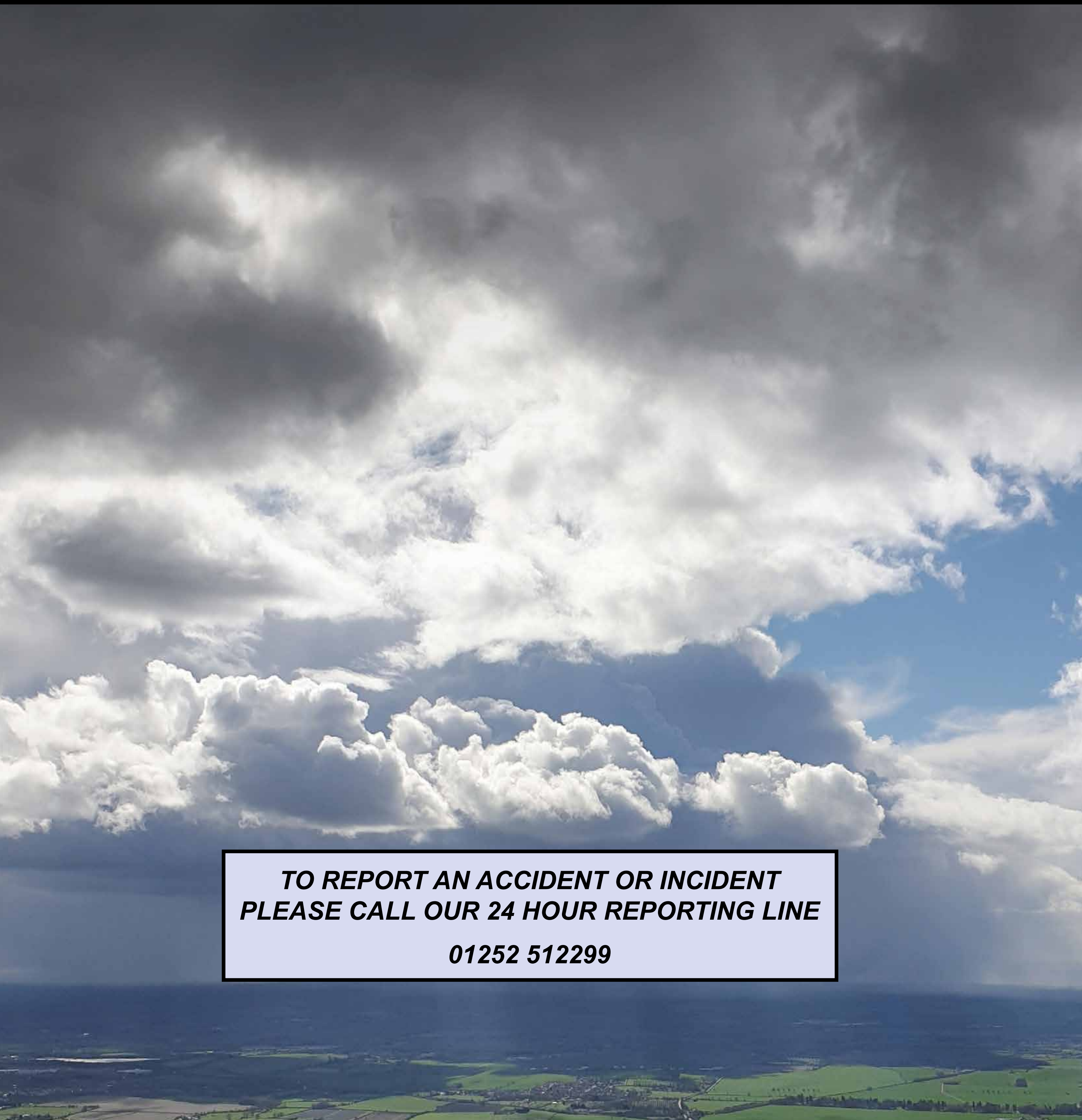
AAIB
Air Accidents Investigation Branch

AAIB Bulletin 1/2021



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(ALL TIMES IN THIS BULLETIN ARE UTC)

