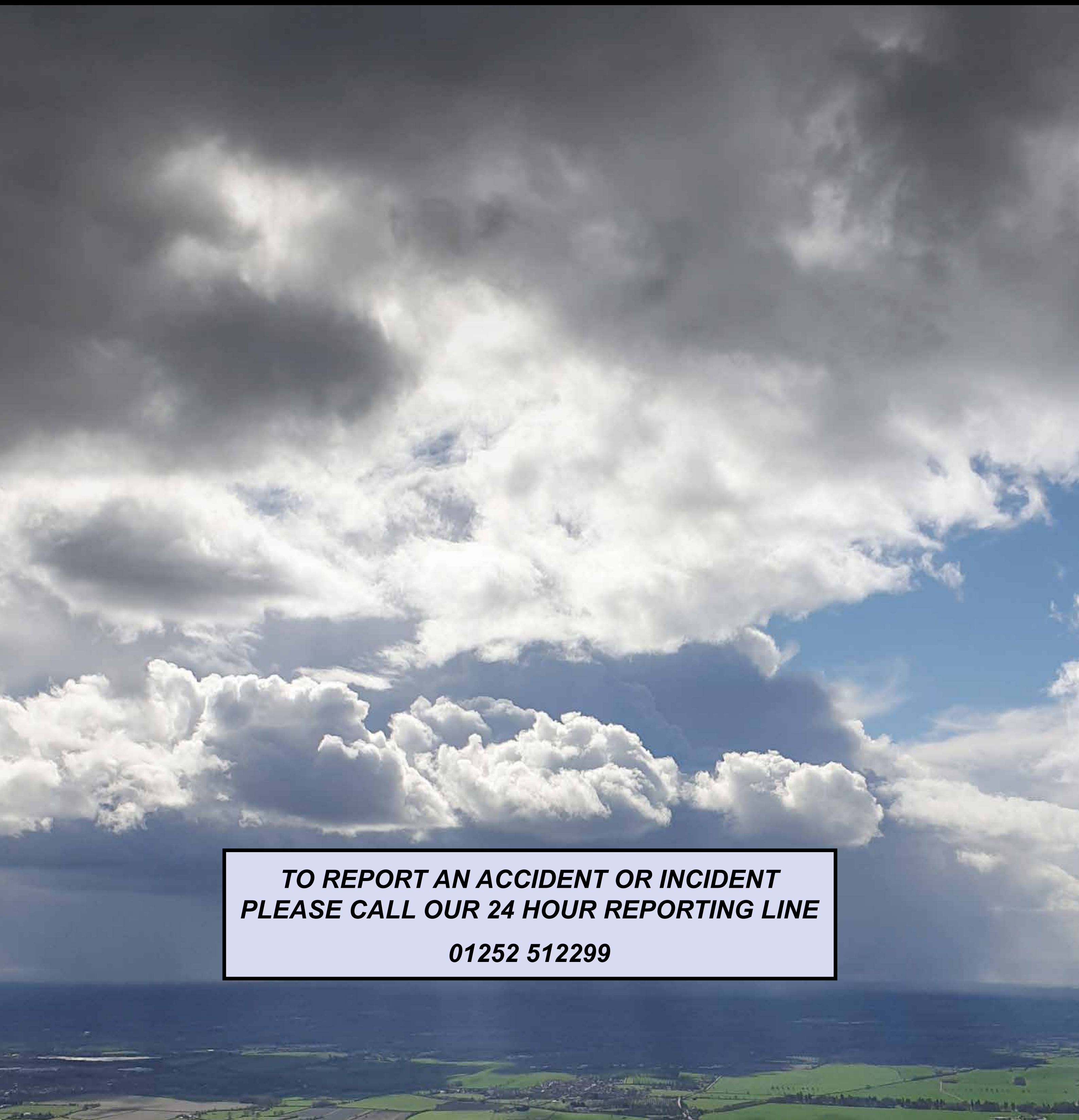
AAIB
Air Accidents Investigation Branch

AAIB Bulletin 7/2021



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

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

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

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ADDENDA and CORRECTIONS

None

(ALL TIMES IN THIS BULLETIN ARE UTC)

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:	Avro 146-RJ85, G-JOTR
No & Type of Engines:	4 Lycoming LF507-1F turbofan engines
Year of Manufacture:	1996 (Serial no: E2294)
Date & Time (UTC):	19 January 2021 at 1428 hrs
Location:	London Biggin Hill Airport, Kent
Type of Flight:	Commercial Air Transport (positioning flight)
Persons on Board:	Crew - 5 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Front left fuselage punctured
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	62 years
Commander's Flying Experience:	10,618 hours (of which 5,761 were on type) Last 90 days - 76 hours Last 28 days - 11 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The crew boarded G-JOTR while it was parked on a taxiway, but airfield restrictions required it to be towed to a designated area on the apron for engine start (Figure 1). The towing route followed the edge of the apron, which was damp and downhill, and involved a 90° left turn to line up for start. A combination of unfamiliarity with a relatively new operating base, towing in reverse and difficulty interpreting "indistinct" taxiway markings meant the tug driver entered the left turn later than intended. The late entry made the turn excessively tight, and the tug lost traction on the damp surface and jackknifed. The resulting combination of a sharp towing angle and the aircraft's downhill momentum caused the towbar shear pin to break. The commander applied the brakes immediately on hearing "the sound of snapping metal" but was unable to prevent the aircraft rolling forward into the tug.

The operator's internal investigation report made several safety recommendations, including a review of towing procedures, enhanced driver training, the use of radios by towing teams and improvements to taxiway markings. The company also reviewed its apron risk assessment and towing was added to their audit plan.

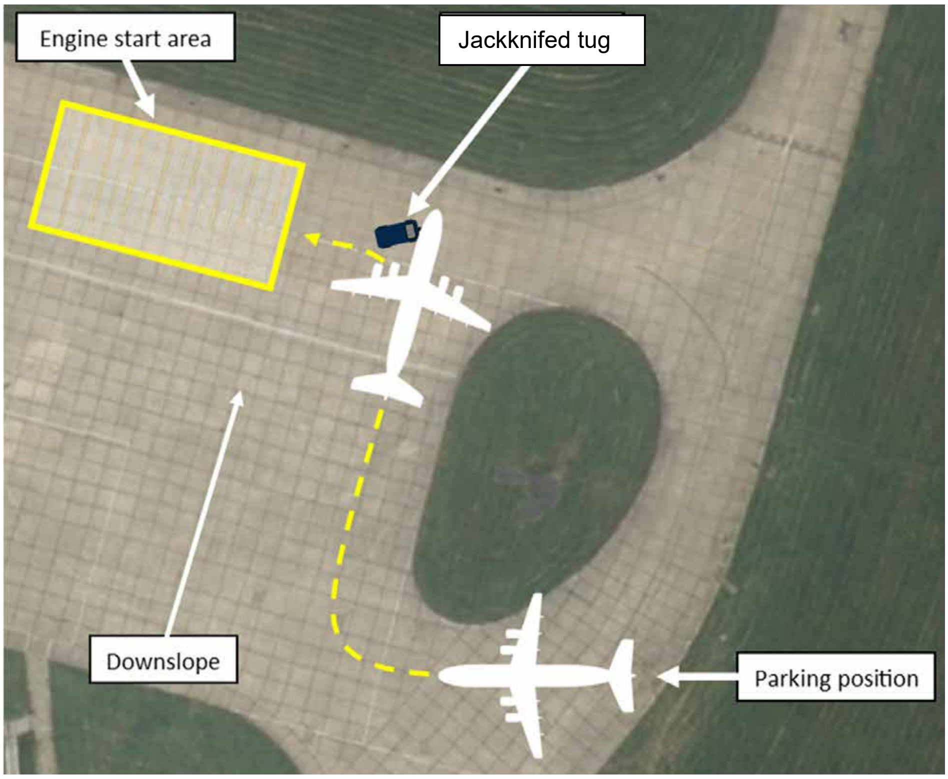


Figure 1

Approximate towing route and accident location
(Image courtesy of Ordnance Survey © 2021 TomTom)

SERIOUS INCIDENT

Aircraft Type and Registration:	Avro 652A Anson T21, G-VROE
No & Type of Engines:	2 Armstrong Siddeley Cheetah 17 piston engines
Year of Manufacture:	1950 (Serial no: 3634)
Date & Time (UTC):	4 July 2020 at 1252 hrs
Location:	Shobdon Aerodrome, Leominster, Herefordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	No damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	76 years
Commander's Flying Experience:	7,642 hours (of which 69 were on type) Last 90 days - 18 hours Last 28 days - 9 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

After encountering a gust of wind which displaced its final approach, the aircraft landed on unprepared ground beside the runway and completed its landing roll on an adjacent taxiway, without reported damage or injury. In deciding to continue the landing the pilot had applied what he considered to be a cautious interpretation of information regarding the conduct of go-arounds in this aircraft.

History of the flight

The aircraft had flown from Coventry Airport to Shobdon Aerodrome. At 1250 hrs, during the latter stage of its final approach to the grass Runway 26, the Aerodrome Flight Information Service Officer (AFISO) transmitted landing information to the aircraft, including an 'instant wind' of 20 kt from 250°.

The pilot stated that shortly before the aircraft reached the aerodrome boundary, a gust of wind displaced it to the right. It subsequently landed on unprepared grass adjacent to the runway[1]. The aircraft completed its landing roll on grass Taxiway A (Figure 1).

[1] The pilot reported the aircraft touched down *'partially'* off the runway.

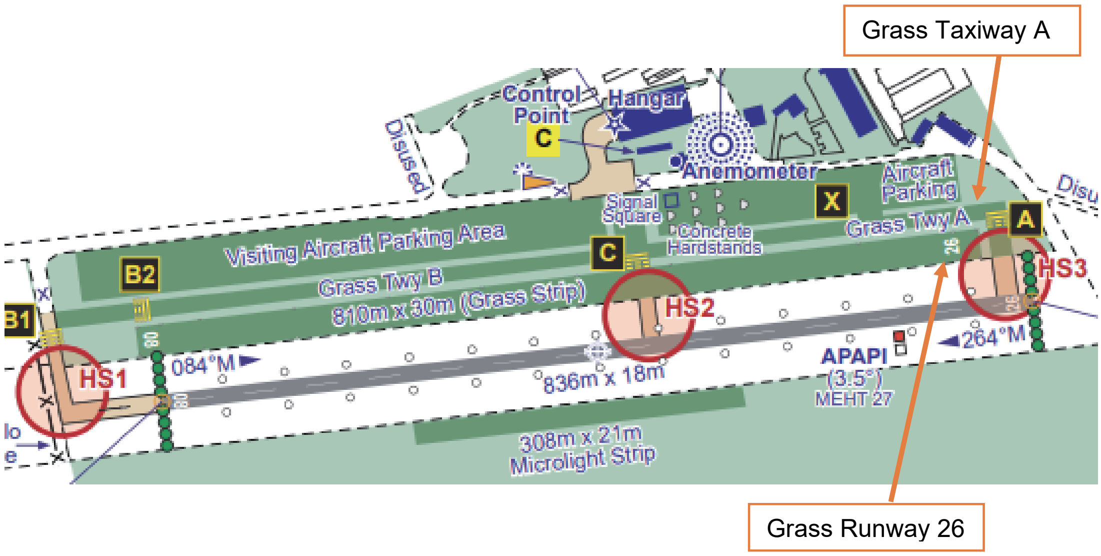


Figure 1

Extract from Shobdon's Aerodrome Chart[2]

Aerodrome information

Shobdon's Runway 26 is 810 m long and 30 m wide. The relevant entry in the Aeronautical Information Publication (AIP) stated *'Departure from the marked movement area can be hazardous'.*

Aircraft information

The Avro Anson T21 is a low-wing monoplane powered by two Cheetah Mk 17 engines, with tail wheel landing gear. It is operated by a single pilot.

Weight and balance

The *'Pilot's Notes Anson 19 & 21'* document, originally published by the Air Ministry, stated the aircraft's maximum weight for takeoff and gentle manoeuvres is 4,717 kg, and for landing (except in an emergency) is 4,581 kg[3].

The operator's Organizational Control Manual (OCM)[4] specified the aircraft's centre of gravity limits as 56.4 inches to 68 inches aft of datum.

The pilot reported G-VROE's basic weight for the incident flight was 3,413 kg and its calculated landing weight was 3,792 kg. Its calculated centre of gravity (C of G) was 57.7 inches aft.

Footnote

[2] From its Aerodrome Information Publication, published by NATS.
[3] The Pilots Notes specified these weights in lb.
[4] Operation of Permit-to-Fly Ex-Military aircraft on the UK register must occur in accordance with an approved OCM (CAP 632 Edition 7 May 2018).

Information from the aircraft's Pilot's Notes document

The Air Ministry's *'Pilot's Notes Anson 19 & 21'* document contained guidance on *'Going round again'*, including:

> *'At normal loads and C.G. positions, and trimmed for an engine-assisted approach, the aircraft will climb away easily, with the undercarriage and flaps down, at 80 to 90 knots…*
>
> *Going round again from a glide approach, especially when loaded to a forward C.G. position, will prove difficult if the airspeed is allowed to fall below 70 knots before the decision to go round again is made, since the strong nose-up change of trim, induced by opening the throttles fully, may prove excessive. It is recommended, therefore, that the aircraft be trimmed progressively nose-down as power is increased…*
>
> *With the C.G. at the aft limit, it may be impossible to overcome the nose-up change of trim...'*

Regarding *'Going round again on one engine'* the Pilot's Notes stated:

> *'The decision to overshoot must be made at a minimum of 600 feet above the ground and before flap has been selected…'*

Additional information from the pilot

The pilot stated that he interpreted the Pilot's Notes document as cautioning against "late" go-arounds *'because the application of full power may produce an uncontrollable change in elevator force'*, and that a decision to "commit" to landing is required when final flap and trim settings are selected.

He stated that a lateral adjustment in G-VROE to compensate for the gust would have resulted in a crabbed touchdown and possible ground loop[5]. Consequently, he opted to land on the grass beside the runway. He felt confident that the landing surface was safe, and there was no other traffic nearby.

Additional information from the aerodrome operator

The AFISO reported that during the time G-VROE made its approach to Shobdon there were no other aircraft in the air or manoeuvring on the ground, but that some aircraft were parked in both of the aircraft parking areas (Figure 1). He had flown himself that day and recalled the wind being "a bit gusty".

He reported that, because of his viewing angle, it was only in the "last few seconds" that he noticed the aircraft appeared aligned with Taxiway A, rather than grass Runway 26;

Footnote

5 Ground loop – significant (usually unintended) yawing of an aircraft on the ground when the yaw is not opposed by effective control inputs or other stabilising forces.

and that he did not have time to alert the pilot. He recalled the aircraft touched down on Taxiway A and turned right onto Taxiway C.

The AFISO recalled previous occasions where aircraft inadvertently approached grass Taxiway A, rather than the adjacent grass runway surface, and went around. As a result of such an approach to grass Runway 08 he had submitted a 'Local hazard report'[6]. The runway numbers were subsequently re-painted.

Information from the operator

The OCM stated:

> *'The Anson should not be operated from airfields with less than 750 metres of take-off and landing distance available. The aircraft can easily be operated from grass runways, and in those cases the minimum runway length will be 900 metres. Operations of the Anson into airfields with less than that stated must be briefed and approved by the Chief Pilot.'*

Analysis

The pilot reported that while approaching the aerodrome boundary a gust of wind caused the aircraft to drift to the right. He believed he was "committed" to landing the aircraft after selecting final flap and trim, and that making a lateral adjustment to its flight path would cause handling difficulties after touchdown. Therefore, he landed the aircraft partially on the grass beside the runway, and completed the landing roll on the adjacent taxiway.

The Anson Pilot's Notes described circumstances in which a go-around should not be attempted. Although the pilot applied what he considered a cautious interpretation of that guidance, the Pilot's Notes indicated that G-VROE's configuration, weight and balance on this occasion would not have precluded a go-around from an engine-assisted final approach.

The investigation did not determine why the aircraft completed its landing roll further right on Taxiway A, rather than returning to the runway. It also did not determine the nature of the operator's briefing and approval process for operating G-VROE on Shobdon's grass Runway 26, which was 90 m shorter than the relevant minimum runway length specified by its OCM.

Shobdon's AIP stated that manoeuvring outside the *'marked movement area can be hazardous'*. The pilot believed that continuing with the landing was the safest course of action, and that the landing surface was safe, with no obvious obstacles or traffic nearby.

Footnote

6 'Local Hazard Report' – the aerodrome operator's internal safety report, which is part of its safety management system.

Conclusion

The runway excursion occurred because the aircraft was not aligned with the runway on landing. The conditions in which the aircraft's operating manual cautioned against going around were not present during the incident approach, but the pilot applied what he considered to be a cautious interpretation of the guidance, believing that adjusting the aircraft's flight path would cause handling difficulties after touchdown.

SERIOUS INCIDENT

Aircraft Type and Registration:	Bombardier BD700-1A10, CS-GLD
No & Type of Engines:	2 BR700-710A2-20 Turbofan engines
Year of Manufacture:	2014 (Serial no: 9538)
Date & Time (UTC):	17 September 2020 at 1145 hrs
Location:	Biggin Hill Airport, Kent
Type of Flight:	Commercial Air Transport (Non-Revenue)
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Abrasion of wing tip, flap, aileron, and canoe fairings
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	7,334 hours (of which 2,422 were on type) Last 90 days - 55 hours Last 28 days - 25 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was on a positioning flight from Edinburgh Airport to Biggin Hill Airport in Kent and, having completed a circle-to-land procedure, carried out the final approach to land. The aircraft was fully configured for landing, established at the approach airspeed of V_{REF}[1] with the autothrottle engaged but being 'hand flown' by the pilot. There was a crosswind component from the right.

