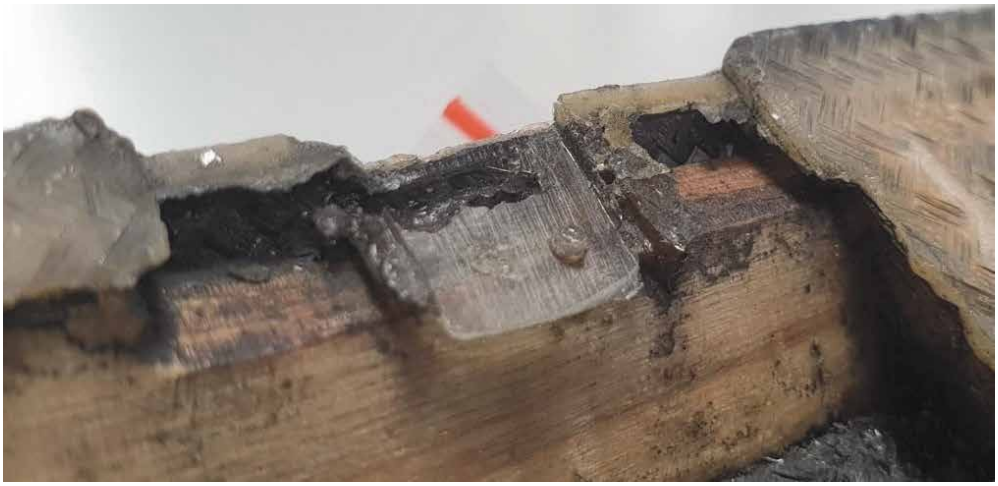


Figure 5

G-ZXEL trim tab bonding surface of the inboard hinge

The outboard trim tab bonding surface revealed that the correct type of hinge had been fitted, but the lower bonding surface was only partially (less than 40%) covered with glue.

Aircraft information

The incident aircraft, G-ZXEL (serial number 1224), was manufactured in 2006 and had accumulated 1,983 hours at the time of the incident.

The aircraft manufacturer's maintenance schedule had a 50-hour check to '*Inspect elevator trim system for proper operation and rigging*'. It also had a 1,000-hour check to carry out a '*Detailed visual of trim tab hinges, actuator lever for damage, cracks, excessive wear and proper bonding to the laminate. Detailed visual for delamination'*.[1]

G-ZXEL's last maintenance check was an annual inspection which included 50-hour check items; this had been carried out 39 hours before the incident at 1,944 hours on 23 February 2022. The aircraft's last 1,000 hour inspection had been carried out 139 hours before the incident, at 1,844 hours.

The horizontal tail assembly, including the elevator and trim tab, was originally manufactured by Extra, but since 2003 it has been manufactured by a sub-contracted external organisation. This organisation checked its paperwork for the trim tab supplied for G-ZXEL and there were no deviations from the type design noted, and they stated that they were not familiar with the type of hinge that was found fitted on G-ZXEL. The aircraft manufacturer also checked its paperwork and there were no deviations noted for the trim tab, and they concluded that the incorrect hinge was fitted during a repair after the aircraft was delivered in 2006.

The aircraft operator had purchased G-ZXEL in 2006 and had been its sole operator. Their maintenance worksheets for this aircraft did not show any elevator trim tab repairs. They also checked the worksheets for their similarly named G-ZEXL aircraft (in case there had been a paperwork mix-up) but there were no trim tab repair items for it either. A discussion with their maintenance organisation did not reveal any information about a trim tab hinge repair to G-ZXEL.

Additional trim tab examinations

After the incident to G-ZXEL the aircraft operator inspected its four other Extra EA 300/L aircraft. Two of these aircraft, G-ZEXL and G-OFFO, were found to have cracks at the trim tab hinges. Their maintenance organisation then inspected the tab of an Extra EA 300LT (G-GEJS) that was undergoing an annual inspection and found that its trim tab also had a cracked hinge, and it was very loose. The build year, total hours and maintenance history for the examined aircraft, including G-ZXEL, are summarised in Table 1.

The top four aircraft in the table have the same build year and sequential serial numbers. All the aircraft in the table had smoke systems fitted although the system had rarely been used on G-GEJS.

Footnote

[1] Extra Service Manual Extra 300L, version 25 February 2022.