AAIB Field Investigation Reports

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

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

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

SERIOUS INCIDENT

Aircraft Type and Registration:	Cessna Citation CJ1+, N680KH	
No & Type of Engines:	2 Williams FJ44-1AP turbofan engines	
Year of Manufacture:	2008 (Serial no:525-0680)	
Date & Time (UTC):	13 April 2019 1422 hrs	
Location:	Bournemouth Airport	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 3
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None reported	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	73 years	
Commander's Flying Experience:	4,400 hours (of which 3,200 were on type) Last 90 days - 17 hours Last 28 days - 13 hours	
Information Source:	AAIB Field investigation	

Synopsis

The aircraft had been modified with a system intended to enhance its performance, which included supplementary control surfaces designed to deflect symmetrically and automatically to alleviate gust loads. Shortly after takeoff, an electrical failure in this system caused one of these control surfaces to deploy separately, causing an uncommanded roll. The resulting aircraft upset caused the pilot significant surprise and difficulty in controlling the aircraft.

The pilot was not aware of supplementary procedures associated with the modification. The procedures did not adequately characterise the significance of the system failure, nor address the failure in all anticipated flight conditions. Certification flight tests of the system did not reveal the severity of possible outcomes. The *'Aircraft Safety and Certification Reform Act 2020'* underway in the USA will review existing assumptions on pilot recognition and response.

Four Safety Recommendations are made, and safety action has been taken or is intended in the areas of training and the information to be provided, both for this system and for other supplementary systems capable of influencing the flight path of an aircraft.

History of the flight

The pilot had recently bought the aircraft, which had been fitted during its previous ownership with 'Active Technology Load Alleviation System'[1] (ATLAS) wing extensions and winglets (Figure 1). He was intending to fly himself and three friends from Bournemouth to Rotterdam. The pilot, who operated the aircraft in a single pilot[2] capacity, occupied the front left seat. One friend occupied the front right seat, and the other two were seated in the passenger cabin.

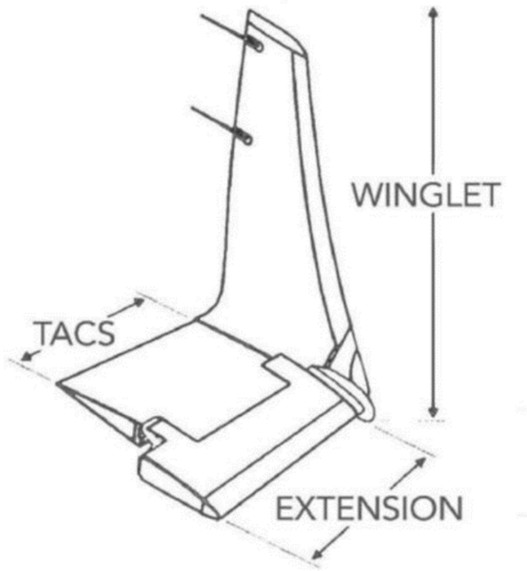


Figure 1

Overview of ATLAS winglet installation

The aircraft took off from Runway 08 at 1417 hrs and the pilot engaged the autopilot shortly afterwards. It flew a heading of 075° and climbed to altitude 3,000 ft. At 1418:35 hrs ATC instructed the aircraft to climb to FL100, which the pilot read back. The ATCO instructed '…RESUME OWN NAVIGATION DIRECT GOODWOOD'[3], which required the aircraft to turn right. No response was received from the pilot to that and two further transmissions.