During the flare, a large amount of right rudder and right roll control was applied with the aircraft in a high nose-up attitude, causing a roll to the right. Although the roll was countered immediately with a large application of opposite roll control, the aircraft touched down before this input took effect, and the combination of nose-up pitch attitude and right wing down caused the wingtip to contact the runway.

The landing technique just before touchdown was not in accordance with the manufacturer's crosswind landing technique. However, a simulation by the manufacturer showed that the roll rate achieved was not accounted for by roll control alone, and it appeared likely that it was increased by localized wind or gust effects.

Footnote

[1] V_{REF} for the Global 6000 was calculated during certification as 1.326 x V_{SMIN}, where V_{SMIN} is the non g-corrected stick pusher activation speed.

History of the flight

General

The flight crew were working a week on, week off roster and were on the third day of their week on. They had arrived at Biggin Hill Airport on 15 September 2020 and the following day had positioned the aircraft to Northolt Airport, where passengers were boarded and flown to Edinburgh Airport. The third sector that day was from Edinburgh to East Midlands Airport where the crew stayed overnight in a hotel. On the day of the incident, the crew flew from East Midlands to Edinburgh before positioning back to Biggin Hill. The flight crew flew alternate sectors as Pilot Flying (PF) or Pilot Monitoring (PM).

The incident flight

The incident flight departed Edinburgh at 1046 hrs to position to Biggin Hill with the co-pilot as the PF and the commander as the PM. There were two cabin crew and no passengers. The weather conditions reported on the METAR at Biggin Hill at 1150 hrs gave the surface wind as from 060° at 15 kt, visibility in excess of 10 km with FEW clouds at 3,400 ft, OAT 18°C, dew point 9°C, and QNH 1029 hPa. This meant that Runway 03[2] was in use and, as there was no instrument approach to that runway, an ILS approach to Runway 21 was made, followed by a circle-to-land procedure onto Runway 03, which the crew had planned for in their pre-flight briefing. The transit was uneventful, and the normal briefing and checks were carried out. The circle-to-land procedure was flown, and a V_{REF} for the final approach of 117 kt was calculated using the Flight Management System. Airspeed during the procedure was 126 kt, and the autopilot was engaged until the base leg, with the autothrottle remaining engaged for the landing.

The commander, as the PM, used the Head Up Display (HUD) for the approach in accordance with the Standard Operating Procedures. No gusts had been reported, and with the Runway 03 PAPIs set to 4°, no increments to V_{REF} were added.

The aircraft was configured for the final approach with slats 20° and flaps 30° selected and was flown with a V_{REF} of 117 KIAS as the approach speed. The PM noticed that the unsteady wind caused the airspeed to vary, momentarily dropping below V_{REF}, but then increasing back to V_{REF}, which was maintained within +/- 2 kt. As the aircraft passed over a valley just before the runway threshold, the airspeed increased to 8 kt above V_{REF}, but was reduced again over the next 12 seconds. As they passed over the runway threshold, ATC passed the surface wind as 070° at 12 kt, with the aircraft heading between 033° and 036° to compensate for the crosswind from the right. At 50 ft over the runway threshold, the auto throttles retarded and the PM thought that the airspeed seemed to drop rapidly. At a height of 10 ft the airspeed was 5 kt below V_{REF}, and after passing the displaced threshold it had reduced to 10 kt below V_{REF}. The PM thought that the pitch attitude seemed higher than normal and was monitoring the Flightpath Vector (FPV) through the HUD, as it provided a sense of where the aircraft was in the flare. Just before touch down, the bank angle increased rapidly to the right in response to control inputs, and the

Footnote

[2] Runway 03 has a magnetic heading of 026°M and threshold elevation of 577 ft amsl.

PF positively applied left roll to correct it. However, at a height of one foot, the airspeed was 10 kt below V_{REF}, nose-up pitch was 9° and there was an angle of bank to the right of 8.5°. As the right main landing gear touched down, the right wingtip contacted the runway. After the landing roll was completed, the aircraft was taxied to the parking area under its own power.

Recorded information

The aircraft was fitted with an FDR and CVR which were downloaded at the AAIB. Both recorders captured the landing event.

At 1145:01 hrs, the aircraft reached 50 ft radio altitude (RA) (Figure 1, point A) with an indicated airspeed of 114 kt and a magnetic heading of 035.4°. The onboard derived wind was a 16.8 kt crosswind from the right.

Two seconds later the aircraft passed through a RA of 30 ft (point B) at an airspeed of 109 kt. The control column was moved progressively aft, with a corresponding increase in aircraft attitude to 9.1° nose up. The aircraft started rolling left (point C) reaching a maximum bank angle of 4.4° left wing down at a RA of 20 ft. As the aircraft started rolling left, the control wheel was moved to a 34.7° right roll command, reducing to 24.2° 1.3 seconds later, along with right rudder pedal producing a rudder deflection of 7.4° to the right. Within this time frame, the aircraft started rolling back to wings level, and the right multifunction spoiler had started to deploy, reaching 5° deflection, where it remained for 1.5 seconds before returning to the retracted position. A data plot of the relevant parameters is shown at Figure 1.

Half a second before touchdown (point D), the roll rate increased to a peak of 14.3°/s right wing down, to which a control wheel input was made to 62.1° left wing down. The right main landing gear touched down first with the aircraft at its peak roll attitude of 8.5° to the right and a pitch attitude of 9.1° nose-up. The aircraft then rolled to the left as the pitch continued to increase to a peak of 10.5° nose-up a second later.

Manufacturer's analysis

Data was sent to the aircraft manufacturer who provided an interpretation of the landing phase. Of significance was the assessment of the yaw damper operation, which was:

> *'Until the aircraft reached a height of 30 ft radio altimeter, rudder deflection ranged between 5.2° trailing edge right to 4.9° trailing edge left. The yaw damper was engaged, and the range of rudder deflection was consistent with yaw damper nominal authority of +/- 6.5° with no rudder pedal movement'.*

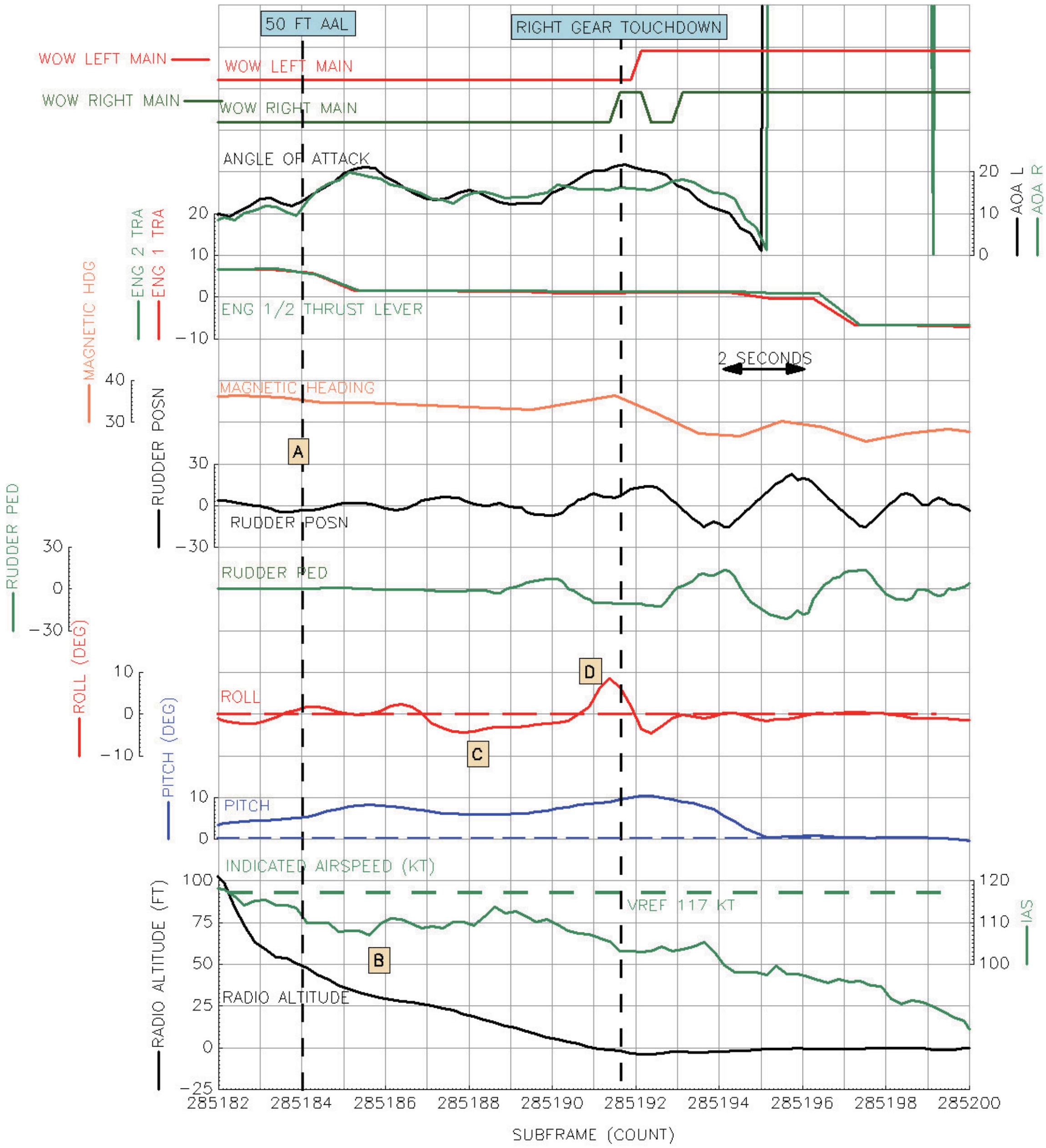


Figure 1

CS-GLD FDR parameters

Aircraft description

General

The Global 6000 is a long-range business jet variant of the Bombardier Global Express aircraft. It is designed to accommodate a crew of 2 to 4 persons and 8 to 10 passengers in a business configuration, or up to 19 passengers in a high density configuration, at a cruising speed of Mach 0.89, up to 51,000 ft, over a range of 6,000 nm. A two-pilot flight deck is equipped with four large Adaptive Flight Display units, and a HUD on the commander's side only.

The aircraft dimensions are shown at Figure 2:

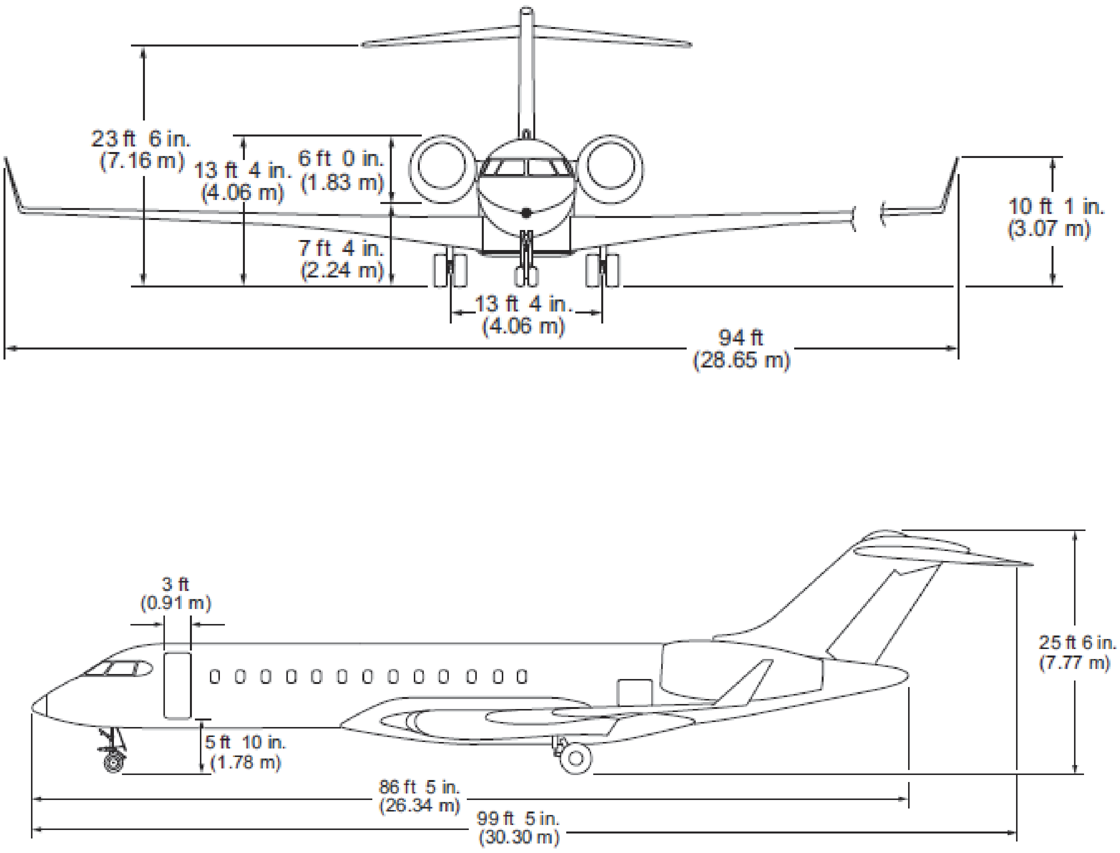


Figure 2

The aircraft dimensions

The flight control system

The Global 6000 flight control system comprises primary and secondary flight controls. The primary flight controls are responsible for the roll, pitch and yaw attitudes of the aircraft. Roll control is achieved through the use of ailerons, pitch control is achieved by the elevators, and yaw control is achieved by the rudder. Manual inputs from the flight crew, autopilot, or trim actuator move cables and control rods, which reposition servovalves on the flight control Power Control Units. Hydraulic pressure then moves the control surfaces to the desired position.

The secondary flight controls include lift-altering devices of leading edge slats and trailing edge flaps, which alter the wing profile, providing increased lift at low airspeeds for takeoff, landing and during low-speed flight, such as a circle-to-land manoeuvre. Multifunction spoilers deploy in the roll assist mode in response to control wheel inputs, and in the lift dumping mode in response to flight spoiler control lever input. Automatic lift dumping is provided on landing by ground spoilers combined with multifunction spoilers. In addition, a yaw damper provides stability augmentation about the yaw axis and assists with turn coordination.

The engines can be controlled using manual throttle levers or an autothrottle system. On landing with autothrottle engaged, the autothrottle will retard the engines to idle at 50 ft agl. The Flight Crew Operating Manual (FCOM) states that, *'As soon as the thrust is reduced to idle, the airplane will decelerate. Touchdown at approximately* V_{REF} *-4 kts is reasonable'*.

The manufacturer also stated that:

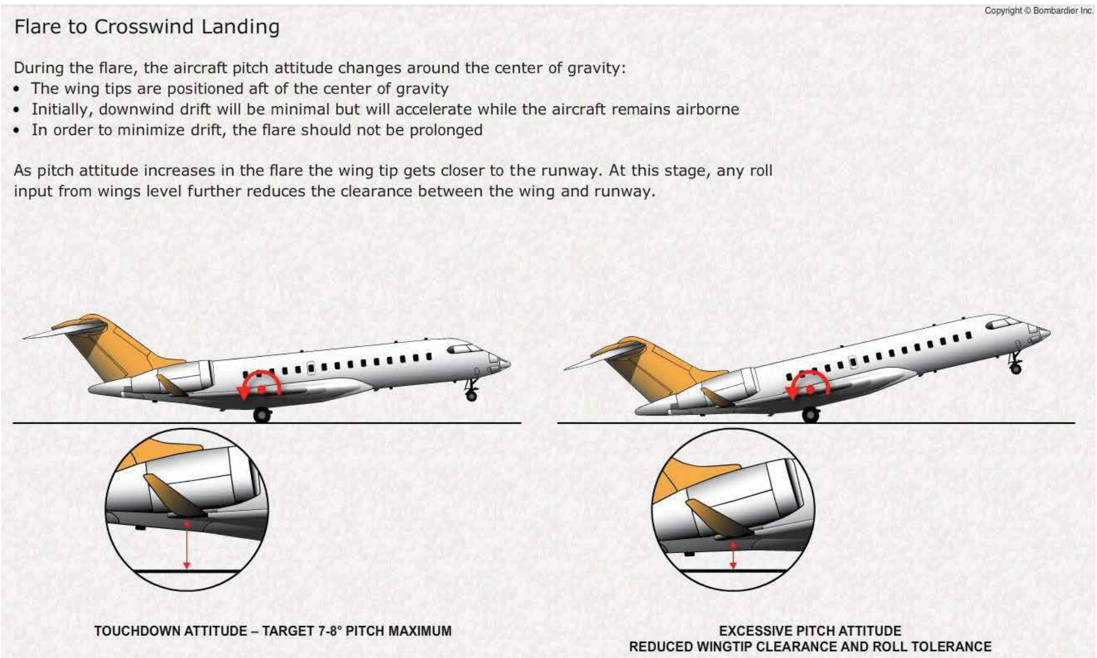
> *'As the thrust is reduced (including spool down time), the airplane starts slowing down. This slow down (over the course of 5 to 7 seconds) will result in the optimal touch down speed and attitude. Speed loss is expected to be 2 to 4% from that at thrust reduction (4 to 7 kts)'.*

Landing technique

The manufacturer's technique for landing the aircraft with a crosswind component is set out in the FCOM, which states:

> *'Crosswind Landing*
>
> *The recommended technique for approach is a wings level crab technique where the aircraft is pointed into wind to control direction. If a crosswind is present, as the flare is commenced, application of rudder is used to align the fuselage parallel with the runway centreline.*
>
> *As rudder is applied the aircraft will tend to roll in the direction of the rudder input. To counter this, simultaneous input of rudder and opposite aileron is required to keep the wings level. In this wings level condition, there will be some sideways drift. A slight, into wind, wing down should control this sideways motion.*
>
> *Excessive wing down can cause the wingtip to contact the runway. In order to minimize this possibility, the bank should be limited to less than 3 degrees and the touchdown should occur as soon as the aircraft is aligned with the runway. Prolonging the flare would increase the pitch attitude which brings the wingtip closer to the ground.*
>
> *The aileron input is required throughout the landing roll and the input should be increased as the airspeed decreases.*
>
> *Any lateral motion on final approach should be controlled using aileron inputs. The rudder should not be used to control lateral motion and should only be used in the flare to align the aircraft with the runway. The use of autobrake is recommended with strong crosswinds.'*

A diagram provided by the manufacturer illustrating the relationship between nose-up pitch and wingtip clearance is shown at Figure 3, along with the angle of bank at which the tip will contact the runway (with the wing on the ground but not producing lift (JIG), and in flight).