Aircraft	Build Year	Total Hours	Trim tab state	Maintenance
G-ZXEL, EA 300/L, sn 1224	2006	1,983	Separated in flight	39 hours since annual; 139 hours since 1,000 hr inspection
G-ZEXL, EA 300/L, sn 1225	2006	2,276	Cracked	41 hours since annual; 541 hours since 1,000 hr inspection
G-OFFO, EA 300/L, sn 1226	2006	2,055	Cracked	15 hours since annual; 217 hours since 1,000 hr inspection
G-ZXCL, EA 300/L, sn 1223	2006	2,049	No cracks	42 hours since annual; 261 hours since 1,000 hr inspection
G-ZXLL, EA 300/L, sn 1319	2011	1,326	No cracks	34 hours since annual; 377 hours since 1,000 hr inspection
G-GEJS, EA 300LT, sn LT032	2015	278	Cracked and loose	36 hours since annual

Table 1

Details of G-ZXEL and other aircraft inspected after the incident

Examinations revealed that all the aircraft in the table, apart from G-ZXEL, had the correct size hinges fitted. Photos of these tabs are shown in Figures 6 to 8.

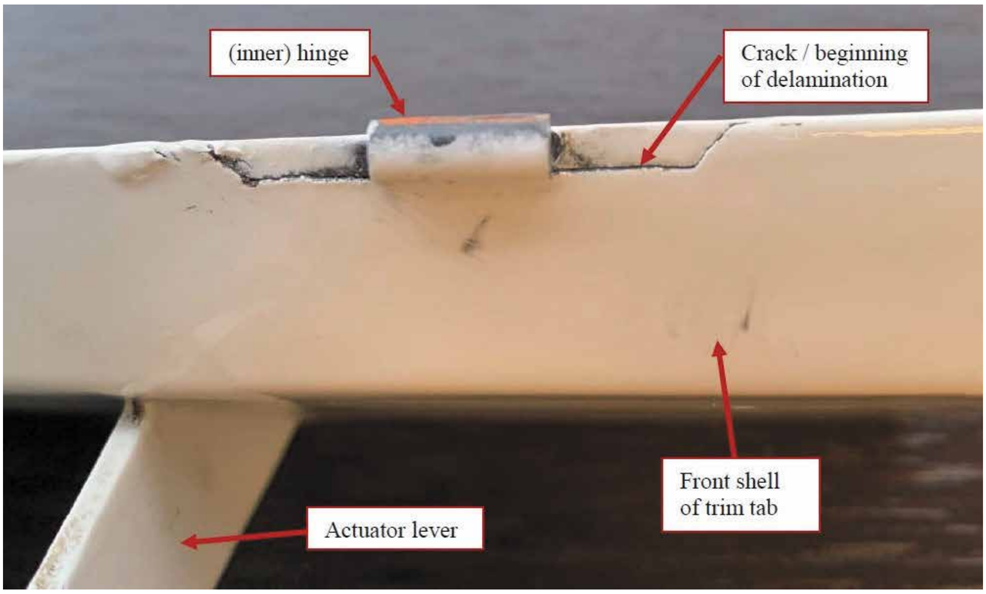


Figure 6

Cracked tab inner hinge from G-OFFO

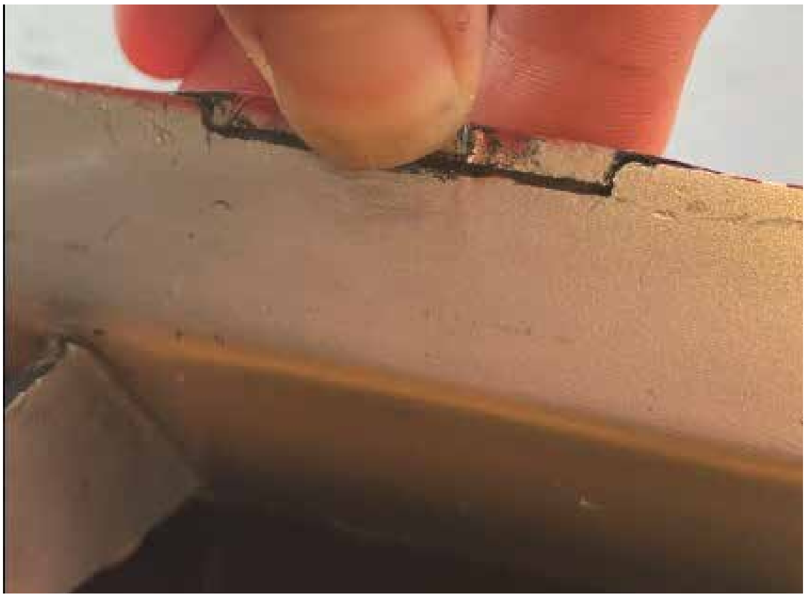


Figure 7

Cracked tab inner hinge from G-ZEXL
– shown with pressure applied to lift the hinge