The pilot recalled feeling light vibration, then a button on the left of the instrument panel labelled 'ATLAS' illuminated (Figure 2), displaying the text 'ATLAS INOP LIMIT 140 KIAS' in red. At 1418:39 hrs, when the aircraft was around 6 nm east of the airport, at 3,000 ft amsl and 258 KIAS, the aircraft rolled left with a rate the pilot described as "very quick"[4]. ATC described N680KH turning "sharply… left and descending" (Figure 3)[5]. As it rolled through 45° the autopilot disengaged automatically.

Footnote

1 These incorporate Tamarack Active Camber Surfaces (TACSs) which are designed to extend automatically to alleviate wing loading, see Aircraft Information Section for more information.
2 The aircraft can be flown by either one or two pilots.
3 Goodwood – a VOR East of Bournemouth.
4 Recorded data showed an average roll rate of approximately 4° per second.
5 The pilot had not finished inputting the required FL100 hence the mode C reading of '094'.

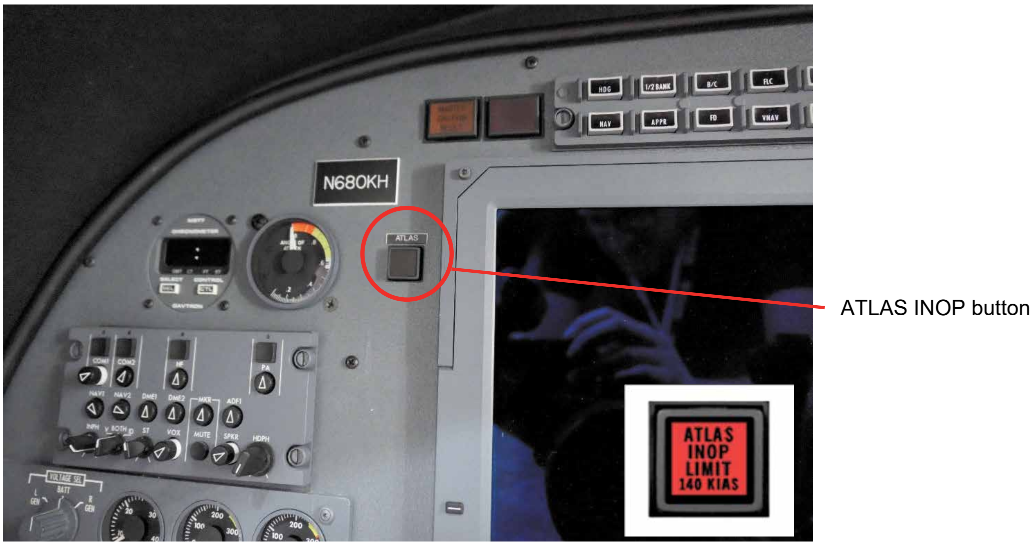


Figure 2

ATLAS INOP button in N680KH, inset representation of button when illuminated

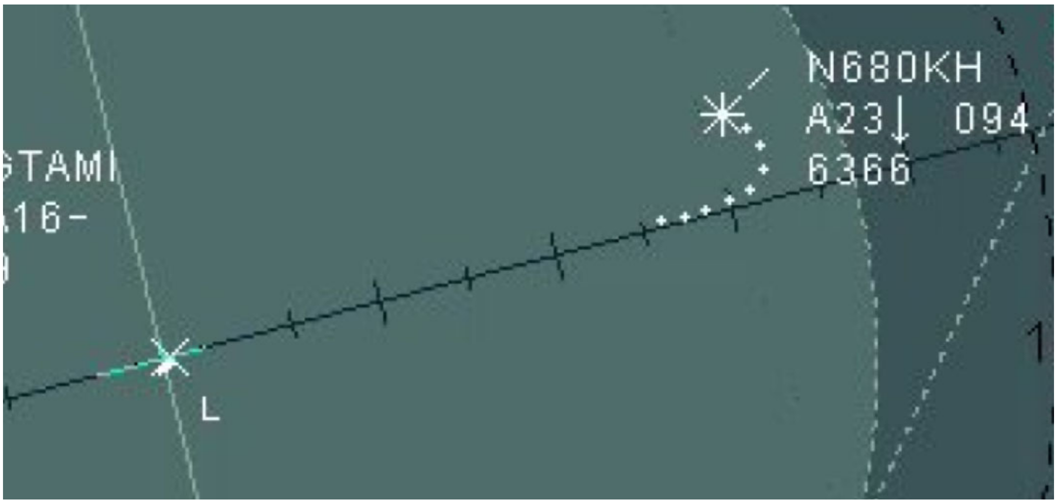


Figure 3

ATC radar screenshot at 1419:14 hrs[6]

The pilot reported applying full right aileron and full right rudder, but these actions were insufficient to control the aircraft. He moved the throttles to idle and used both hands on the control column, but the aircraft continued descending. Recorded data showed that a bank angle alert[7] was generated at around 60° roll, and there was a sharp increase in normal acceleration, which reached +2.65 g. The aircraft's roll angle peaked at 75° left wing down, with 9° nose down pitch, 19 seconds after the onset of the roll. Its rate of descent peaked soon after at 4,500 ft/min, corresponding with an airspeed of 235 KIAS, reaching a minimum altitude of 2,300 ft.

Footnote

6 Each marking across the extended centreline represents 1 nm.
7 The aural warning "Bank angle…Bank angle…Bank angle…Bank angle" was heard on the CVR.

During the upset the pilot pressed the illuminated ATLAS button and re-set the ATLAS MAIN circuit breaker (CB)[8], but neither action had an effect.

At 1419:18 hrs the pilot reported 'A PROBLEM' to ATC. The ATCO attempted to ascertain what was wrong but the pilot sounded breathless and strained, and his transmissions were incomplete and difficult to decipher. Whilst the pilot did not declare an emergency the ATCO, believing he sounded "extremely shaken", advised him to join left hand downwind for Runway 08, and instigated a full emergency procedure[9].