PITCH°	JIG°	FLIGHT°
0	10.6	13.5
3	9.6	12.3
6	8.5	11.2
9	7.4	10.1

Figure 3

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

Approach airspeed gust correction

When ATC reports gusts in windspeed, an increment is added to V_{REF} as set out in the Operator's Operations Manual Part B, shown below. The conditions during this approach were light turbulence but with no gusts reported. Adding gust increments also requires the increased Landing Distance Required to be considered.

'2.12.3 GUST CORRECTION

Approach speed on finals is calculated as V_{REF} + ½ the gust value up to maximum correction of 10 knots. Example: The gust value of a wind 27020G35 is 15 knots. The correction for V_{REF} is ½ x 15 = 8 knots. If a gust correction is calculated, set the speed on the FCP[3]. With autothrottle engaged, this corrected speed will be held until 50 ft AGL, when the autothrottle retards. Therefore, it is important that the resulting increase in landing distance has been considered with reference to the following factors:

Footnote

3 FCP: Flight Control Panel.

A 1 knot increase above V_{REF} increases the landing distance by 2%, thus:

V_{REF} + 5 increases the landing distance required by 10%:

V_{REF} + 10 increases landing distance required by 20%'.

'Note: It is recommended to disengage the autothrottle during gusty approaches.'

Landing attitude and roll control

The manufacturer also provided an indication of the nose-up attitude on the final approach at V_{REF} on a 3° glideslope, based on flight test data. The PAPIs at Biggin Hill, Runway 03 are set to 4° approach angle.

'The Global 6000 attitude on approach at V_{REF} is approximately 4° while on a 3° approach. At V_{REF} + 5 (for ½ gust), attitude is about 3° while on a 3° approach. Bombardier selected an optimal height above ground (50 ft) for thrust reduction to optimize landing distance and handling. This was meant to expose the airplane to an air-time of about 5 to 7 seconds in calm air'.

The effectiveness of the ailerons at low airspeed was demonstrated during a V_{MCL}[4] Flight Test point as follows:

'The static V_{MCL} demonstration for the slats out, flap 30°, landing gear down configuration was completed with the right engine at 99.6% of maximum takeoff power and the left engine shutdown. A constant heading was maintained to stick shaker activation at 89 KIAS using 19° of rudder and 3.9° of bank into the operating engine. The roll through 20° was completed in 3.1 seconds without using full roll control'.

Head Up Display

The HUD generates and superimposes flight data into the pilot's field of view. Displayed symbology is derived from aircraft flight instruments and navigation sensor data. The HUD is available during all phases of flight and serves to enhance situational awareness, aid in more precise aircraft handling and improve energy management.

A dual-channel computer receives data similar to that displayed on the pilot flight displays. Displayed information includes flight monitoring data (altitude, airspeed, inertial flightpath and acceleration), flight director information (autothrottle modes and related guidance cues), and situation and navigation data (position, altitude, course, heading, track, wind groundspeed and other navigation data). As the aircraft descends through 50 ft RA, a flare cue (+) is shown above each wing of the FPV referenced to the horizon line. Both the flightpath reference line and the flare cue remain displayed during the approach and are removed at main gear touchdown. They are flare cues and do not provide guidance.

Footnote

[4] V_{MCL}: the minimum speed the aircraft can be controlled in the air in the landing configuration, while applying maximum possible variations of power on the remaining engine after failure of the critical engine.

An illustration of the display is shown below at Figure 4 at a height of 50 ft above the runway as the autothrottle retards and airspeed starts to reduce with the flare cues (+) above the wings of the FPV[5].

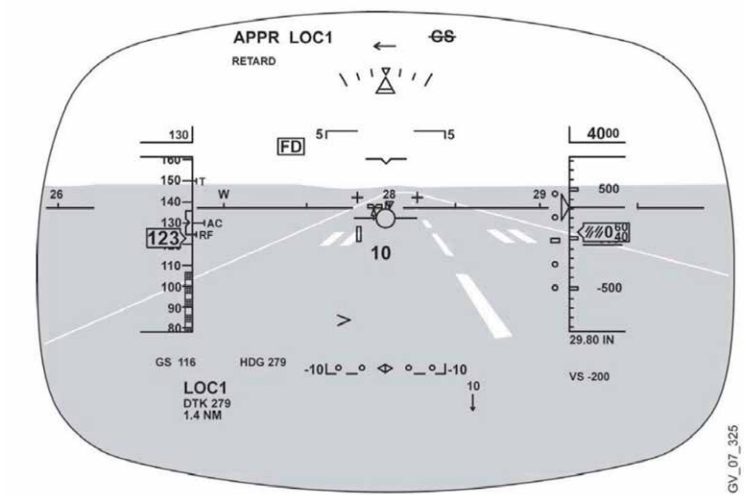


Figure 4
The Head Up Display presentation

The PM was using the FPV to monitor the approach and flare as it provides information on the aircraft flightpath as well as airspeed trends. Selected FPV symbols are shown below at Figure 5 with their description.

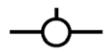
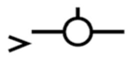
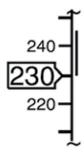
9	Flight Path Vector		The flight path vector (FPV) is derived from inertial information and provides indications of the aircraft path. It is displayed with segmented lines (ghosted) when it is non-conformal to the external scene. The vector will mask any other symbol except the guidance cue and selected course symbol.
12	Flight Path Acceleration Cue		The acceleration cue, shown relative to the left wing of the FPV represents inertial longitudinal acceleration or deceleration. It is shown above the FPV during acceleration, below it during deceleration, and a beam the wing when in a steady state.
29	Speed Error Tape		The speed error tape is shown as a rectangle of varying height shown relative to the left wing of the FPV. The height is proportional to the difference between the selected or target speed and the IAS. Tick marks represent 5 knot increments and is limited to a maximum size of 15 kts of difference. It is shown above the wing when IAS is greater than the selected speed, and below when IAS is less than the selected speed. The tape is not displayed during the takeoff ground roll nor is it displayed when the airspeed tape is displaying MACH data. It is also disabled during a go-around, and when windshear symbology is displayed.
30	Trend Vector		The trend vector indicates what the airspeed will be in 10 seconds at the current aircraft acceleration or deceleration rate.

Figure 5
HUD FPV Symbols with airspeed trends and airspeed indication with trend

Footnote

5 In Figure 4, the flare cue (+) should be displayed 1° below the horizon line.

Aircraft damage

When the right wingtip contacted the runway, four areas of the structure were damaged as they briefly scraped along the runway. They were the underside of the winglet, the aileron, wing leading edge and both outer canoe fairings. The damage is shown below at Figure 6.

Figure 6
The damaged components which contacted the runway

Airfield information

Biggin Hill Airport has a single runway orientated 03/21, which is 1,820 m long and 45 m wide with a 1.13° downslope on Runway 03. The Landing Distance Available for Runway 03 is 1,555 m. The airfield elevation is 599 ft, with a deep valley immediately before a road on the edge of the airfield adjacent to the threshold of Runway 03. The valley slopes up steeply towards the Runway 03 threshold. The PAPIs for Runway 03 are set to a 4° approach angle. The airport surface wind speed and direction is reported by the Air Traffic Control Officer (ATCO) using equipment in the tower connected to two sensors located near the thresholds of Runways 03 and 21. The ATCOs select which sensor to use according to the wind direction. The equipment constantly displays wind speed, direction and variation, and has three settings: instant wind direction and speed; a two-minute average, which is used for the ATIS; and 10-minute average used for the METAR. The normal operating position is the two-minute setting, but "instant wind" can be selected at ATCO discretion (normally if the gusts are much greater than 10 kt) or when requested by the pilot.

The airfield chart is shown at Figure 7.

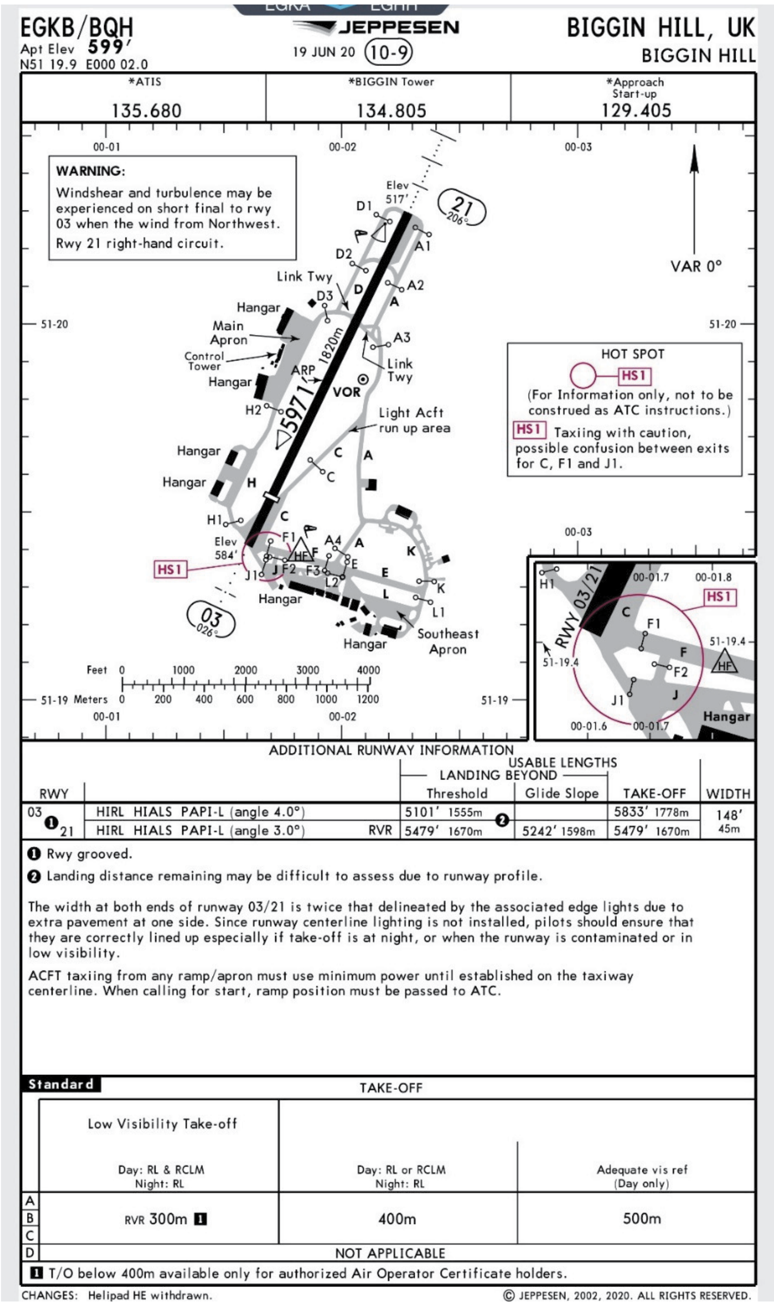


Figure 7

The Biggin Hill Airport chart

Tests and research

Background

The operator and the manufacturer had previously held discussions regarding wingtip strikes against a background of earlier events and near contacts. A concern of the operator had been the possibility of the down-going wing stalling at a speed below V_{REF} in ground effect and dropping to contact the runway. Both pilots on the incident flight thought that adding an increment to V_{REF} during turbulence or crosswinds, even without gusts reported, might reduce the risk of wingtip strikes. This proposal had previously been put to the manufacturer but was not supported by them for smooth constant crosswinds or as a general procedure. Adding more speed on top of the appropriate gust addition could present additional challenges during the landing phase.

In November 2020, the manufacturer added a new section to the FCOM called 'Recommended Operational Procedures and Techniques' (ROPAT). The intent was to provide a single reference document for both training and operations, eliminating the need for a dedicated Training Manual.

ROPAT provides guidance on the use of autothrottle during the approach in turbulent conditions, and suggests adjusting V_{REF} so that speed fluctuations occur from V_{REF} and up. The text is shown in Figure 8.

BOMBARDIER GLOBAL 6000

ROPAT
NORMAL AND NON-NORMAL PROCEDURES

H. Landing (Cont'd)

(3) LANDING - DEMONSTRATED CROSSWIND

NOTE

The maximum demonstrated crosswind component for takeoff and landing at 10 m (33 ft) tower height is 29 kts and is not considered limiting. Landings were demonstrated at an approach speed of V_{REF} + 1/2 of the gust.

(4) AUTOTHROTTLE DURING APPROACH

Use of autothrottle is recommended to reduce crew workload during the approach and landing. Approaches in turbulent conditions may be treated similarly to gusty conditions. Adjust V_{REF} such that speed fluctuations occur from V_{REF} and up. For example if turbulence is causing the speed to dip 3 kts below V_{REF} then compensate by adding 3 kts to the approach speed to ensure adequate speed margin. It is highly likely that turbulence and gusts may be coincident.

Figure 8

FCOM extract covering autothrottle use in turbulence

Manufacturer's technical investigation

The manufacturer used their Global 6000, six-degree-of-freedom simulation model to review the FDR data. The aerodynamic model is a high-fidelity, flight test validated, desktop computer model and has demonstrated representative flight characteristics across the full flight envelope. Their responses were also based on past flight test experience during the development and certification programmes. The simulation analysis used the aircraft gross weight, CG, and atmospheric conditions at the time of the event. A Rolls-Royce engine deck model was used to produce engine thrust (gross thrust, ram drag[6], net thrust) with FDR parameters used as inputs to drive the engine model.

Footnote

6 Also known as momentum drag. Drag due to the change in momentum of air entering the engine intake.

Simulation modelling

To establish if the angle of attack (AOA) of the wing just before the wingtip strike was within the normal AOA range, various landings carried out during the development and certification flight test programme were reviewed. Pitch angles at touchdown were generally between 6.5° and 8.0°. However, the touchdown pitch angles in service are expected to be closer to the lower range at around 6.5°. Although CS-GLD FDR data labels the AOA as body angles (AOA-b), they are actually Stall Protection System vane angles (AOA-v). The AOA-v reads generally higher than AOA-b and can be converted to AOA-b through a calibration curve.

'Abuse' landing cases carried out during certification (landings performed at V_{REF} - 5 kt) showed pitch angles up to 9°, similar to the event, but with AOA-b slightly lower than in the event. The AOA value in the event was above the range expected for a landing carried out at an appropriate V_{REF} with a typical assumed loss of airspeed from the flare to touchdown (about 4% of V_{REF}).

With respect to the rolling motion to the right observed just prior to touchdown, the simulation model did not reproduce that behaviour from the flight control inputs alone. However, the FDR data parameters and low sampling frequency did not allow for further root cause identification. Flight reconstruction was limited and key external influences, such as localized winds and gusts, could not be properly accounted for. The analysis did not see any evidence of a stall on the wing, which might have been indicated by a decrease in vertical acceleration (N_z).

Roll rate recorded on the FDR indicated a peak of 14.3˚/sec (to the right); however, the manufacturer explained that this was a snapshot of the rate at that instant of the FDR sample. The FDR sampling rate for that parameter was only once per second. The simulation analysis, output at a much higher sampling rate, showed that the flight control inputs that were applied to counter the right roll rate were acting to arrest the wing-drop and would have eventually recovered it if sufficient height had been available; in the event, reaction forces from the landing gear and the wing tip contacting the runway contributed to arresting the wing-drop. However, the observation from the simulation analysis supported a conclusion that the wing had not stalled.

The aerodynamic simulation model was used to determine the change in AOA in ground effect. There was good correlation between the model output and the FDR data, up to just before the wing made contact with the runway. Based on all the aircraft data available for this wing, the lift coefficient remains linear in this AOA range and '*a good margin to the stall is maintained*'.

Even with the reduction in airspeed below V_{REF} observed in the event, flow separation on the wings would not be expected. However, the lower airspeed would reduce the roll response. The roll response of the aircraft, for a given aileron/multifunction spoiler deflection, is a function of the dynamic pressure (or the square of the airspeed). At a V_{REF} of 117 KCAS, the dynamic pressure is 46.3 pounds per square foot (psf), while at the expected touchdown speed of 112 KCAS, dynamic pressure would be 42.5 psf. The touchdown speed of CS-GLD based on the FDR data was measured at 106 KCAS, which corresponds to a dynamic pressure of 38 psf. It is therefore reasonable to expect that there was a reduction of roll response of approximately 20% between when the aircraft was approaching at V_{REF} and at touchdown.

Throughout the development and certification flight test programme of the Global aircraft, many landings were carried out at an approach speed of V_{REF} - 5 knots, flap 30, slats out and at various weights. In particular, a few tests were performed with a touchdown speed around 103 KCAS, but with stable, into wind conditions. In spite of the lower dynamic pressure at that speed, '*no handling issues were reported by the flight test crew*'.

The manufacturer was asked to establish if the autothrottle had maintained the V_{REF} target speeds within the design specification. The autothrottle is designed to maintain the selected airspeed within +/- 4 kt in calm air conditions. The selected reference speed (V_{REF}) was 126 kt between 1,000 ft and 435 ft RA, and the selection was then changed to 117 kt for the rest of the final approach. At 50 ft RA the autothrottle commanded the throttle to idle, and it disconnected on main gear touchdown. The lowest airspeed reached while the autothrottle speed tracking was active was 114 kt. The review concluded that, '*The [autothrottle system] performed as expected*'.