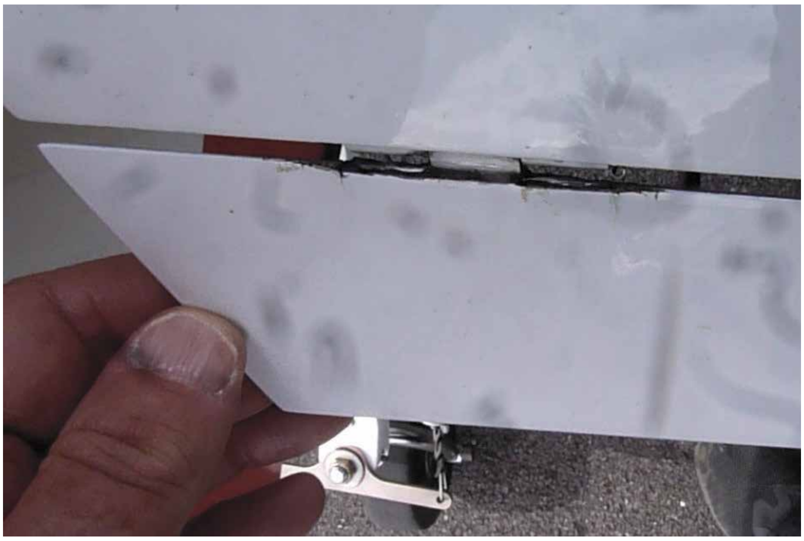


Figure 8

Cracked and loose tab inner hinge from G-GEJS
– shown with aft pressure applied to tab

All the failed and cracked trim tabs identified in this report were visually examined by the aircraft manufacturer in conjunction with an investigator from the German Federal Bureau of Aircraft Accident Investigation[2]. The tabs from G-ZEXL and G-GEJS were also taken apart to assess the bonding areas. The bonding surfaces of these revealed the use of insufficient glue resulting in a reduced bonding area.

Footnote

2 Bundesstelle fur Flugunfalluntersuchung (BFU).

According to the aircraft manufacturer the bonding of the lower surface of the hinge normally fails first in overload which leads to visible cracks, while the upper bonding will remain secure for longer because the upper surface is larger and more elastic. They stated that this should ensure that a debonding of the hinge is detectable before it fails completely.

In the case of G-GEJS both the lower and upper bonding surfaces had failed, but the tab was still able to take load due to three remaining glue joints which pass through the three holes in the hinge bonding surface.

Until the incident to G-ZXEL the aircraft manufacturer was not aware of any previous in-flight elevator trim tab failures and was not aware of any cracked hinge issues. There were no repair instructions for a de-bonded trim tab hinge and therefore the manufacturer would have expected to be contacted if an operator experienced such cracks. More than 700 Extra 300 aircraft have been manufactured since early 1990.

Safety Actions

> As a result of this accident, the aircraft manufacturer published Mandatory Service Bulletin SB-300-2-22[3] on 10 August 2022 which explains the issues identified during this investigation and requires a detailed visual inspection of the elevator trim tab hinges within 25 hours, and a recurring detailed visual inspection as part of the normal 50-hour inspection programme.
>
> The CAA and EASA reviewed the Service Bulletin and decided that an accompanying Airworthiness Directive was not required.
>
> The aircraft manufacturer also advised the external trim tab manufacturer to ensure that sufficient glue is used when bonding the hinges to the tabs.
>
> As of 22 December 2022 the aircraft manufacturer has received results from 17 aircraft which have been inspected in accordance with the Service Bulletin and none had evidence of cracks.

Analysis

The elevator trim tab detached in flight due to a combination of the wrong hinge type being fitted at the inboard location and insufficient glue having been applied to the outboard hinge. Because the tab was still attached to the aircraft via its control cables, it flapped in the slipstream causing it to move the elevator up and down which resulted in the pitch oscillations. The pilot was able to control the aircraft, but he was very alarmed by the loud banging noise caused by the trim tab striking against the side of the rudder. The banging noise stopped when the trim tab tip lodged itself into the side of the rudder.

The pilot found that the aircraft was controllable with the detached trim tab and did not have any difficulties landing. However, if the banging noise had not stopped then this would have provided a significant distraction to the pilot during the landing phase.