The pilot recalled it took all his strength to lift the aircraft's nose, reduce its airspeed, and recover the bank angle to around 30° left wing down. He climbed the aircraft to 3,200 ft and its airspeed reduced to 144 KIAS. It then entered a descending left turn.

After descending from 900 ft to 300 ft amsl during the downwind leg, the aircraft turned on to base leg above a sports field. The pilot reported using continuous full right aileron and some right rudder until landing. Less right rudder was required as airspeed reduced, and he achieved lateral control by modulating his right foot pressure. By reducing that pressure the aircraft turned continuously through left base on to a 1 nm final approach, right of the runway centreline at 200 ft amsl (Figure 4). The tower controller described the turn as so tight that the aircraft appeared to be "on its side". He and several colleagues believed the aircraft would crash short of the airfield. At the landing speed of 105 KIAS the pilot believed he could land the aircraft straight so used "less right foot" to straighten the approach and, when over the runway, applied full flap. The aircraft landed at 1423 hrs.

Figure 4
ATC radar screenshot at 1422:31 hrs

Footnote

8 The ATLAS circuit breakers were located on the cockpit's 'right CB panel', adjacent to the co-pilot's seat.
9 The unit ATC Manual describes this as follows. *'When it is known, or is suspected to be, that an aircraft in the air is in such difficulties that there is a danger of an accident… The outside services are to be called for all Full Emergencies'.*

Meteorological information

The aerodrome weather was reported at 1420 hrs as wind of 12 kt from a direction of 140°, visibility greater than 10 km, broken clouds at 4,000 ft amsl, temperature 9°C and QNH 1025 hPa.

Personnel

The pilot operated N680KH privately under the privileges of his FAA ATPL and held a valid Class 1 medical certificate. He undertook his initial Citation type conversion and subsequent recurrent training at a simulator training facility owned by the parent company of the aircraft manufacturer. The record of his three-day recurrent check beginning 3 May 2018 showed he achieved the top grading of *'1'*[10] in all of the simulator items, and a written exam score of 100%.