The review and analysis of the FDR data and simulation model output concluded that the AOA value in the event was above the range expected for a landing carried out at an appropriate V_{REF} with a typical assumed loss of airspeed from the flare to touchdown. However, flight reconstruction was limited and key external influences such as localised winds and gusts could not be properly accounted for. The analysis did not see any evidence of a stall, which might have been indicated by a decrease in vertical acceleration (N_z). While there was a significant margin of airspeed above the stall, the review was unable to conclusively state that there was not a reduction of lift on the right wing during the roll to the right. However, modelling showed that without unidentified external influences and with sufficient height available, the opposite control inputs would have rolled the aircraft to the left, reducing the angle of bank to the right, and perhaps avoiding the impact.

Analysis

The crew were properly rested and licensed to conduct the flight, which was their fifth sector in two days. During their pre-flight briefing, they had discussed the weather at Biggin Hill and had planned to carry out a circle-to-land approach. The transit from Edinburgh was uneventful and the FDR data showed nothing abnormal, with some light turbulence on the final approach causing the airspeed to fluctuate +/- 2 kt. Prior to that, there had been no rudder pedal movements from the PF, with the yaw damper driving rudder movement to coordinate roll inputs (the manufacturer assessed that the yaw damper was operating correctly and did not contribute to the event).

At 30 ft above the runway, the aircraft flare was progressively increased to a +9.1° nose-up attitude. During that attitude change, the aircraft initially rolled left to a 4.4° bank angle before the pilot reversed the roll and applied right rudder and control wheel, which caused the aircraft to roll to the right. This roll rate peaked at 14.3°/s, resulting in an angle of bank of 8.5° to the right at a pitch angle of 9.1˚, and at a height of 1.5 ft with an airspeed of 105 kt. To restore wings level for touchdown, the pilot made a large left roll input, but before it could take effect the right main landing gear compressed at touchdown. The right wingtip contacted the runway surface before the aircraft rolled left and the left gear touched down. Just before touchdown, the aircraft system computed the wind was from 099° at 19 kt giving a crosswind component of 18.1 kt with an aircraft heading of 036°.

The aircraft was yawed to the right during the final stages of the approach but, apart from a small left rudder input, it did not appear to have been yawed left to align with the runway. During the flare, a roll angle of 8.5° developed to the right, which was greater than the 3° limit given by the manufacturer for landing in a crosswind. With a nose-up pitch attitude of 9°, the roll angle required for a wingtip to contact the runway is 7.4° with the wing unloaded and 10.1° in flight.

Roll control effectiveness was reduced by approximately 20% as the airspeed decayed from the V_{REF} of 117 kt to the touchdown speed of 106 kt. However, during certification flight testing, roll control was demonstrated down to 89 kt in the landing configuration.

The manufacturer's modelling showed that the aircraft's rate of roll to the right just before the wingtip contacted the runway was not solely the result of the pilot's flight control inputs. They considered that: *'Important external or other influences that could have provoked the right roll to wing tip contact at touchdown, could not be identified with the data and tools available'*. There were no gusts reported by ATC, but it was likely that localised wind or gusts caused the additional right roll identified by the simulation.

Conclusion

The serious incident occurred when large right rudder and roll inputs just before touchdown combined with unidentified external or other influences - likely to be localised wind or gust effects - to cause a rapid roll to the right and a bank angle which exceeded the recommended maximum of 3°. Despite a prompt and positive reversal of those inputs, the nose-up pitch attitude combined with the rate of roll reduced the wing tip clearance to the extent that the right wingtip contacted the runway surface.

ACCIDENT

Aircraft Type and Registration:	Cessna 310Q, N25XL
No & Type of Engines:	2 TCM 10-470-VO piston engines
Year of Manufacture:	1974 (Serial no: 310Q)
Date & Time (UTC):	17 January 2021 at 1354 hrs
Location:	Belfast International Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Substantial damage to aircraft and minor scrape damage to runway surface and runway edge lighting
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	1,590 hours (of which 900 were on type) Last 90 days - 5 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot intended to fly some circuits to maintain recency and to conduct engine health checks. On the first landing the aircraft suddenly veered to the right and came to rest on the grass beside the runway. The pilot was uninjured and reported the landing was normal, and during approach the three green lights, indicating the landing gear was down and locked, were illuminated.

The AAIB did not attend, but the aircraft was later examined by a licenced engineer. It was identified that the right landing gear torque tube had failed in torsion (Figure 1). This torque tube should not have been carrying any load once the gear was locked down. Further examination revealed the landing gear had visible corrosion and an apparent lack of adequate lubrication of the pivot joints (Figure 2). An Annual / 100-hour inspection had been completed on 30 September 2020, 3½ months earlier, which included an inspection of the landing gear.

The AAIB has previously reported on other similar events to this type of aircraft[1] where lack of lubrication and/or freedom of movement of the landing gear mechanism pivot joints was a factor.

Footnote

1 See AAIB reports [accessed June 2021]:
N119RS - EW/G83/12/07 (https://www.gov.uk/aaib-reports/cessna-c310q-n119rs-30-december-1983)
G-SOUL - EW/C95/11/6 (https://www.gov.uk/aaib-reports/cessna-310r-g-soul-22-november-1995)
N850KF - EW/G2008/05/19 (https://www.gov.uk/aaib-reports/cessna-310q-n850kf-10-may-2008)

Figure 1
Right main landing gear torque tube showing condition and torsional failure

Figure 2
Images showing condition of right main landing gear mechanism pivot joints

SERIOUS INCIDENT

Aircraft Type and Registration:	Reims Cessna F406, G-RVLW
No & Type of Engines:	2 Pratt & Whitney Canada PT6A-112 turboprop engines
Year of Manufacture:	1991 (Serial no: F406-0052)
Date & Time (UTC):	6 March 2021 at 1500 hrs
Location:	North Sea
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None reported
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	34 years
Commander's Flying Experience:	4,244 hours (of which 390 were on type) Last 90 days - 64 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot was operating a cargo flight from Göteborg Landvetter Airport, Sweden to East Midlands Airport. The aircraft was at FL 180 when the pilot began to experience a headache. He then noted that his cognitive ability was declining. Realising that he may be suffering the effects of hypoxia, he checked his equipment, before noting that his oxygen saturation as displayed on his finger pulse oximeter was low. He immediately switched oxygen bottles and the symptoms resolved. The pilot was able to continue the flight to East Midlands without further incident.

History of the flight

The flight took off from Göteborg Landvetter Airport, Sweden, at 1330 hrs for a flight to East Midlands Airport. The pilot had already flown the aircraft from East Midlands to Göteborg earlier in the day. The flight time for both sectors was around three hours. With the aircraft in the cruise at FL180 over the North Sea, the pilot was alerted to a problem by a rapid onset headache, followed by being unable to find a regularly used function on the electronic flight bag. As a result of being aware these could be symptoms of hypoxia, he checked his oxygen system. He also checked his oxygen levels on his pulse oximeter, which were much lower than normal, prompting him to increase the flow of oxygen through the regulator. When this did not improve the situation, he changed the supply bottle, and within a few minutes he was feeling better and the oxygen level had recovered to a normal level.

Hypoxia

Hypoxia may be defined as a state of oxygen deficiency in the body sufficient to impair function of the brain and other organs[1]. Whilst there can be a number of medical causes of hypoxia which could occur at any time, hypobaric hypoxia is altitude related. As the altitude increases and barometric pressure decreases, the partial pressure of oxygen decreases. This reduction in partial pressure simply means there are fewer oxygen molecules per volume of air as altitude increases. It becomes increasingly difficult for the human body to supply its oxygen needs as the aircraft climbs if no supplementary oxygen is supplied.

The brain is usually the first organ to suffer from the diminished oxygen supply. Even at 8,000 ft altitude, where there is a 25% reduction in the partial pressure, it is possible to detect impairment in some mental performance. This can make it challenging for the pilot to recognise the symptoms and to act effectively. Early symptoms of hypoxia are subtle and may include rapid breathing, headache, drowsiness, nausea, behavioural changes (eg euphoria and irritability), slurred speech, and diminished thinking capacity. It is also the case that symptoms can be individual and variable.

Aircraft information

The Reims Cessna F406 Caravan II (F406) is an unpressurised twin turboprop aircraft with a service ceiling of 30,000 ft. If the pilot is required for operational reasons to cruise above 10,000 ft altitude, then the aircraft carries two 682 litre portable oxygen bottles which are fitted with regulators and a cannula to fit to the nose of the pilot. The regulator allows the pilot to select a rate of oxygen delivery suitable for the cruise altitude. The aircraft operator limited the aircraft to a maximum altitude of 18,000 ft. At this altitude, the delivery rate of oxygen is recommended by the operator to be 0.6 litres per minute giving each bottle a capacity of over 18 hours for a single user. Although the pilot elected to select an oxygen flow of 1.0 litre per minute as he found this a more comfortable setting, this would still have meant a capacity of more than 11 hours.

Both oxygen bottles were full at the start of the pilot's duty and he had completed two previous flights before the incident flight. The primary oxygen bottle had worked without incident on the previous flight and for a significant proportion of the incident flight. With the flight times, the bottle can only have been used for a maximum of 275 minutes before the incident.

The operator supplied finger pulse oximeters to allow the monitoring of oxygen levels. They provide a very rapid way of assessing the oxygen saturation in the bloodstream. Whilst these can be unreliable in that they may underread the level of oxygen in the blood, especially with cold or dirty fingers, they do not overread the level.

Both the oxygen bottle and regulator were removed from the aircraft and tested at an approved maintenance facility. The function test of the regulator showed all flows to be within parameters and no faults could be found with either the bottle or the regulator.

Footnote

1 https://www.easa.europa.eu/sites/default/files/dfu/210635_EASA_HYPOXIA_BROCHURE.pdf [Accessed 21 May 2021]

Organisational information

As a result of a previous hypoxia event on a company F406, the operator reviewed and revised their existing standard operating procedures for the oxygen system as well as introducing an extensive training programme for its pilots in the operation of the equipment, possible failure modes as well as how to recognise the symptoms of hypoxia. The pilot commented that this training, as well as being alert to the possibility of hypoxia given the altitude of the aircraft, helped in identifying and rectifying the problem rapidly.

At the time of writing, the operator was in the process of re-instating the originally-installed aircraft oxygen system on the company F406 aircraft. It would be a fully integrated system utilising oxygen masks rather than cannulas.

Analysis

The pilot began to feel unwell when in the cruise at FL 180. The training and equipment provided by the operator allowed the pilot to recognise the problem and rectify it without delay, and the rapid response prevented a much more serious incident occurring.

Hypoxia can be subtle with symptoms that can vary between individuals. The nature of the reduction of oxygen usually affects the brain first meaning it can be difficult for the sufferer to process the problem and take the correct action. Being vigilant, using a pulse oximeter and taking quick action if hypoxia is suspected can ensure the safety of the crew and any passengers.

Conclusion

The pilot's oxygen level fell, and he began to experience the symptoms of hypoxia. The problem was resolved when the pilot switched the supply bottle, and the flight was able to continue without further incident. No fault was found with either the bottle or the regulator so a cause for the reduction of oxygen supply could not be established.

Safety action

The operator began a retrofit programme to install/reactivate all Cessna F406 aircraft operating above FL100 with a fully integrated oxygen system utilising oxygen masks rather than cannulas.

ACCIDENT

Aircraft Type and Registration:	Boeing A75L300 'Stearman', G-CGPY
No & Type of Engines:	1 Lycoming R-680-E3B piston engine
Year of Manufacture:	1945 (Serial no: 75-5303)
Date & Time (UTC):	23 June 2020 at 1420 hrs
Location:	Culmhead, Somerset
Type of Flight:	Commercial
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to wingtip and fuselage
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	17,219 hours (of which 12 were on type) Last 90 days - 9 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries by the AAIB

Synopsis

After performing several wing-walking experience flights at Chiltern Park Aerodrome, Oxfordshire, the aircraft was returning to Dunkeswell Airport, Devon, when its engine stopped producing power. The pilot performed a forced landing in a field.

The investigation revealed inconsistencies in fuel planning assumptions, and it is likely that insufficient fuel reserves were onboard for the accident flight.

The operator has taken safety action to improve fuel planning and pilot technical knowledge, and has amended its process for authorising flights.

History of the flight

Background

On the morning of the accident the pilot (Pilot A) flew G-CGPY from Dunkeswell Airport, Devon, to Chiltern Park Aerodrome, Oxfordshire. He and another pilot (Pilot B) employed by the operator would each perform a number of 'wing-walking' experience flights at Chiltern Park, before Pilot A returned the aircraft to Dunkeswell later that day.

Pilot A reported that the aircraft left Dunkeswell with a full tank of fuel[1] and while at Chiltern Park uplifted 100 litres of fuel from jerrycans[2].

The flight

Pilot A reported that on the return flight towards Dunkeswell the aircraft began to "struggle" near Culmhead disused aerodrome in Somerset, at around 2,000 ft amsl (1,100 ft agl) and with low cruise power set.

He applied carburettor heat but the engine "ran rough" and the aircraft started to descend. "Cycling" the throttle did not help and, although he anticipated the engine would "clear", it was not producing sufficient power.

Forced landing options were limited because of surrounding obstructions and the characteristically high descent rate of the Stearman with a windmilling propeller[3]. However, Pilot A performed a curved approach to a nearby grass field (Figure 1), located around 5 nm north-east of Dunkeswell.

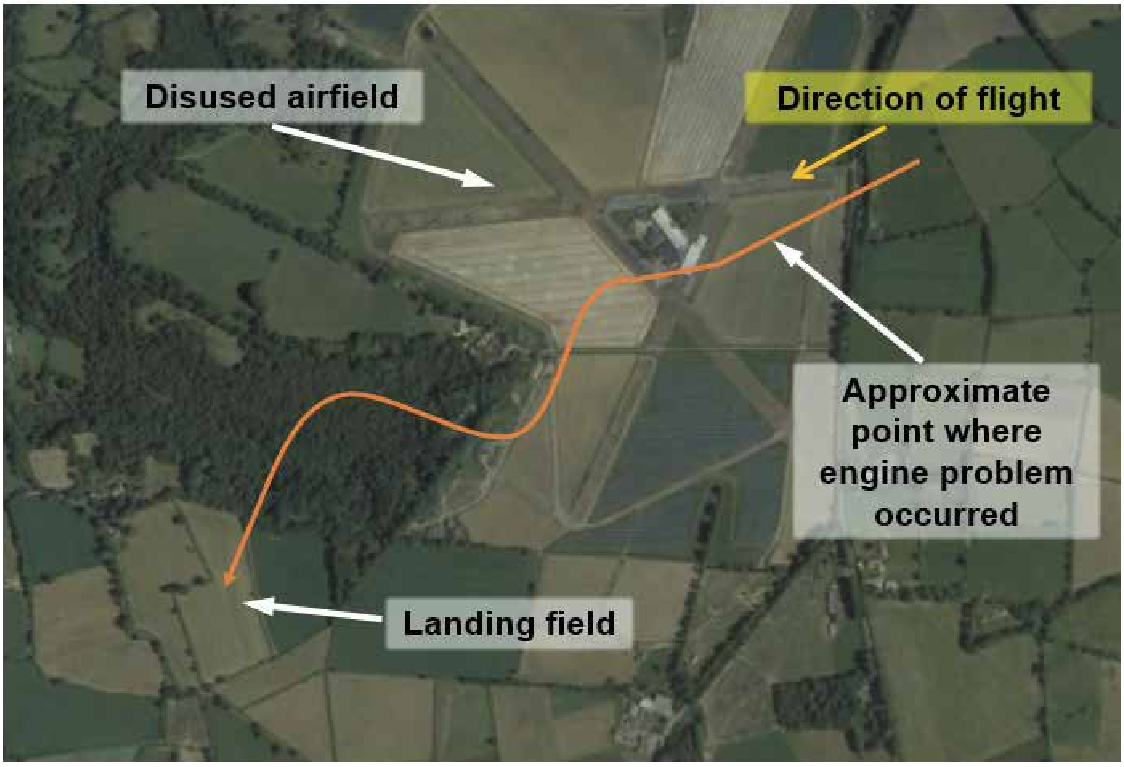


Figure 1

Approximate flight path reported by Pilot A
(© Google 2021, Image © Landsat / Copernicus" for google earth)[4]

Footnote

1 Pilot A recorded the *'Fuel* [onboard]*'* in the aircraft's technical log as *'Full'*.
2 Five cans of 20 litres each.
3 A propeller that is rotated by air flowing over the blades rather than powered by the engine, which creates significant drag.
4 Pilot A reported that at the time of the accident the aerodrome contained more obstructions than Figure 1 suggests – including a solar farm and industrial buildings.

Pilot A reported turning the magnetos off before landing, and while securing the aircraft afterwards noticed the throttle was fully open and the carburettor heat was ON. He did not report being injured but the extent of the damage to the aircraft was such that it could not be flown again until repaired.

Meteorological information

The Bristol Airport 1420 hrs METAR reported wind of 9 kt from 170°, visibility 10 km or more, no cloud detected, temperature 24°C, dewpoint[5] 14°C, and QNH 1022 hPa.

The Exeter Airport 1420 hrs METAR reported wind of 10 kt from 130°, CAVOK[6], temperature 23°C, dewpoint 14°C, and QNH 1022 hPa.

Aircraft information

General description and modifications

The Boeing Stearman is a biplane with tail-wheel landing gear. G-CPGY had been modified to perform wing walking experience flights.

The Continuing Airworthiness Management Organisation (CAMO) for the aircraft stated it had a Lycoming R-680-E3B engine installed around February 2019. The aircraft's technical log indicated it first flew with that engine in November 2019.