Footnote

[3] https://www.extraaircraft.com/docs/service/S300222A_20220712.pdf accessed on 6 January 2023.

The aircraft had undergone an annual inspection just 39 hours prior to the failure. Although the detailed visual inspection of the area that was required every 1,000 hours was not required at the time, an annual inspection would normally uncover cracks of the type seen in Figures 6 to 8. It is possible that 39 hours previously the cracks had not yet formed or were not as perceptible, or the inspection of the area was not sufficiently thorough to detect them.

How, when and where the incorrect hinge was fitted to G-ZXEL could not be determined, but the evidence indicated that a repair had probably been carried out.

Following this incident, five other Extra 300 aircraft were examined and three had cracked inboard hinges due to debonding, but these all had the correct type of hinge fitted. These revealed that the issues were caused by insufficient glue being applied during manufacture. These aircraft had all accumulated less than 50 hours since their last annual inspection.

The aircraft manufacturer has taken safety action, in the form of a Service Bulletin, to mandate a detailed visual inspection of the elevator trim tab hinges within 25 hours and then subsequently every 50 hours. This time interval is greater than the time between the cracked trim tabs being detected and their previous annual inspection for the three aircraft identified. However, the aircraft manufacturer is confident that the 50-hour interval is appropriate given the long service history of the Extra 300, and that cracks do not immediately lead to failure. Also, there are no other known in-flight failures of elevator trim tabs with the correct hinges fitted.

Conclusion

The elevator trim tab detached in flight due to a combination of the wrong hinge type being fitted (with only one third of the glue bonding area compared to the type of hinge that should have been fitted) and insufficient glue having been applied. How, when and where the incorrect hinge was fitted to G-ZXEL could not be determined. Other aircraft with cracked hinge tabs were found which indicated that insufficient glue had also been applied between the hinges and the tab structure. The aircraft manufacturer has published a Service Bulletin to mandate more frequent visual detailed inspections of the trim tab hinge areas and has advised the external trim tab manufacturer to ensure that sufficient glue is used when bonding the hinges.

Accident

Aircraft Type and Registration:	Tekever AR3	
No & Type of Engines:	1 Sky Power piston engine	
Year of Manufacture:	2021 (Serial no: 335)	
Date & Time (UTC):	2 July 2022 at 0738 hrs	
Location:	English Channel	
Type of Flight:	Commercial Operations (UAS)	
Persons on Board:	Crew - N/A	Passengers - N/A
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Damage from seawater immersion and recovery	
Commander's Licence:	Other	
Commander's Age:	35 years	
Commander's Flying Experience:	1,166 hours (of which 185 were on type) Last 90 days - 100 hours Last 28 days - 56 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent AAIB enquiries	

Synopsis

During a Beyond Visual Line of Sight (BVLoS) flight over the English Channel, the engine stopped. The aircraft descended on a parachute into the sea and was subsequently recovered. Investigation revealed an issue with the Low Pressure fuel pump which caused it to fail and trip its associated electrical fuse. This fuse also provided electrical power to the High Pressure fuel pump and, with both pumps stopped, the engine was starved of fuel.

The operator ceased operating the aircraft type until a number of improvements had been implemented.

History of the flight

Prior to takeoff, the preflight Normal Operational Checklist was completed with no defects or faults found. Engine tests were also performed which all passed as expected. Takeoff commenced at 0502 hrs in good weather from a site near Dover. The aircraft proceeded to the mission area over the English Channel where it commenced a Beyond Visual Line of Sight (BVLoS) maritime surveillance operation in Temporary Danger Area (TDA) D098.

The aircraft was monitored at all stages by two remote pilots who reported that the initial part of the flight progressed as normal. After approximately one hour and eleven minutes of flight, the aircraft was in a loiter mode at 800 ft amsl. The pilots then noted that the engine rpm had dropped to zero and throttle command had risen to 98% which is the maximum. The altitude started to reduce, and the pilots realised that the engine had stopped. The aircraft continued to navigate on the programmed route until reaching 550 ft amsl after which the emergency procedure for activating the parachute was triggered automatically and the aircraft descended under parachute into the sea, within the TDA. The operator stated that there were no other vessels in the vicinity at the time.

The operator advised the Coastguard, activated the Emergency Response Plan and informed the CAA. The aircraft was subsequently found floating by a fisherman who recovered it and returned it to the operator for investigation.

Aircraft information

The UAS was manufactured and operated by the same company. It has an operating range of up to 60 km, an endurance of between 8 and 16 hours and a MTOW of 23 kg. There was a real-time data link from the aircraft to the remote pilots which included relevant aircraft parameters and a video feed from the onboard camera.