Since 1998 the pilot had bought four Cessna Citations; three[11] new from the manufacturer and one, N680KH, from a private owner. He flew all of these except one, which he re-sold before it was delivered.

Previous event

On 16 March 2019 at 1306 hrs, while flying from Buffalo (USA) to Goose Bay (Canada), the aircraft experienced an uncommanded roll to the left, and the ATLAS INOP button illuminated.

The pilot described the roll as less severe than the incident on 13 April 2019, with a maximum bank angle around 50°. The ATLAS INOP button was lit for around three to five seconds then extinguished without being pressed, after which the aircraft behaved normally. He estimated the event lasted around twenty seconds. He stated that he did not investigate it further because the system functioned normally for the remainder of that flight, and on four subsequent flights.

Recorded data

Several sources of recorded data were available for N680KH and have been used to create the combined plot in Figure 5.

Flight recorders

N680KH was not fitted, nor was it required to be fitted, with a Flight Data Recorder but was fitted with an optional CVR capable of recording for two hours before overwriting the oldest data. The CVR was downloaded and was found to cover the entire incident flight. Relevant detail from the CVR is annotated on Figure 5.

Footnote

[10] The grading range was 1 *'Proficient'*, 2 *'Normal progress'*, 3 *'Needs additional training'*, and 4 *'Unsatisfactory'*.
[11] Different types – CJ3, CJ4, Excel.

Maintenance Diagnostic System

N680KH was equipped with a Rockwell Collins Proline 21 avionics suite that incorporated a maintenance diagnostic system (MDS) function. Data from the MDS was downloaded and a fault history was retrieved, beginning on 14 April 2018. This data covered the last 500 faults and showed that two fault messages were generated on 13 April 2019, during the incident flight. Both faults were logged when the autopilot disengaged at 1418 hrs[12] having detected excessive pitch or roll. The equipment manufacturer defined an excessive pitch or roll attitude as exceeding one of the following:

- a pitch angle lower than -15° nose down,
- a pitch angle higher than 25° nose up,
- or, a roll angle greater than ±45°.

Five flights earlier, on 16 March 2019 at 1306 hrs, corresponding with the leg from Buffalo to Goose Bay Airport and shortly after takeoff from Buffalo, the same fault message was recorded but this time from only one of the Flight Guidance Computers.

No other autopilot disengagements were recorded in the MDS fault history.

Terrain Awareness and Warning System (TAWS)

A TAWS was fitted to N680KH and was activated three times during the incident flight. The TAWS was not activated during the previous event on 16 March 2019.

Each time the TAWS is activated it issues an alert to the pilot, automatically stores 20 seconds of data prior to the event and then records the following 10 seconds.

Data for the incident flight showed that after takeoff from Bournemouth the aircraft briefly levelled at approximately 3,000 ft[13] , with a pitch attitude of 0° at between 250 KIAS and 260 KIAS (between Point 1 and 2 on Figure 5). The aircraft then began to roll to the left at approximately 4° per second (Point 2 on Figure 5). Data from the CVR shows the pilot acknowledged an ATC clearance shortly afterwards and recorded data shows the revised climb altitude being selected. Eleven seconds later, the aircraft rolled through approximately 45°. The excessive roll caused the autopilot to disconnect automatically and was accompanied by an aural disconnect warning that was audible on the CVR. At this time the recorded pitch angle markedly decreased to 9° nose down (Point 3 on Figure 5). As bank angle exceeded 60° a bank angle alert[14] was generated (Point 4 on Figure 5) and a sharp increase in normal acceleration was recorded which reached +2.65 g. The bank angle reached a maximum of 75° left wing down, 19 seconds after the onset of the roll (between Point 4 and 5 on Figure 5), although the rate of descent

Footnote

[12] Autopilot disengagement is accompanied by an aural warning "Autopilot"; this was heard on the CVR for the incident flight.