Fuel system

Fuel is gravity fed to the engine from a tank within the centre of the upper mainplane. There are four outlets from the tank (Figure 2). Pipes are connected to each outlet, which join forward to aft before entering the fuselage at the front supports. The left and right pipes join aft of the firewall before going to the engine as a single pipe. Fuel should therefore be available to the engine throughout the pitch and roll range provided positive g is maintained.

G-CGPY's *'Pilot's Flight Operating Instructions'* specified a fuel tank capacity of 46 USG (174 litres), and its *'Weight and Centre of Gravity Schedule'* described all of this as usable. The CAMO stated that momentary fuel starvation of the feed sumps was considered possible in some attitudes at low fuel levels.

Another operator of wing walking flights, in a Stearman with the same engine type and fuel tank as G-CGPY, reported that its aircraft's fuel tank capacity was approximately the same[7] as G-CGPY's. That operator specified an unusable[8] fuel quantity of 5.5 litres for its aircraft, indicating a usable capacity of around 167 litres.

Footnote

5 Dewpoint – the temperature at which the relative humidity of that air would reach 100%, based on its current degree of saturation.
6 Visibility ≥10 km; no CB or TCU; no cloud below 5,000 ft; and no significant weather at or near the aerodrome.
7 Placard 38 imperial gallons –approximately 173 litres.
8 Contained in the tank but not available to the engine in flight.

G-CGPY's CAMO thought the reason for the discrepancy between the two aircraft in what was considered 'usable' fuel was probably the addition of a safety margin by the other operator, in order to avoid conditions for starvation of the fuel feed sumps.

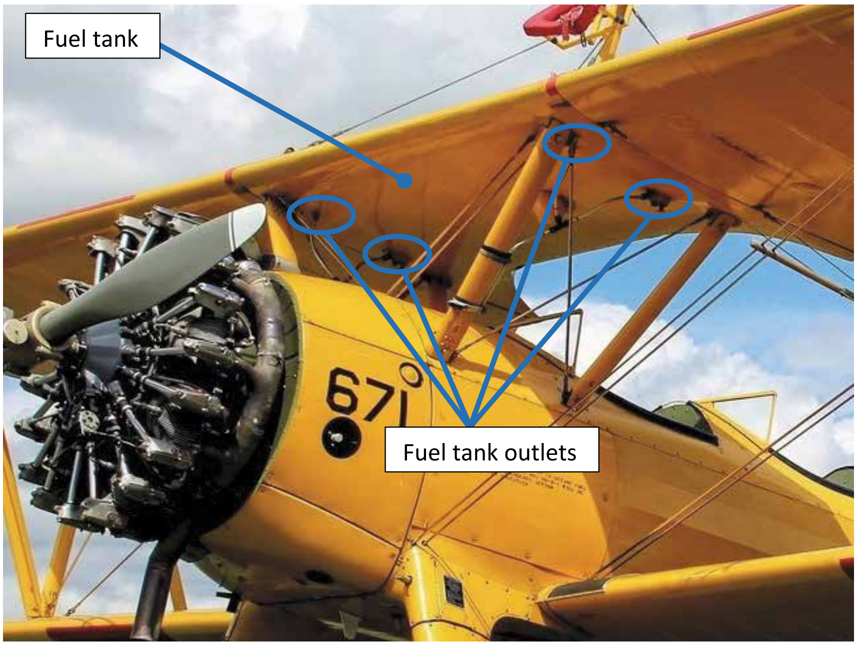


Figure 2

Fuel tank and fuel pipes from tank of G-CGPY (image used with permission)

Information from the CAMO

An engineer from the aircraft's CAMO attended G-CGPY at the accident site.

Following a subsequent inspection of the aircraft, its technical log stated that '*no mechanical reason*' was found for the engine to stop producing power.

Fuel planning information

The operator's operations manual did not contain guidance on fuel planning. Pilot A stated that he operated the aircraft according to guidance from Pilot B, and his own experience.

Fuel gauge

Pilot A reported that some time prior to the day of the accident, the aircraft's fuel gauge was "stuck on empty". There was no associated entry in the technical log. The CAMO stated that after the aircraft had been recovered "the fuel gauge in the fuel tank was found to function normally."

Regulatory information

G-CGPY was operated within the CAA's Safety Standards Acknowledgement and Consent (SSAC) framework, which allows recreational flights for fare-paying passengers in certain aircraft that are unable to meet commercial safety standards.

EASA NCO.OP.125 *'Fuel and oil supply – aeroplanes'*, applicable to the operation of G-CGPY, stated:

> *'The pilot-in-command shall only commence a flight if the aeroplane carries sufficient fuel and oil… by day, to fly to the aerodrome of intended landing and thereafter to fly for at least 30 minutes at normal cruising altitude.'*

Fuel planning information from Pilots A and B

Pilot B reported that he understood G-CGPY's fuel tank capacity to be 148 litres. He stated he had previously calculated a fuel consumption rate for G-CGPY based on having flown for 2 hours 50 minutes between two airports, which left 15 minutes of reserve fuel.

Pilot A reported that he understood G-CGPY's fuel tank capacity to be 170 litres, of which 155 litres was usable. He assumed a fuel consumption rate at cruise power of 48 to 60 litres per hour[9], and allowed 2.5 hours of endurance from a full fuel tank. For each ten-minute wing walking flight he assumed a total consumption of 15 litres.

Pilot A stated that after he and Pilot B refuelled the aircraft with all the jerrycans at Chiltern Park, the tank appeared "a few inches from full", and before departing for the accident flight appeared "approximately three quarters" full.

Pilot A stated that he drained approximately 20 litres of fuel from the aircraft's tank two days after the accident, immediately before the aircraft was recovered from the landing field.

G-CGPY's technical log included takeoff-to-landing times for each flight. Taxi times were not recorded.

Fuel planning information from the other operator

The other operator stated that it used the following fuel planning assumptions[10], based on experience of operating wing walking flights in its aircraft:

- Consumption rate at a normal cruise power setting – 65 litres per hour
- Total consumption for taxi, takeoff and climb – 15 litres
- 1 hour flight 'chock-to-chock' – 80 litres
- Total consumption for a ten-minute wing walking flight – 15 to 17 litres
- Maximum planned flight time on a full tank of fuel, allowing reserves – 2 hours[11,12]

Footnote

9 He reported using 0.8 to 1 litre per minute.
10 These assumptions did not preclude pilots using more conservative figures as required by the circumstances of the flight.
11 Using 65 l/hr average consumption, fuel remaining after a 2 hour flight would be around 44 litres or 41 minutes endurance.
12 One of its pilots stated he had never exceeded 2 hours and 15 minutes on a full tank of fuel.

Carburettor icing

The CAA's *'Safety Sense leaflet 14 Piston Engine Icing'* explains that carburettor icing:

> *'can occur at any time… It can be so severe that unless **correct** action is taken the engine may stop (especially at low power settings during descent, approach or during helicopter autorotation).'* [Emphasis in original.]

Analysis

Introduction

The total of all fuel provided for G-CGPY on the day of the accident, including a full tank and the amount uplifted, was a maximum of 274 litres, some of which may have been unusable.

Fuel planning - Pilot B

Pilot B reported calculating a fuel consumption rate for G-CGPY, based on a 2 hr 50 minute flight, at the end of which 15 minutes of reserve fuel remained. However, by assuming a smaller fuel tank capacity than that specified in the *Pilot's Flight Operating Instructions*, the consumption rate he calculated was less than the actual rate. It is not clear how he quantified the 15 minute reserve (which is less than the EASA requirement). The flight on which he based these calculations appeared to have occurred before the Lycoming R-680-E3B engine was installed on the aircraft and therefore was not reliable.

Fuel planning – Pilot A

Using Pilot A's assessments and information from the aircraft's technical log – and adding 30 litres for the taxi, takeoff and climb phases[13] of the two positioning flights – 250 litres could have been consumed up to the time of the accident. Assuming the fuel tank was filled to maximum capacity to begin with, and using Pilot A's consumption rate of 1 litre per minute, approximately 24 minutes[14] of fuel may have remained after the accident, of which he considered 15 litres (or 15 minutes at cruise power) was unusable.

Whether or not all the fuel was usable, the aircraft would, prior to reaching *'the aerodrome of intended landing'* (Dunkeswell) have been consuming the 30 minute reserve required by Part-NCO.

Fuel planning – the other operator

The other operator's fuel planning figures were more conservative than those used for G-CGPY. Using the more conservative assumptions suggested G-CGPY may have consumed up to 273 litres throughout the day, which was approximately all of the fuel that had been loaded on the aircraft.

Footnote

[13] Pilot A did not specify fuel planning assumptions for these flight phases, which are dependent among other things on their duration. The figures specified by the other operator have been added to enable an estimate to be made.

[14] Using the other operator's figures the calculated endurance would be approximately 22 minutes.

Discussion

Carburettor icing was a possibility, and the investigation did not exclude other technical reasons for the engine to stop producing power. Without a record of accurate measurements it was not possible for the investigation to determine the actual fuel quantities. However, the available information indicated that the aircraft's fuel tank did not contain sufficient fuel, including the required reserve, for the intended flight. When the engine stopped producing power, Pilot A's prompt actions reduced the severity of the outcome.

The pilots of G-CGPY did not appear to have a complete understanding of the usable fuel quantity and consumption rate for the aircraft. If the fuel gauge remained unserviceable as previously reported this would have exacerbated any uncertainty.

Conclusion

It is likely that the engine stopped producing power when it had consumed all the usable fuel onboard. Uncertainty about the aircraft's fuel consumption and tank capacity contributed to the circumstances.

Safety action

As a result of this accident, the operator has:

- mandated a refuel stop for its aircraft, after a maximum of 1.5 hours of flight time
- introduced a requirement for cross-country flights to depart with a full fuel tank
- introduced a requirement for its pilots to check and record an aircraft's fuel quantity every second wing walking flight using a calibrated fuel tank dipstick
- revised its aircraft technical log pages to include 'engine start' to 'engine stop' times, for accurate monitoring of fuel use and engine parameter trends
- introduced an annual technical questionnaire for its pilots, to refresh significant aspects of their safety knowledge
- introduced an SSAC Pilot Manager, in addition to the Chief Pilot role already in place, to share decision making for the operation – each post holder having equal right to prevent a flight taking place if there were safety concerns.

SERIOUS INCIDENT

Aircraft Type and Registration:	Cessna F177RG, G-AYSY
No & Type of Engines:	1 Lycoming IO-360-A1B6 piston engine
Year of Manufacture:	1971 (Serial no: 26)
Date & Time (UTC):	7 September 2020 at 1500 hrs
Location:	Leicester Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Damage to the nose landing gear, propeller and engine
Commander's Licence:	Light Aircraft Pilot's Licence
Commander's Age:	31 years
Commander's Flying Experience:	105 hours (of which 76 were on type) Last 90 days - 20 hours Last 28 days - 12 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Returning to Leicester Airport after a flight away from base, the pilot of G-AYSY completed a normal join and circuit to Runway 28. The landing gear was lowered and a check of both the indicator lights and the external mirror showed it to be down and locked. Shortly after landing, as the aircraft reduced speed, the nose landing gear collapsed. Both the pilot and passenger were able to vacate the aircraft and suffered only minor injuries. The cause of the nose gear collapse was not established.

History of the flight

The pilot had completed three circuits at Leicester before meeting up with his passenger for a flight to Newquay via Cardiff before returning to Leicester. The pilot reported no technical issues with the aircraft all day. There was no indication on any of the previous flights or landings that there were any issues with the landing gear and the pilot reported that the extension prior to the landing at Leicester was normal.

Having touched down, the pilot reported that the aircraft began to slow as he expected. The pilot retracted the flaps and as the aircraft speed passed around 40 mph the nose gear collapsed following what he reported as a "metallic sound". The aircraft continued along the runway for approximately 70 metres before coming to a stop, still on its main wheels but with the nose resting on the tarmac. Both the pilot and passenger were able to vacate the aircraft and suffered only minor injuries. The aircraft suffered damage to the nose landing gear and nose gear doors, propeller and engine. Figure 1 shows the aircraft on the runway.

Figure 1
G-AYSY on the runway at Leicester

Aircraft information

G-AYSY is fitted with a retractable tricycle landing gear. The landing gear is retracted and extended by hydraulic actuators powered by an electrically driven hydraulic power pack. The nose gear has an over-centre mechanical linkage to provide positive up and down locks for the nosewheel. It also has mechanically actuated gear doors that are open if the nose gear is down and closed if it is up. When the over-centre link is made, the hydraulic pressure to the actuator is removed. Proximity microswitches are used to sequence and control the landing gear system. When all three gear legs are down and locked, the electrically driven hydraulic pump is stopped. The green cockpit light illuminates only when all the gear is down and locked, and when the electrically driven hydraulic pump is no longer running.

There are two gear position indicator lights fitted in the cockpit. A green light indicating the gear is down and an amber light indicating the gear is retracted. There is also a mirror fitted to allow inspection of the position of the gear from the cockpit. The indicator lights use a microswitch which must be made in order to ensure the gear is in the selected position before the light will illuminate. The aircraft is also fitted with a warning horn which sounds intermittently when the throttle is retarded below approximately 12 inches of manifold pressure when the gear is up, or not down and locked. The pilot commented that the green extension light illuminated, and the gear extension looked normal in the examination mirror. There was no warning horn during the approach or landing. He has been flying the aircraft for some time, and having experienced a previous landing gear problem, he stated that he is very careful about its operation and indications.

The nose landing gear is fitted with a squat switch which prevents the gear being retracted when the aircraft is on the ground. The squat switch is a ‘weight on wheel’ switch. Until the squat switch is compressed it is possible to retract the gear, although the main gear is over-centred when down so is unlikely to be able to retract as soon as ground contact is made. The nose gear retracts rearwards.

G-AYSY had previously experienced a gear problem in 2019 which resulted in a landing without the main gear being locked down[1]. This was as a result of a failure of a hydraulic pipe within the gear system. The aircraft was repaired and returned to flight.

Aircraft examination

After the landing a bolt was recovered from the runway which was identified as the nose gear centre torque link bolt. This bolt had been in contact with the runway surface after the nose gear collapse and as a result suffered significant damage. The nut from the bolt was also missing. There was also corresponding runway contact damage to the nose gear torque link. These were the only two parts of the nose gear that were found to have sustained damage, and they are shown in Figure 2. Their positions in the nose gear assembly are shown in Figure 3.

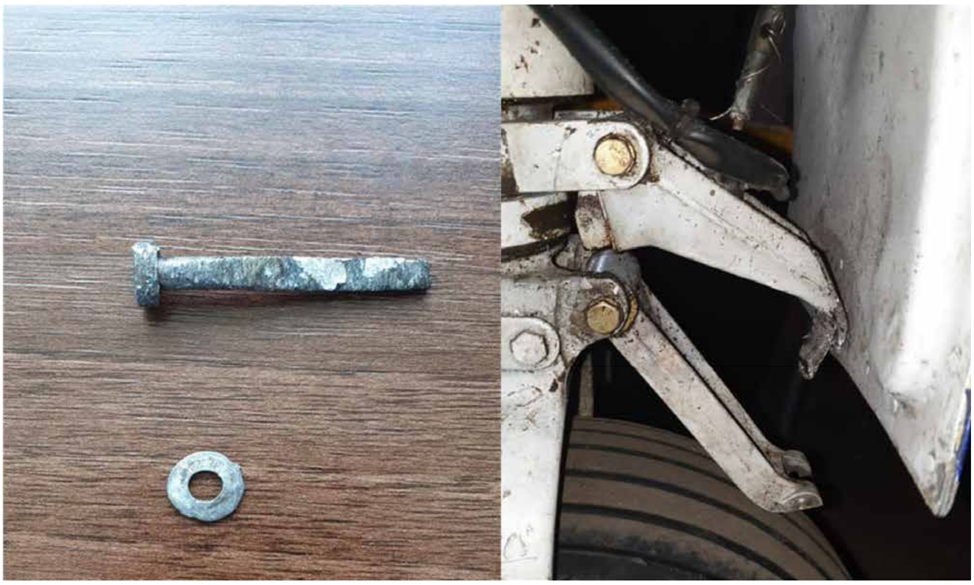


Figure 2

Centre torque link bolt (left) and torque link (right)
(used with permission)

Footnote

1 https://www.gov.uk/aaib-reports/aaib-investigation-to-cessna-f177rg-cardinal-rg-g-aysy [Accessed May 2021]

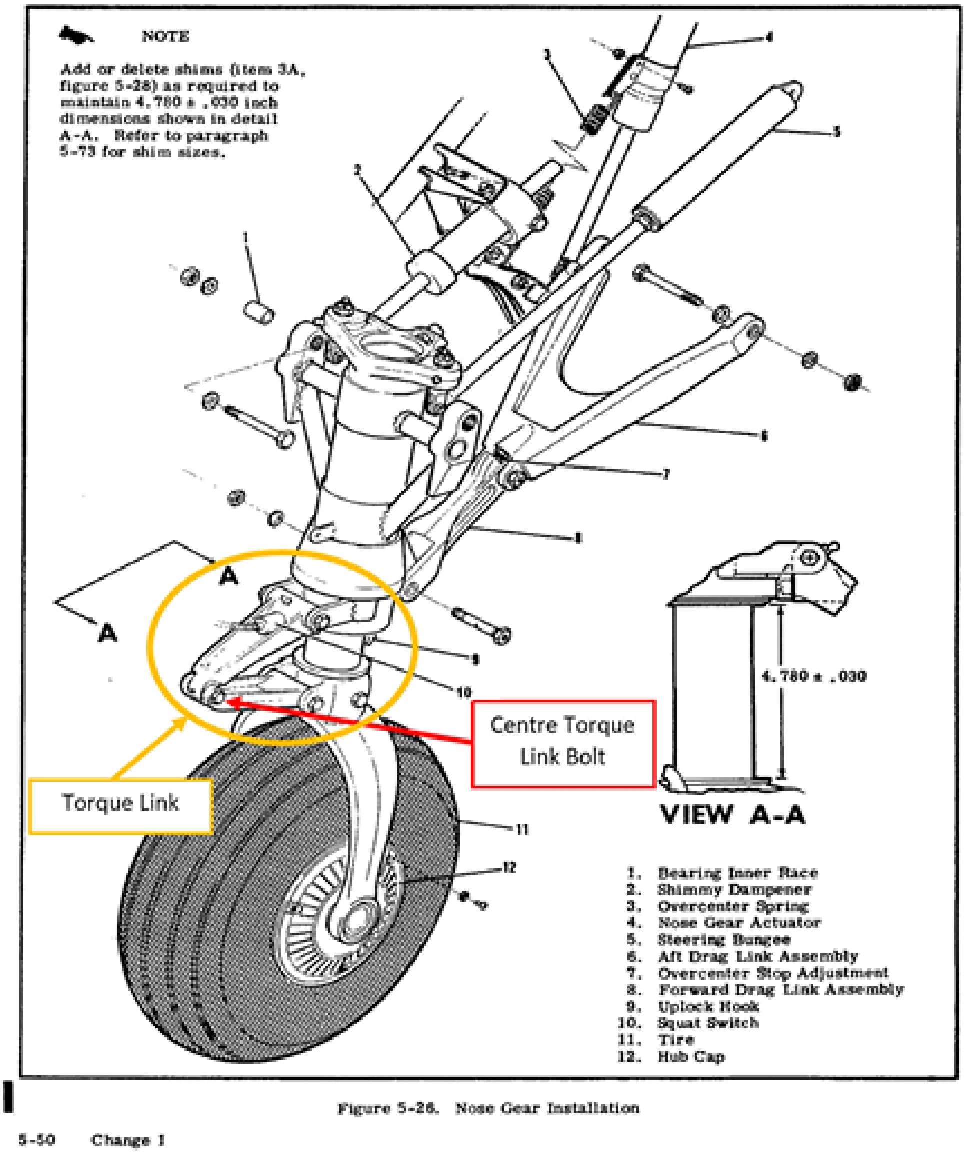


Figure 3

Nosewheel diagram from the Maintenance Manual showing the torque link and bolt (© Textron Aviation)

The aircraft was recovered from the runway and examined by a maintenance organisation. Testing of the individual components of the nose gear found no faults that could have caused the collapse. The retraction and extension system were tested and found to work normally. The maintenance organisation considered that the damage to the torque link bolt and torque link was an artifact of being in contact with the runway after the collapse, rather than contributing to the accident.