The single piston engine was supplied with fuel from a high pressure (HP) fuel system. This system used the HP fuel pump to pressurise the fuel from a header tank. Fuel was supplied to the header tank using the low pressure (LP) fuel system which used a separate LP fuel pump to transfer fuel from the main tank to the header tank via a fuel filter / strainer.

Both the HP and LP fuel pumps were controlled by the Engine Control Unit (ECU) and both pumps need to be operating for the engine to continue running. Electrical power to both fuel pumps shared the same electrical fuse which meant that if the fuse tripped, both fuel pumps would stop.

Operator's investigation

The operator performed an extensive investigation using telemetry data and examination of the recovered aircraft. They elected not to fly the aircraft type until the cause was known and their internal investigation was complete.

The aircraft, propeller and engine components were examined and found to be in good condition apart from effects of the saltwater environment and minor damage from the recovery operation.

Review of the telemetry data suggested an engine rpm response typical of fuel starvation. The fuel system was examined, and the only issue identified was damage to internal components of the LP fuel pump. The cause of this damage remains unexplained.

Review of the recorded fuel system electrical parameters suggested that the effect of this damage resulted in an electrical short circuit. This short circuit was expected to trip the associated fuse and cut the power supply to the LP fuel pump. As the HP fuel pump also shared the same fuse, it would also become isolated. This sequence of events would lead to engine fuel starvation.

Safety action

The operator identified that the loss of the LP fuel pump, triggering of the fuel pump fuse and the internal failure of the LP fuel pump were all design issues that could lead to engine fuel starvation.

As a consequence, the operator has implemented the following design improvements:

- A modification to the fuel tank such that if the LP pump fails, the HP pump is able to draw fuel into the header tank.
- The LP and HP fuel pumps are provided with separate electrical fuses.
- Use of an upgraded version of the LP fuel pump.

The operator advised that the CAA has been informed of the investigation details and the subsequent modifications.

ACCIDENT

Aircraft Type and Registration:	1) UVify IFO 1 2) UVify IFO 2
No & Type of Engines:	1) 4 electric motors 2) 4 electric motors
Year of Manufacture:	1) 2021 (Serial no: 213682ifod0106000497) 2) 2021 (Serial no: 213682ifod0106000370)
Date & Time (UTC):	31 December 2022 at 2359 hrs
Location:	Horse Guards Parade, Whitehall, London
Type of Flight:	Commercial Operations (UAS)
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Both UA's airframes damaged beyond repair
Commander's Licence:	Other
Commander's Age:	36 years
Commander's Flying Experience:	33 hours (of which 33 were on type) Last 90 days - 4 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During a public display of 400 synchronised unmanned aircraft (UA), several were seen to deviate briefly from their pre-programmed position. Shortly afterwards, two UA fell to the ground and sustained damage. It is likely the deviation was caused by a gust of wind resulting in two UA colliding and losing control. The safety zone put in place on the ground by the operator and organiser mitigated any risk to the public.

History of the flight

Four hundred UA were launched as part of a synchronised swarm to carry out a public New Year's Eve display. About 30 seconds into the display, several UA briefly failed to maintain their pre-programmed position. This slight deviation lasted for approximately 2 seconds. About 5 seconds afterwards two of the UA were seen in an uncontrolled descent eventually hitting the ground. They landed in the safety zone, Horse Guards Parade in the centre of London, beneath the display area. Both UA were damaged beyond repair. The remainder of the swarm completed the display sequence and landed without incident.

Investigation

The operator conducted a detailed investigation to establish the cause. A download and analysis of the on-board data logs found no technical reason for the UA deviation. An assessment of the weather conditions at the time suggested that a localised gust of wind may have affected some of the UA. It is possible that the two UA that fell to the ground sustained damage by colliding with each other. This compromised their flightworthiness and caused them to descend out of control. To mitigate the possibility of this happening again, the operator is researching a way by which to measure wind speed within the display envelope to supplement the preparatory wind speed measurements taken at ground level.

AAIB Observation

The use of multiple UA, in this case 400, for public display and entertainment will, by their nature, attract large numbers of people on the ground. Displays such as these are generally carried out in a large three-dimensional area of the sky and the UA at the top of the swarm, in some cases, may reach heights of several hundred feet agl. In this case the operator and organisers of this display had taken this into account and a large safety zone had been established on the ground. This greatly reduced any risk to the public and meant a safe outcome in this accident.