[13] All altitudes, unless stated otherwise, in the recorded data section of this report are barometric altitudes based on 1026 hPa.

[14] The aural warning "Bank angle…Bank angle…Bank angle…Bank angle" was heard on the CVR for the incident flight.

continued to increase and reached 4,500 ft/min (Point 5 on Figure 5), when the aircraft's airspeed was 235 kt.

A 'TOO LOW – FLAPS' alert occurred when the aircraft was on short final at approximately 230 ft radio altitude, indicating that landing flap was not selected, followed immediately by a second bank angle alert (Point 6 on Figure 5). This was triggered because the bank angle had reached 40° left wing down, 3 seconds earlier, at 260 ft radio altitude.

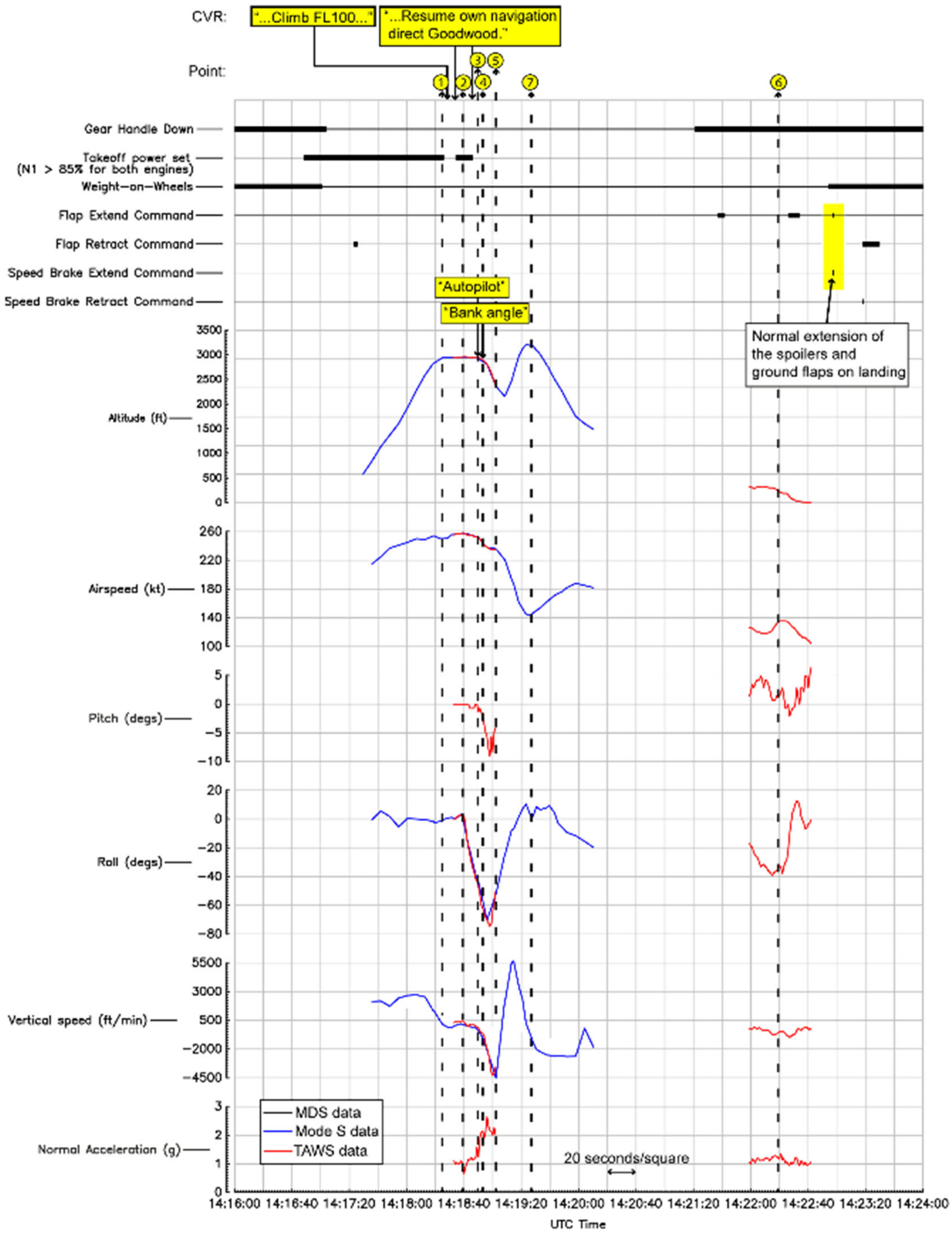


Figure 5

Summary plot of recorded information

Cessna Aircraft Recording System data

N680KH was fitted with a Cessna designed Aircraft Recording System, a diagnostic and troubleshooting tool. Several flights, including the incident flight, were recorded by the unit but the data covered a limited number of parameters. Corrupted timestamp information required repair before the flights could be viewed using the manufacturer's software. Data for the incident flight confirmed that the speed brake was not used during the upset and the throttles were positioned such that both engines were operating at an N_1 of 85% or less. It was not possible to determine if the throttles had been moved to idle during the upset.

Mode S radar data

Mode S radar data was consistent with the TAWS data and showed that, after the TAWS data stopped following the first bank angle alert, the aircraft climbed at up to 5,500 ft/min and reached 3,200 ft (Point 7 on Figure 5). During this climb the aircraft's airspeed reduced to 144 kt, a loss of approximately 90 kt, before the aircraft entered a descending left turn and returned to the airport.