Analysis

With no damage to the remaining nosewheel structure it was considered unlikely that the nose gear had collapsed due to a heavy landing or overload. Such a load would have caused significant damage to the drag link assembly as well as the shock strut.

The pilot of G-AYSY had operated the retractable gear without incident or concern on the day of the accident. When he approached Leicester for his final landing of the day, he extended the gear, saw the green downlock indicator light and checked the gear extension in the mirror. After a normal landing, as the aircraft began to slow, the pilot retracted the flaps and shortly afterwards the nose gear collapsed. After a further 70 m, the aircraft came to a halt resting on its nose.

There are two possible scenarios for the retraction of the nose gear. Firstly, had the nose gear not been fully extended, with the over-centre lock not made, then a collapse of the nose gear could have occurred with little or no damage except for those parts in contact with the runway. For the gear down indicator light to illuminate in the cockpit and for the warning horn to be absent, the system must 'believe' that the legs were down and locked. The power pack pump must also no longer be pressurising the system. This can only occur when the microswitches that control the extension circuits are closed. The microswitches are proximity switches, and it is possible that a misalignment in one of these switches caused the extension system to indicate that the nose gear was down and locked when it was not.

Secondly, it is possible that the pilot inadvertently selected the gear to retract when he reached for the flaps after landing. Whilst the nose gear is fitted with a squat switch to prevent retraction on the ground, it may be that the weight was not sufficiently on the nose wheel for the switch to be made, and therefore retraction began. As soon as the over-centre mechanical lock begins to fold, any weight on the nosewheel would assist the retraction. The pilot is sure that he did not inadvertently knock or move the gear handle after landing. Having previous experience of gear problems on this aircraft, the pilot also commented that he was extremely vigilant about its operation.

The nose gear centre torque link bolt was recovered from the runway, which together with the torque link had suffered damage from contact with the runway. These were the only two parts of the nose gear to have been damaged. After the aircraft was recovered to a maintenance facility, the nose gear was checked with no further faults found.

Conclusion

After landing, and as the aircraft slowed on the runway, the nose gear collapsed. The damage found to the centre torque link bolt and the torque link was attributed to being in contact with the runway and was considered unlikely to have been a causal factor in the accident. No other components of the nose gear were found to be faulty and a test of the retraction/extension system worked correctly. Given the lack of further structural damage to the nose gear, it is likely that the nose gear mechanical over-centre lock was not fully extended, either due to a technical fault or because the gear was retracted inadvertently after landing. It was not possible to determine what caused the collapse of the nose gear.

SERIOUS INCIDENT

Aircraft Type and Registration:	DA 42 NG, G-HAKA	
No & Type of Engines:	2 Austro E4-C piston engines	
Year of Manufacture:	2015 (Serial no: 42.N158)	
Date & Time (UTC):	8 December 2020 at 1020 hrs	
Location:	Leeds Bradford Airport, West Yorkshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	2,013 hours (of which 930 were on type) Last 90 days - 44 hours Last 28 days - 16 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot, operator's safety report and further enquiries by the AAIB	

Synopsis

The aircraft lost electrical power shortly after takeoff because the alternators had not been switched ON. The pilot did not notice the incorrect switch setting before takeoff, or when carrying out the abnormal checklists in flight. The engines continued to operate, and the pilot returned to the departure airport with the aid of the standby artificial horizon and a mobile phone based flight planning application.

As a result of this serious incident, the AAIB submitted an observation to the aircraft manufacturer, and the operator took safety action to better inform its pilots.

History of the flight

The pilot and passenger intended to fly to Southampton Airport where the aircraft was required for aerial work. Neither engine would start, and the pilot reported no glow-plug indications and poor engine turnover when using the starter motors. Engineers from the operator's maintenance provider eventually started the engines with the aid of a ground power unit. Engine ground runs and a download of the engine Electronic Control Units (ECUs) showed no anomalies. A maintenance release form was signed off on the basis that the main aircraft battery charge state was probably low, and the pilot and passenger reboarded the aircraft approximately 1 hour 45 minutes behind schedule.

The pilot reported that the engines started, but the LOW VOLTS cautionary alert was displayed shortly after the cockpit checks were complete. This was disregarded "*as a likely result of the earlier problems and something that would clear with engine running*".

Following a normal takeoff there was an audible alert and the pilot again observed low voltage cautions for both main electrical busbars[1]. The pilot decided to return to Leeds Airport but did not declare an emergency because "*the checklist suggests 30 minutes time available*". The abnormal checklist for LOW VOLTS refers to two more checklists; 4B.3.7-VOLTAGE and 4B.4.6 - L/R ALTN FAIL. The pilot reported that the checks required by 4B.3.7 were completed, but not those in 4B.4.6 because an alternator failure was not displayed. The first action in checklist 4B.3.7 is to ensure that the alternators are switched ON.

Following the checklist, the pilot reduced electrical loads but the busbar voltages decreased to 21 volts as the aircraft was on the downwind leg. After completing the pre-landing checks the pilot used a GPS tracking device to send a message to the operator informing them of the problem and selected the ILS approach plate on an electronic tablet. The electrical load was further reduced by switching off the lights apart from the strobes. As the aircraft started the turn onto the base leg the busbar voltages decreased rapidly and the pilot informed ATC that communications might be lost. They provided vectors to intercept the ILS, clearance to land and requested confirmation of the number of people on board. The pilot responded and having acquired the localiser the landing gear was lowered and the aircraft captured the glideslope for the landing. Shortly after, all electrical power was lost, which resulted in the loss of the electronic flight displays.

The pilot switched on the emergency power for the standby artificial horizon, levelled off, and started a turn to the right. The cloud base was approximately 700 to 800 ft agl so, when a suitable gap was found, the pilot descended whilst maintaining sight of the ground. With the aid of a mobile phone based flight planning application, the pilot was able to return to the airport where an uneventful landing was carried out.

Aircraft information

The DA42 NG is a four-seat, twin-engine aircraft designed to Joint Aviation Requirements (JAR) 23[2]. The aircraft is equipped with two Austro diesel engines and is equipped with a Garmin G1000 glass cockpit display suite.

G-HAKA is equipped with mission equipment specific to the aircraft's role, and which increases the loads on the electrical system.

Footnote

[1] The pilot took a photograph during the flight, which shows that the stall warning system was also showing a failure.

[2] The Joint Aviation Requirements were issued by the Joint Aviation Authorities (JAA) as a set of common requirements that participating countries would comply with. The European Aviation Safety Agency (EASA) has taken over most of the JAA functions and the JARs have been replaced by EASA Certification Standards. JAR-23 defined the requirements for Normal, Utility, Aerobatic and Commuter Category Aeroplanes.

Power generation and electrical distribution

The aircraft has two alternators, one being driven by each engine. They are connected to the respective main electrical busbars (left and right) via alternator relays and circuit breakers. The main busbars are connected to the battery busbar via another circuit breaker.

If the main aircraft battery fails, the alternator field windings are energised by ECU back-up batteries and, if the alternators fail, these back-up batteries can power the ECUs for 30 minutes so that the engines continue to operate.

Each alternator has its own control unit, which includes diagnostic functions to warn the pilot of certain failure conditions using a caution message (L/R ALTN FAIL) on the G1000. The alternators can be switched ON or OFF using toggle switches on the left side of the instrument panel, below the ECU test buttons. Selecting an alternator switch to ON connects the output of the respective alternator to its main electrical busbar. If the engine is running and the switch is in the OFF position, the alternator will still provide power to the alternator control unit, fuel pumps, ECU, and ECU back-up batteries, but the main busbar will be powered by the main aircraft battery.

A voltmeter shows the main busbar voltages on a horizontal scale, Figure 1. Under normal operating conditions, with both alternators switched ON, the displayed voltages will show the alternator output. If an alternator is switched OFF, the respective voltmeter will show the main battery voltage, because the affected busbar will now be powered by the battery. If both alternators are switched OFF, both voltmeters will show the main battery voltage. The status of the alternator switches is not shown on the G1000.

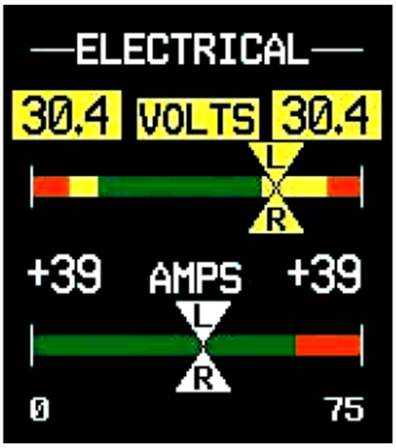


Figure 1

Schematic showing the voltmeter and ammeter displays on the G1000
(Schematic from the manufacturer's AFM)

A sensor on each alternator output measures the electrical current, which is displayed on the G1000 ammeter. If an alternator switch is OFF, but the associated engine is running, the respective ammeter will still show an electrical current because the alternator will be supplying power to the alternator control unit, fuel pumps, ECU and ECU back-up battery.

A non-rechargeable battery provides an emergency power source for a standby artificial horizon, which is activated when the pilot selects the EMERGENCY switch to ON.

Operator's investigation

The main aircraft battery was found to be depleted after the incident. Engine ground runs showed no anomalies and a check flight was successfully completed. The operator concluded that the most likely scenario was that the alternators were not switched ON before the incident flight.

Engine runs and maintenance checks prior to the incident flight

When the pilot was initially unable to start the engines, the maintenance provider carried out engine ground runs before downloading the ECUs to check for faults. This work was conducted in accordance with the AFM, the aircraft maintenance manual (AMM) and the engine maintenance manual (EMM).

The AMM procedure for downloading the ECU referred to the EMM, and contained a cautionary note that stated:

> '*WHEN OPERATING THE AIRPLANE ELECTRICAL SYSTEM WITH ENGINE MASTER ON (LH OR RH) AND THE ENGINE IS NOT RUNNING ALWAYS CONNECT AN EXTERNAL SUPPLY WITH A PRESET VOLTAGE OF 29V TO THE AIRPLANE. OTHERWISE THE ALTERNATORS MAY BE DAMAGED.*'

The ECU download procedure did not mention the alternator switches, but five similar cautionary notes in other sections of the AMM all included this additional text:

> '*e.g. EVENT LOG READOUT*' and '*ADDITIONALLY, IF MAM 42-551 IS INSTALLED, SWITCH OFF BOTH (LH AND RH) ALTERNATOR SWITCHES*'.

Modification MAM 42-551 was installed on G-HAKA during build, so these other cautionary notes indicated that the alternators should be switched OFF when downloading the ECUs. The ground engineers were reported to have switched the alternators OFF because this is what the aircraft manufacturer had taught them to do. They did not switch the alternators ON again when they completed their work.

Checklists and pilot actions

The pre-flight inspection checklist in the AFM includes a check that the alternator switches are ON. The before engine start checklist also includes a check that the switches are ON.

The pilot reported to the AAIB that under normal operating conditions, the alternator switches are always ON, because the AFM does not require them to be switched OFF after a flight. The pilot also reported that "fundamental to the loss of electrical power, I twice checked the Alternator Switches and saw them as On when they were, in fact, Off".

The LOW VOLTS abnormal checklist indicates that possible causes include a fault in the power supply or the alternators being OFF. It directs the pilot to a separate VOLTAGE checklist (4B.3.7), but it also contains a cautionary note that '*if both low voltage indications are ON, expect failure of both alternators and follow 4B.4.6 – L/R ALTN FAIL*'. In the case of G-HAKA, both low voltage indications were on, but there were no associated alternator indications, so checklist 4B.4.6 was not relevant.

Checklist 4B.3.7 is split into two scenarios: on the ground and in-flight. The first action in both scenarios is to check that the alternators are switched ON. If the fault occurs on the ground and cannot be cleared, the flight should be terminated. If the fault occurs in flight and cannot be cleared, the checklist directs the pilot to procedure 4B.4.6. The pilot reported that the LOW VOLTS indication occurred on the ground shortly after starting the engines, but believed it was associated with the earlier problems and dismissed it without referring to the abnormal checklists. It is not known if the LOW VOLTS indication cleared prior to takeoff but, with the alternators switched OFF, there would be no mechanism for this.

Once airborne, the pilot heard an audible alert, and when they checked the G1000, both LOW VOLTS cautions were displayed. A photograph that was taken during the incident flight showed that the stall warning system was also showing a fault.

Other information

The aircraft manufacturer reported that they were aware of one previous similar event.

Analysis

Initial problems when trying to start the engines

The pilot was unable to start the engines and the most likely scenario is that the main aircraft battery charge state was low.

Engine ground runs

The maintenance provider started the engines and ground runs showed no anomalies. They switched the alternators OFF when they downloaded the ECUs, but this was not a requirement of the download procedure in the AMM. It was noted that five other procedures in the AMM contained cautionary notes that the alternators should be switched OFF during an event log readout, which is what the engineers said the aircraft manufacturer had taught them to do. The alternator switches were left in the OFF position when the work was complete.

The AAIB believe that the contradicting cautionary notes can cause confusion and, potentially, aircraft system damage. The AAIB highlighted the anomaly as an observation to the aircraft manufacturer so that the AMM can be reviewed and amended accordingly.

Incident flight

The pilot reported that the LOW VOLTS cautionary alert was displayed shortly after the engines were started and the cockpit checks were complete. This was dismissed as being associated with the earlier problems.

Shortly after takeoff, the pilot heard an audible alert and observed that both LOW VOLTS indications were displayed. A photograph taken during the flight showed that the stall warning system was also displaying a fault, and the aircraft manufacturer stated that this was the probable cause of the audible alert. It is not known if the LOW VOLTS indications cleared prior to takeoff[3] but checklist 4B.3.7 stated that if the fault could not be rectified on the ground, the flight should be terminated.

The pre-flight and engine start checklists include checks that the alternator switches are ON. The pilot reportedly checked the switches on two occasions, believing them to be ON when they were OFF. It was stated that the alternator switches are normally left in the ON position because the AFM does not require them to be switched off after flight. It is, therefore, probable that confirmation bias[4] resulted in the pilot seeing what they expected when the switches were checked.

The G1000 display system does not depict the alternator switch status and has two voltmeters, one for each of the main busbars. If the alternator switches are OFF, the voltmeters continue to show the busbar voltage, which will be the main aircraft battery voltage. Furthermore, if the alternator switches are in the OFF position and the engines are running, the ammeters will show a current demand because the alternators will be supplying electrical power to the alternator control units, fuel pumps, ECUs and ECU back-up batteries. This could potentially reinforce the belief that the alternators are switched ON when they are OFF.

The electronic display suite shut down when the main aircraft battery voltage reduced below the requirement to power the system. The engines continued to run because the alternators continued to supply electrical power to the alternator control units, fuel pumps, ECUs and ECU back-up batteries.

Conclusion

The most likely scenario is that the alternators were not switched ON prior to takeoff and the pilot did not identify the incorrect switch position. When the aircraft battery depleted the electronic displays failed, but the engines continued to operate because, despite being OFF, the alternators continue to power the ECUs and fuel pumps.

The pilot successfully returned to the airport with the aid of a mobile phone and the standby artificial horizon.