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: January - February 2023

1 Apr 2022 **Pitts S-2E** **G-KITI** Sleap Aerodrome, Shropshire

After landing and reducing speed the aircraft yawed to the right, resulting in the left wing hitting the ground and damaging the left aileron and wingtip. The pilot thought a tail wind might have caused the ground loop. Ground handling of taildragger aircraft is explored in the AAIB report concerning G-HRLI (https://www.gov.uk/aaib-reports/aaib-investigation-to-hawker-hurricane-1-g-hrli [accessed January 2023]).

18 Aug 2022 **Vans RV-4** **G-CDJB** Nayland Airfield, Essex

The pilot said that a strong gust of wind blew the aircraft towards some trees when he was landing. The aircraft struck a tree and was extensively damaged, but the pilot was uninjured.

15 Sep 2022 **Vans RV-9** **G-CDMN** Stone Acre Airstrip, Kent

Following a local flight with an instructor, the Vans RV9 became slow on final approach to Runway 24 at Farthing Corner airfield. The pilot described the left wing dropping suddenly before impact with the airfield boundary fence. He stated that he suddenly found the aircraft on the ground facing along the runway before veering left and stopping in an adjacent field. The aircraft sustained significant damage to the left wing and some minor damage to the right wing, landing gear and propeller.

7 Dec 2022 **Cessna 152** **G-BSCZ** Near RAF Halton, Buckinghamshire

As the aircraft climbed through approximately 200 ft agl after a touch and go, its engine failed. The instructor took control and executed a forced landing in a nearby field. During the landing roll the nosewheel dug into the soft surface and the aircraft inverted. Another aircraft, airborne in the vicinity at the same time, experienced severe carburettor icing on several occasions. On reflection, G-BSCZ's pilots considered it most likely that carburettor icing caused their engine failure.

5 Jan 2023 **Cessna R182** **G-CBMP** Great Massingham Airfield, Norfolk

The aircraft landed heavily in gusty conditions. The propeller touched the runway and the nose gear was damaged.

20 Jan 2023 **Bulldog Series 120 Model 122** **G-BCUS** Oaksey Park, Gloucester

The pilot misidentified the airstrip because of the low sun and landed on an adjacent field. The landing was normal but during the rollout the nose landing gear dug into the soft ground and the propeller struck the surface.

Record-only investigations reviewed: January - February 2023 cont

22 Jan 2023	**Taylor Titch**	**G-BFID**	Sibson Aerodrome, Peterborough

The pilot lost directional control during take off, the aircraft veering off the runway leading to damage to the landing gear and a propeller strike.

27 Jan 2023	**Druine D.62B Condor**	**G-ATAU**	Firs Farm Airfield, Leckhampstead, Berkshire

On late finals to land at Firs Farm Airstrip the pilot encountered stronger than expected winds. The airspeed dropped and the aircraft sank heavily, striking the top of a small bank and causing the right wheel to detach. The right gear leg then caught in the ground, shearing the right-wing main spar at the wing root.

28 Jan 2023	**Cessna 152**	**G-BZHE**	Andrewsfield, Great Dunmow, Essex

The aircraft, which was being flown by a student pilot, bounced during landing and the nose landing gear was damaged.

4 Feb 2023	**Jodel DR1050**	**G-CEIS**	Prestwick Airport

The aircraft encountered a gust shortly before landing and touched down, probably left wing first, beside Runway 21. When power was applied to discontinue the landing the instructor, believing the aircraft may be damaged, took control to remain on the ground. During the ground roll it struck approach path indicator lights, damaging the lights and the underside of the aircraft. Damage to the wings restricted aileron movement. The wind reported shortly afterwards was from 210-220° at 17 kt, gusting to 28 kt.

7 Feb 2023	**Jurca Spitfire MJ-10**	**G-CHBW**	St Merryn Airfield, Cornwall

At a point about 65 m into the landing roll, the right landing gear torque link failed. The aircraft departed the runway and tipped onto its nose, damaging the main spar, propeller and shock loading the engine.

11 Feb 2023	**Bell 206B**	**G-CDGV**	Near Stockton-on-Tees

While manoeuvring at low height and speed over a helipad in preparation for parking, the aircraft tail rotor struck a CCTV mounting on the hangar. Yaw control was lost, and the aircraft struck the ground suffering extensive damage.

Miscellaneous

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

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

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

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

Published July 2015.

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

Published August 2015.

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

Published November 2018.

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

Published March 2020.

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

Published May 2021.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

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