Aircraft information

The Cessna Citation CJ1+, a variant in the Cessna Model 525 series, is a light business jet configured to carry six passengers and operated by one or two pilots.

N680KH had a valid airworthiness certificate and was maintained in accordance with the authorised aircraft maintenance manuals. The aircraft was fitted with a Tamarack ATLAS, a modification approved under a supplemental type certificate (STC). The aircraft was built in 2009 and the STC was incorporated in November 2017. The aircraft had been purchased in March 2019 by the pilot, who was in the process of transferring the aircraft to the Belgian register.

At the time of the serious incident the aircraft had accumulated 1,487 flying hours and the STC had been installed for 190 of those hours. The last maintenance on the aircraft had been accomplished between 14 February and 7 March 2019, 14 flying hours before the serious incident.

Tamarack ATLAS

The ATLAS is intended to provide increased aerodynamic efficiency without adverse structural effects due to the winglet installation. The system operates independently of other aircraft systems.

To install the system on a Cessna Citation CJ1+, the original wing tips are removed and 22 inch extensions, incorporating the winglets, are attached (Figure 6). Active aerodynamic control surfaces are positioned in the horizontal section of these extensions. These control surfaces (known as Tamarack Active Camber Surfaces, or TACS) are automatically activated in high positive or negative g situations to unload the wing and keep the wing loading within the original envelope.