Footnote

3 If the alternator switches were OFF, there is no mechanism for the LOW VOLTS cautions to have cleared.
4 Confirmation bias is the human trait whereby we seek to identify aspects around us that prove a hypothesis, understanding or perception we have.

Safety actions

The operator issued an Operational Crew Instruction to:

1. Require pilots to complete the before engine start checklist as a read-and-do checklist instead of from memory.
2. Highlight the fact that the G1000 does not show if an alternator is switched ON or OFF.
3. Highlight the requirements of the low voltage abnormal checklist and require pilots to study it prior to their next flight in a DA 42.
4. Remind pilots that the AFM does not permit flight with a discharged battery under IFR or night VFR conditions.

ACCIDENT

Aircraft Type and Registration:	Nicollier HN 700 Menestrel II, G-MINS
No & Type of Engines:	1 Volkswagen 1900 piston engine
Year of Manufacture:	1996 (Serial no: PFA 217-12354)
Date & Time (UTC):	30 March 2021 at 1200 hrs
Location:	Bedlands Gate Airfield, Cumbria
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller and engine shock loaded
Commander's Licence:	Light Aircraft Pilot's Licence (Aeroplanes)
Commander's Age:	60 years
Commander's Flying Experience:	1,328 hours (of which 1 were on type) Last 90 days - 2 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot stated that having bought the aircraft, he planned to fly it from Bedlands Gate Airfield, Cumbria, to relocate it. As the grass strip was wet after recent rain the pilot walked the length of Runway 16 with an experienced pilot friend and noted the surface was firm along the entire length.

After start-up, the pilot taxied the aircraft down Runway 34 and attempted a 180° left turn using the turning circle. While doing so the aircraft's right wheel sank into a patch of soft ground at the edge of the turning circle. The aircraft then slewed right and tipped onto its nose, damaging the propeller and stopping the engine. The pilot exited the aircraft normally and, with the help of his friend, removed the aircraft from the mud and towed it back to the hangar.

Although the main runway was firm, the pilot and his friend did not notice the soft ground at the extreme edge of the turning circle. The pilot added that he will never again take for granted the condition of the extreme edges and far ends of an unfamiliar grass strip.

ACCIDENT

Aircraft Type and Registration:	Pioneer 300, G-GTOM
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2008 (Serial no: LAA 330-14795)
Date & Time (UTC):	28 February 2021 at 1718 hrs
Location:	Wadswick Farm airstrip, Box, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Cracked propeller blades, damage to nose landing gear and engine cowling
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	75 years
Commander's Flying Experience:	628 hours (of which 102 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot had flown a short maintenance flight and was on a stable approach for Runway 10 at Wadswick Farm airstrip. The pilot reported a moderate bounce after touchdown, applying slight power and then landing normally. He applied the brakes as there was a downslope to the runway and, at a 'slowish' speed, the nose landing gear collapsed and the aircraft came to a halt.

The landowner has subsequently filled in several defects in the runway surface, one of which was 6" to 8" deep on the runway centreline, after being notified by several pilots and an LAA Inspector of the rough surface. The pilot assessed the nose landing gear collapse may have been caused by striking a defect in the runway combined with braking for the downslope.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-181, G-JANT
No & Type of Engines:	1 Lycoming O-360-A4M piston engine
Year of Manufacture:	1983 (Serial no: 28-8390075)
Date & Time (UTC):	30 April 2021 at 1814 hrs
Location:	Bolt Head Airfield, Kingsbridge, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to fuselage, both wings, undercarriage and propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	143 hours (of which 73 were on type) Last 90 days - 11 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot overflew the 600 m grass strip, which was familiar to him, and after seeing that there was no wind decided to land on Runway 11 to avoid the glare of the sun on the approach to Runway 29. The aircraft was high on the first approach, so the pilot decided to go around.

On the next approach, with full flap selected, the pilot slowed the aircraft from a 70 kt approach speed, flared and touched down about 50 m beyond the threshold. After bouncing once, the brakes were progressively applied to slow the aircraft on the damp grass. The pilot sensed that the aircraft was not slowing as anticipated so released and pumped the brakes, but without much apparent effect. Seeing the 4 ft high wire boundary fence about 150 m ahead, the pilot decided to go around. Two stages of flap were selected, and full power applied. The pilot allowed the aircraft to accelerate for "as long as possible" before pulling back on the stick. As the aircraft became airborne the pilot "possibly heard the stall warner and so pushed forward slightly to gather speed". However, the aircraft's landing gear contacted the fence and a second 4 ft high wire fence 2 m beyond, after which the nosewheel and right landing gear became detached. The aircraft came to a stop after sliding for about 300 m into a further field boundary fence (Figure 1).

The pilot and passengers were unharmed and exited the aircraft once the pilot had removed the ignition key and turned off the fuel. The pilot later confirmed that the brakes were working correctly when tested during taxiing prior to take off from the departure airfield.

Figure 1

Final resting position of G-JANT
(used with permission)

ACCIDENT

Aircraft Type and Registration:	Robinson R44 Clipper I, G-CLIO
No & Type of Engines:	1 Lycoming O-540-F1B5 piston engine
Year of Manufacture:	2000 (Serial no: 742)
Date & Time (UTC):	17 December 2020 at 1530 hrs
Location:	Private landing site, Holmfirth, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - 1 (Minor) Passengers - 2 (Minor)
Nature of Damage:	Tail rotor shaft fractured, tail rotor damaged, damage to skids and belly of the aircraft
Commander's Licence:	Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	108 hours (of which 108 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

A downwind 'out-of-ground-effect' transition to the hover resulted in overpitching of the main rotor. The subsequent reduction of rotor rpm caused a rapid increase in descent rate and a loss of tail rotor authority. The pilot was unable to react in time to prevent a turning, descending flight path and the helicopter struck the ground causing substantial damage.

Safety Sense Leaflet 17 – '*Helicopter Airmanship*', published by the CAA and Safety Notice SN-42 – '*R44 Pilot's Operating Handbook*', published by the Robinson Helicopter Company contain relevant safety advice to prevent this type of accident. A safety course is also available from the Robinson Helicopter Company for rated pilots.

History of the flight

The pilot had planned to take two passengers to visit his friend at a farm in Holmfirth, where he intended to land in a nearby field. He was aware of obstacles near the field such as trees, power lines and sloping ground, but he intended to make an out-of-ground-effect (OGE) hover to allow him to assess the landing spot visually before landing.

The take off at 1435 hrs and the 20 minute VFR flight to Holmfirth were uneventful. The pilot identified the destination field and completed two overflights to assess his landing point. He observed the overhead domestic power lines running alongside the southern edge of the field and a wind turbine nearby, indicating the wind direction.

He made a steep approach to clear the power lines, but realised he was running out of room to land and raised the collective lever to slow down. He found there was insufficient power to arrest his descent and with about 6 ft of height remaining, the low rpm warning horn sounded and the rpm warning light illuminated. The helicopter yawed through 180° before striking the ground hard in a flat, slightly tail down attitude.

The pilot switched off the fuel valve, disengaged the clutch and turned the master switch off. He applied the rotor brake and he and his passengers vacated the aircraft. There was no fuel leak and no fire.

Accident site

The aircraft had landed in a part of the field where the ground was undulating, sloping and boggy. To the east and west of the field were ridge lines with a wind turbine situated to the south and power lines positioned to the south and south-east (Figure 1).

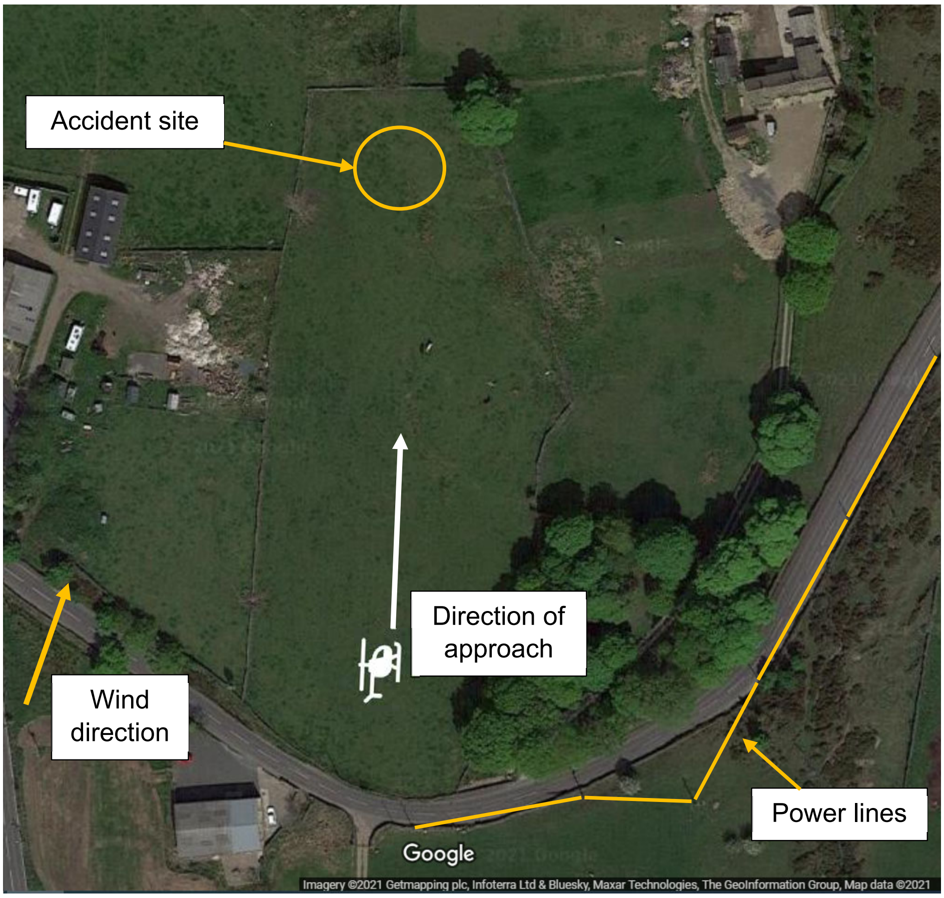


Figure 1

Landing field showing power lines, wind direction and crash site

There were ground impact marks directly below the tail rotor where the blades had hit the soft, grassed surface. The tail rotor blades were bent and twisted and one of them had broken off near the root.

The vertical stabiliser, tail rotor guard and tail skid were damaged and disrupted. A large hole had been made in the left side of the tail boom where the tail rotor had punctured the skin and struck the tail rotor shaft, which had sheared. The landing skids were bent upwards and outwards and were partially disrupted (Figure 2). There was evidence of yielding of the cockpit seat structure and keel panels, and the lower belly of the aircraft was damaged.

In the cockpit, the engine fuel mixture control was found pushed in and guarded, and the carb-heat lever was unlatched and pulled halfway out.

Figure 2

Tail and tail rotor damage, ground impact marks and disrupted landing gear skids

Aircraft information

The Robinson R44 Clipper I[1] (Figure 3) is a four-seat light helicopter powered by a single Lycoming O-540, six-cylinder, carburetted piston engine. The carburettor system features a heat assist function to adjust carburettor heat mechanically as the collective lever is raised or lowered, which is designed to improve safety and reduce pilot workload.

Figure 3

G-CLIO
(Image used with permission)

Footnote

[1] The Robinson Helicopter Company also manufacture an R44 Clipper II model.

Aircraft examination

The skid mounting structure was crushed and torn, particularly around the right cross-tube tunnel area, and the lower right side of the fuselage was distorted. The engine's lower carburettor and filter housing was buckled and crushed. The main rotor mast and housing were undamaged and there was no evidence that the main rotor had been in contact with any obstacles or the aircraft structure. The fuel bladder tank was also intact.

Meteorology

The weather at Walton Wood Airfield was dry and bright with no significant cloud and good visibility. The Leeds/Bradford METAR at 1450 showed the wind from 210° at 14 kt, the visibility greater than 10 km, the temperature at 8°C with a dew point of 5°C, and the QNH was 1009 hPa.

Downwind approach

From a video of the approach and landing taken from ground level, smoke from the exhaust can be seen blowing away from the aircraft in a northerly direction after the landing, which shows the pilot had made a downwind approach. This was confirmed by the direction of a nearby wind turbine which showed the prevailing wind was behind the aircraft during the approach.

Pilot's assessment

The pilot knows from the video footage that he misjudged the wind direction and made a downwind approach to the landing site. At the time, he didn't believe the wind direction indicated by the wind turbine because it did not fit with his 'mental picture.' He stated that when he turned final, he increased his speed from 40 mph to 50 mph. He noted his descent rate was 500 fpm and the aircraft felt stable. After clearing the power lines, he realised that he had a high groundspeed and felt forced into slowing the aircraft down sooner and at a greater height than he had planned, therefore, his chosen landing profile would require more power.

His intention had been to raise the collective at approximately 20 to 30 ft agl to flare and transition into a hover, but when he tried there was not enough power available. He stated that this had been a surprise because during the two overflights of the field there seemed to be power to spare.

When he reached 100 ft agl, the wind speed appeared to suddenly reduce, possibly due to the terrain profile of the valley he had flown into. He thinks he might have placed the aircraft into a 'vortex ring state' which caused the aircraft to descend rapidly. The sudden onset of yaw to the right was so rapid he was unable even to attempt any correction before striking the ground.

Overpitching and vortex ring state

Overpitching

'Overpitching' is a dangerous condition in helicopter flight which occurs when rotor blade pitch is increased (from raising the collective lever) without sufficient engine power to compensate for the extra rotor drag produced. The result is a high rate of descent. This is usually because the aircraft is heavy, downwind, at a high density altitude, travelling too fast or too slow, the approach has been misjudged or the pilot has not managed the aircraft to control the rate of descent; or any combination of these factors. In this case the aircraft was flying downwind and the pilot agrees that the approach had been misjudged.

Vortex ring state (VRS)

Although vortices are always present around the outer section of the rotor, under certain airflow conditions, where the helicopter is descending into its own downwash, the vortices will be recirculated and intensified, reducing lift at the blade tips. Coupled with a stall spreading outwards from the root of the rotor blades, the area of the main rotor blades producing lift is substantially decreased. The result is a sudden reduction in vertical rotor thrust and a rapid descent.

As well as a high rate of descent, the symptoms of VRS include random pitching, rolling and yawing which occurs due to the dissymmetry of lift as pressure variations under the main rotor disc cause large and erratic changes to the angle of attack. The controls feel 'mushy' or sluggish and there is usually a marked vibration during the incipient stages. In this instance, the pilot later stated that apart from the rate of descent, none of the other symptoms of VRS appeared to be present.

Survivability

The soft ground, cockpit seats structure and skids absorbed much of the vertical impact with the ground and distorted. However, whilst the occupants walked away from the aircraft without assistance, the pilot later reported that he and his two passengers were suffering from neck and lower back pains.

Analysis

From the video footage of the event, when the helicopter reached the middle of the field the rate of descent and forward speed suddenly increased. This was likely to have been the point the pilot raised the collective lever to slow the aircraft and transition to a hover, but the engine had already reached its power limit. The main rotor speed reduced but torque continued to rise as torque has an inverse relationship with rotor speed. Pulling more collective only reduced rotor speed further, resulting in the rapid loss of lift observed in the video and experienced by the pilot.

As torque was increasing, so was the torque reaction. The R44 has an anti-clockwise rotating main rotor, therefore, the nose of the fuselage rotates to the right with the torque reaction which should be countered by pushing the left yaw pedal. As rotor speed reduces, the tail rotor becomes less effective, requiring more pedal movement to counter the increasing torque reaction. Once the pedal stops are reached, the yaw cannot be prevented.

The pilot's incorrect assessment of wind direction and his downwind approach whilst distracted by the nearby obstacles, resulted in over-pitching of the main rotor and a high rate of descent. The reducing rotor speed and the subsequent increasing torque reaction caused the nose of the aircraft to yaw to the right which the reducing tail rotor authority could not prevent before the hard landing.

Safety messages

Safety Sense Leaflet 17- *'Helicopter Airmanship',* published by the CAA contains a range of advice which is relevant to avoiding this type of accident including:

> *'Awareness of the importance of maintaining rotor rpm, and proficiency at recognising and recovering from low rotor rpm conditions, both with power ON and with power OFF'*
>
> *'The unplanned down-wind approach is particularly hazardous. It can lead to over-pitching, and loss of rotor rpm and lift, resulting in a hard contact with the ground. (Correlators are less effective at high power settings, so maintain rotor rpm by leading with the throttle before applying pitch).'*

Safety Notice SN-42 – *'R44 Pilot's Operating Handbook',* (POH), published by the Robinson Helicopter Company contains the following safety advice:

> *'Note that thrust of any tail rotor decreases significantly as RPM decreases. Low RPM combined with high torque, as occurs when over pitching, may result in an uncontrollable right yaw.'*

The Robinson Helicopter Company also offers a pilot's safety course[2] which is designed to provide specific safety training for rated pilots. The course consists of theoretical and practical training and covers subjects such as aircraft handling procedures, a review of major accidents and how they could be avoided, emergency procedures and critical flight conditions. Although not mandatory in Europe, the course is recommended by the company to improve safety when flying their helicopters.

Conclusion

The helicopter hard landing occurred due to a downwind approach and attempt to flare the aircraft. The main rotor was overpitched when the engine had reached its rpm limit causing a high rate of descent and an uncontrolled yaw to the right before impact with the ground.

The CAA Safety Sense Leaflet 17 and the Robinson R44 POH Safety Notices contain a range of advice on preventing this type of accident.

The Robinson Helicopter Company also offers an optional but recommended safety course for rated pilots which includes safety subjects such as aircraft handling procedures, major accidents and how they could be avoided, emergency procedures and critical flight conditions.

Footnote

[2] https://robinsonheli.com/robinson-courses/robinson-pilots-safety-course/ [accessed May 2021]

ACCIDENT

Aircraft Type and Registration:	Starduster Too SA300, G-WINN
No & Type of Engines:	1 Lycoming O-360-C2D piston engine
Year of Manufacture:	1973 (Serial no: 615)
Date & Time (UTC):	26 November 2020 at 1346 hrs
Location:	Haverfordwest Airport, Pembrokeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Landing gear collapsed, right wing and propeller damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	385 hours (of which 235 were on type) Last 90 days - 12 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was flying circuits and practice landings at Haverfordwest Airport in clear weather conditions with no reported wind. The pilot completed five successful landings but, on the sixth, whilst landing downhill on asphalt Runway 03, the aircraft started to veer to the right. The pilot stated that he over-corrected which resulted in a left turn and the aircraft skidding to the right. The right wing contacted the ground and the right landing gear leg collapsed; the propeller was damaged when it contacted the runway.

ACCIDENT

Aircraft Type and Registration:	Vans RV-7, G-CDME
No & Type of Engines:	1 Superior XP-IO-360-A1A2 piston engine
Year of Manufacture:	2006 (Serial no: PFA 323-14151)
Date & Time (UTC):	28 February 2021 at 1400 hrs
Location:	Farm strip near Goose Green, West Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Moderate damage to engine and mount, propeller, canopy, rudder, fin and spats
Commander's Licence:	Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	2,743 hours (of which 300 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries made by the AAIB

Synopsis

Approximately 140 m into its landing roll on a grass runway, the aircraft encountered an area of soft ground. The wheels and spats sank in and caused a rapid deceleration during which the tail rose, the propeller dug in and the aircraft over-ended onto its back. The pilot was tightly strapped in but was able to exit the aircraft uninjured. The cause of this accident was the sudden increase in drag created by the wheel and spats clogging with soil.

History of the flight

The pilot was landing at this private grass strip after carrying out a short flight within the COVID restriction regulations. The touchdown was normal and slightly to the left of the runway centre line. After the aircraft had travelled approximately 140 m, it encountered a patch of soft ground which caused a rapid deceleration as the wheels sank in. The tail started to rise until the aircraft nose and propeller struck the ground and dug in, resulting in the aircraft nosing over and coming to rest upside down on its back. The propellor, engine and its mounting, were damaged as was the canopy, fin and wheels spats. The pilot was tightly strapped in by his four-point harness and was uninjured. He made the aircraft safe and was able to exit the aircraft. Figure 1 shows the deep tracks made by the aircraft wheels. Figure 2 shows the condition of one of the wheel spats.

Figure 1
Tracks made by the aircraft wheels

Figure 2
Contamination and damage to one of the wheel spats
(pictures courtesy of the pilot)

Circumstances of the accident

Having not flown for several weeks, the pilot, who was also the owner of the airstrip, had cut the grass with a tractor and gang mower, and had walked the runway prior to deciding to fly. In his assessment of the accident causes, he drew the following conclusions.

- Having cut the grass on the runway using a tractor with low footprint tyres, the runway conditions seemed normal. But with hindsight, he considers that he should have carried out a slow taxi test in the aircraft. This may have enabled his discovery of any softer less suitable areas of the runway.
- Although the wheel spats had been modified to create more wheel clearance, they quickly became blocked when the aircraft entered the area of soft ground (Figure 2).
- He also considers that a complete removal of the spats would have resulted in a different outcome.
- He also observed that his attention to the safety harness being correctly worn prevented injuries.

AAIB comment

The cause of this accident was the sudden deceleration of the aircraft due to the increased drag created by the mainwheels and spats as they became clogged with soil. The tail started to rise and the propeller contacted the ground and dug in; the speed and momentum of the aircraft resulted in the aircraft nosing-over.

The AAIB has reported on numerous accidents where the combination of soft grass runways and aircraft fitted with wheel spats have been causal or contributory to an accident. These have often resulted in aircraft damage or injury, in some cases serious, to the occupants.

The pilot of this aircraft had taken steps to ensure his safety harness was properly fastened with tight straps as per his normal practice. He described how when the aircraft came to rest, the "straps held well". The correctly fastened safety harness is likely to have greatly reduced his risk of injury in this accident. The AAIB has reported on numerous low energy accidents where safety harnesses had not been properly worn and the occupants of aircraft have sustained varying degrees of injury and in some of these cases, fatal injuries.

Safety actions

As a result of this accident wheel spat contamination was discussed with the CAA. Accordingly, the CAA has taken several actions to ensure General Aviation (GA) pilots aware of the risks. These safety actions are as follows:

> CAA Safety Sense Leaflet 12 – *'Strip Flying'* includes a note to remind pilots to ensure that the wheel spats are clear of mud and grass and that temporary removal of the wheel spats must be agreed with the CAA regional office.

As part of the safety promotion and safety education service to pilots across GA, there will be reminders to pilots to inspect wheel spats and to consider ground conditions at grass strips as part of the aircraft loss of control focus.

CAA GA Unit Communications will share on social media the request to inspect spats for mud accumulation using the pictures supplied by the AAIB.

The CAA will raise the matter at the GA Safety Council meeting as part of the safety information exchange.

ACCIDENT

Aircraft Type and Registration:	RAF 2000 GTX-SE, G-BXKM
No & Type of Engines:	1 Subaru EJ22 piston engine
Year of Manufacture:	1998 (Serial no: PFA G/13-1291)
Date & Time (UTC):	2 April 2021 at 1257 hrs
Location:	Whitby, Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	Substantial damage to rotor blades, hoses and pipes; bent hub bar, rotor head, control rods, wheel fork and a detached wheel
Commander's Licence:	Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	263 hours (of which 147 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The gyroplane, with the pilot and a passenger, took off at close to the maximum takeoff weight from a field predominantly enclosed by a tree plantation. The pilot pulled back to clear the trees, but the aircraft then sank, contacted the treetops, and fell to the ground. The occupants received only minor injuries, but the aircraft suffered substantial damage.

History of the flight

The pilot and passenger were departing on a takeoff heading of 250° from a field mostly enclosed by a plantation of trees. The weather conditions were good with a 15 kt wind from 270°. The gyroplane was close to the maximum takeoff weight. After becoming airborne, the pilot continued to build speed whilst just above the ground. He reported he was running out of field when, with approximately 50 mph of speed, he had to pull up to clear the trees. Once above the trees, the aircraft "sank" and the landing gear caught the top of a tree bringing the aircraft to a rapid halt; it fell to the ground vertically with the rotor slowing the descent as it caught on the foliage. The aircraft came to rest on its side amongst the trees. The pilot and passenger received only cuts and bruises and were able to exit the aircraft unaided, but the aircraft sustained significant damage.

The pilot did not report any issues with the aircraft prior to contact with the trees but he advised that, with the takeoff at close to the maximum weight and not quite fully into wind, the aircraft had built up speed slowly. He also considered it possible that the aircraft "sank" after the pull up to clear the trees because it encountered a "wind rotor" from the windward side of the plantation and that he was "flying behind the power curve" at that point.

ACCIDENT

Aircraft Type and Registration:	Parrot Anafi
No & Type of Engines:	4 electric motors
Year of Manufacture:	2020 (Serial no: P1040505AA0K000249)
Date & Time (UTC):	19 February 2021 at 1400 hrs
Location:	Highlands Road, Fareham, Hampshire
Type of Flight:	Commercial Operations (UAS)
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Battery and front left propeller arm detached, both front propellers damaged.
Commander's Licence:	Other
Commander's Age:	34 years
Commander's Flying Experience:	11 hours (of which 11 were on type) Last 90 days - 5 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

A failure of the bonding between two halves of the front left propeller arm may have caused the unmanned aircraft to repeatedly lose control in flight until it collided with trees. The aircraft was substantially damaged.

The manufacturer has notified the five other UK owners of the Parrot Anafi USA aircraft to inspect the propeller arms and return the aircraft to their supplier for replacement propeller arms if the bonding problem is identified.

History of the flight

The unmanned aircraft (UA) was operating at 58 m agl to maintain a minimum distance of 50 m from nearby buildings. The UA was stable and hovering without difficulty, the weather was overcast but with good visibility and low wind. After the UA was repositioned, the operator looked down at his electronic tablet to check the remaining battery life and the camera image. When he looked back at the UA, it was spinning and descending towards the nearby buildings. By applying full thrust, the pilot was able to stabilise the aircraft and regain height. There was a minor gust of wind a few seconds later but the UA remained stable and in the same position. During the spinning event, there had been no vibration feedback through the controller to indicate a problem with the aircraft or the controller.

The pilot kept his eyes on the aircraft to maintain visual line of sight so he could react quickly if the loss of control reoccurred. He had decided to return the UA to the launch site but a few seconds after turning the aircraft around, it spun violently and started to descend. Once again, the pilot regained control by applying full thrust and he activated the return to home function. The pilot was unsure if this was effective because he was also using the hand controller to manually control the UA's return flight. The aircraft was returning to the launch area when it suddenly spun violently again before flying over the heads of the pilot and observer and colliding with trees in nearby woodland.

Accident site

Most of the UA was found at the base of the trees, however, the main body upper casing, the upper half of the front left propeller arm and the battery pack were discovered in a nearby clearing next to a car park. The lower half of the propeller arm and one blade from each of the front propellers could not be located.

Aircraft information

The Parrot Anafi USA is a small Class C1 drone[1] with a maximum takeoff weight of 501 grammes. The body of the UA contains the battery, flight and camera control circuitry, communications link to the ground controller and flight sensors. Gimbal stabilised optical and thermal imaging cameras are mounted on the front of the body. Lift and flight capability is provided by four 60 watt electric motors each mounted on an arm attached to the aircraft body (Figure 1). Each motor powers two propeller blades.

Figure 1
Parrot Anafi USA

Footnote

1 A Class 1 drone weighs less than 900 grammes with a maximum speed of 15 m/s and includes certain safety features. CAP722 Chapter 3, *Unmanned Aircraft System Operations in UK Airspace – Guidance*, 5 November 2020. Available at https://publicapps.caa.co.uk/docs/33/CAP722%20Edition8(p).pdf [accessed April 2021].

Aircraft examination

Examination of the remains of the front left propeller arm revealed the bonding between the upper and lower halves of the arm had failed allowing the two halves to separate (Figure 2).

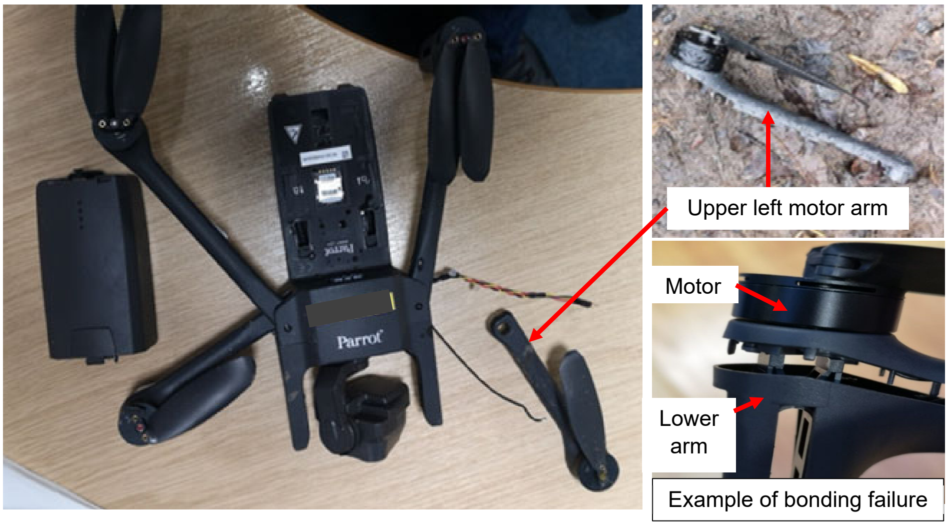


Figure 2

Recovered aircraft, battery, and motor arm plus an example of bonding failure

Three other UAs had also been discovered with similar bonding faults, two before the incident flight during the operator's pre-use checks and one after the incident by the manufacturer.

Analysis

If separation of the two halves of the front left propeller arm had occurred in flight, it is likely the upper arm containing the motor and propeller would have lost rigidity allowing the arm to bend and twist unpredictably due to a combination of lift and gyroscopic forces from the propeller and vibration from the motors. The increased bending and twisting would have resulted in variations in the direction of thrust produced by the front left propeller. The UA's flight control system may have been unable to compensate for this resulting in the repeated loss of control. It is also possible that these forces caused the lower half of the arm to fail and break away from the UA during its return to the launch point.

Other information

During consultation between the operator of the UAS and the manufacturer it was determined that six of the operator's 10 Anafi USAs were included in a batch of 269 which the manufacturer had identified as potentially suffering from propeller arm bonding problems. Inspection confirmed that four of the six UAs showed bonding failures, including the accident aircraft. All four were sent to the manufacturer for repair. The manufacturer recommended that a strong adhesive tape should be used to secure the upper and lower halves of the propeller arms of the two remaining UAs from the same batch. The manufacturer has since stated that they could not reproduce the symptoms experienced by the customer and similar failures had been cosmetic rather than causing control problems.

The manufacturer identified a further five UAs from the affected batch that were sold in the UK and have contacted the operators to request they return the aircraft to their supplier to have the propeller arms replaced if the bonding problem is present.

Conclusion

Failure of the bonding between the upper and lower halves of the front left propeller arm may have caused loss of control of the aircraft and resulted in a collision with nearby trees. The UA has been repaired by the manufacturer together with a further three of the operator's aircraft that were discovered with similar bonding problems.

The manufacturer has notified the UK operators of a further five Anafi USAs that may have similar propeller arm bonding problems, to inspect the bonding and return the aircraft to their supplier for replacement propeller arms if the bonding problem is present.

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only UAS investigations reviewed: April - May 2021

20-Mar-21 **DJI Mavic Mini** Stockport, Greater Manchester
The UAS was being used to film a moving car. However, the UA collided with the side of the car and fell to the ground. It suffered substantial damage when it was then run over by the car.

30-Mar-21 **Parrot Anafi USA** Cassington, Oxfordshire
The UA struck overhead telephone wires and fell to the ground.

30-Mar-21 **Parrot Anafi** Cassington, Oxfordshire
During a night takeoff, the UAS collided with an unseen telephone wire approximately 20 m above ground level.

31-Mar-21 **DJI Unknown** Trellech, Monmouthshire
While taking photographs of a building, the UAS clipped the branch of a tree and fell to the ground.

31-Mar-21 **DJI FPV** Waskerley, County Durham
The pilot was flying the UA over a hillside. He lost control of the UA and it fell to the ground.

4-Apr-21 **DJI Phantom 4 Pro** Holywell, Flintshire
The UA was flown to a height of 55 m for handling checks when power to the motors was lost. It descended rapidly colliding with the ground close to the takeoff point.

4-Apr-21 **DJI Inspire 2** Covent Garden, London
The UAS was in a stable hover while the operator was looking at the screen. The UAS flew into a nearby building before falling to the ground.

11-Apr-21 **Align T-Rex 500x** Little Stoke, Bristol
The UA, a model helicopter, was being flown from a playing field. The operator hit the rescue button on the transmitter, the button jammed and the UA did not respond. It disappeared into a housing estate and was not recovered.

14-Apr-21 **DJI Matrice 300** Guildford, Surrey
During night training operations, a warning appeared on the control unit that the UAS was not receiving data from the gimbal payload. The operator was bringing the UA in to land when, at a height of around 10 m, the payload dropped to the ground.

Record-only UAS investigations reviewed: April - May 2021 cont

14-Apr-21 **Sky Falcon P93** Salisbury Plain, Wiltshire
The UA made an uncommanded climb while in a height-holding manoeuvre. The remote pilot shut down the engine and attempted to recover the UA which resulted in a hard landing.

15-Apr-21 **DJI Unknown** Sawtry, Cambridgeshire
The pilot, who was visual with the UA, misjudged its trajectory and it hit a tree despite the UA's collision avoidance having been turned on.

17-Apr-21 **FPV Iflight Protek certified HD** Newquay, Cornwall
The UAS was conducting commercial photography shoot some 15 m above the cliff top near Newquay when the control feed cut out and the pilot lost control. The UA struck the cliff top, rolled down the cliff into the sea and was not recoverable.

21-Apr-21 **DJI Phantom 4** Swindon, Wiltshire
Shortly after takeoff, control of the UA was lost. It flew into a fence and sustained damage to three propellers.

23-Apr-21 **DJI Mavic 2** King's Lynn, Norfolk
The UAS was being used to for aerial photography. During manoeuvring the UA struck a tree and fell to the ground.

24-Apr-21 **Radio Controlled Glider** Near Abingdon, Oxfordshire
From a model flying club, the pilot was flying his model glider at 50 m above the ground towards him. However, it flew past him, disappeared and was not recovered.

27-Apr-21 **DJI Mavic 2 Pro** Gainsborough, Lincolnshire
The propellers of the UAS struck the branches of the tree causing it to fall onto a parked car.

2-May-21 **DJI Matrice 210 V1** Bury St Edmunds, Suffolk
The operator started the rotors and the UA took off to a height of about 5 m where the response checks were carried out. After the first check the UA turned, but did not respond to control inputs and struck a tree. The UA sustained substantial structural damage.

Record-only UAS investigations reviewed: April - May 2021 cont

6-May-21 **DJI M300 RTK** New Malden, Surrey

The UAS was being operated in the hours of darkness in support of a police operation. Whilst manoeuvring to land it collided with some unseen telephone wires causing it to fall to the ground and collided with a parked car. All propeller blades, a propeller arm, leg and camera mount were broken in the accident.

19-May-21 **DJI Phantom 4 Pro V2** Brent Cross, London

After surveying from a height of approximately 10 m, the pilot flew the drone to a height of 30 m when, without warning, it flipped over and fell to the ground. The UA came to rest on a rubble plie approximately 50 m from any person. The pilot reported that, on inspection, it appeared that the battery connector had melted.

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

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