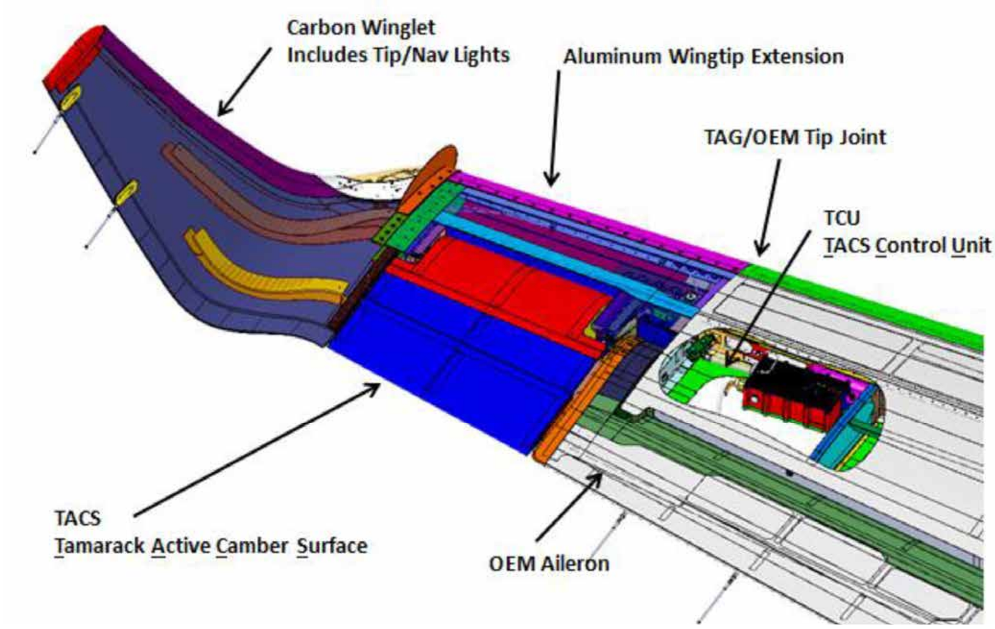


Figure 6
Cessna 525 wing with ATLAS installed

A TACS Control Unit (TCU) is mounted in each wing. The TCU comprises analogue control circuitry, an electric motor, gearing and a ball screw actuator module (Figure 7). This drives each TACS mechanically as shown in Figure 8. The TCUs are controlled by an ATLAS Control Unit (ACU), which is mounted close to the aircraft centre of gravity. The ACU houses two accelerometers which monitor the aircraft's movement in the vertical axis. When aircraft vertical acceleration exceeds specified positive or negative values, the ACU activates both TCUs symmetrically to aerodynamically unload the wings.

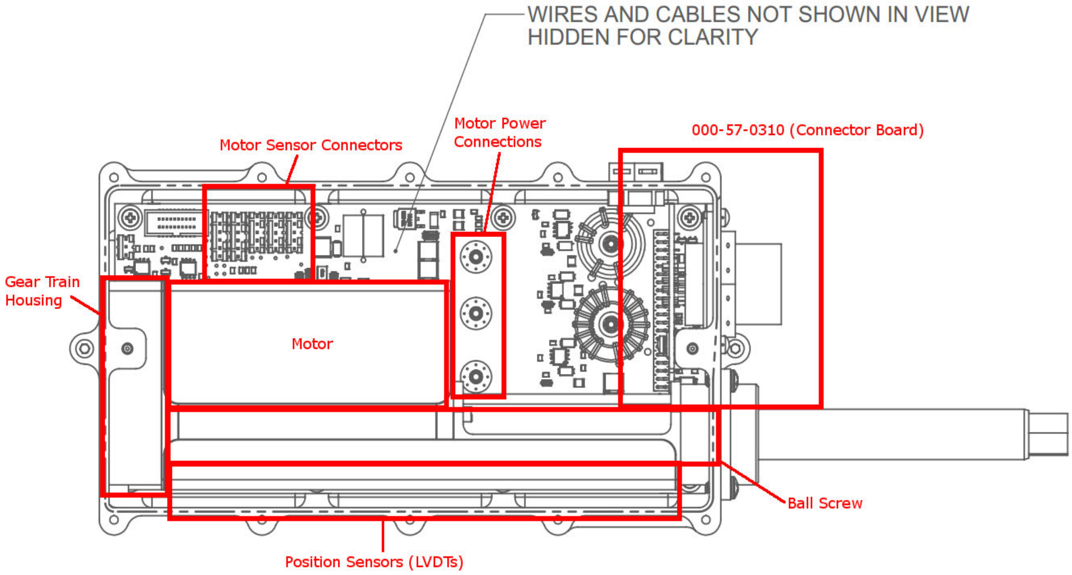


Figure 7
Internal layout of TCU

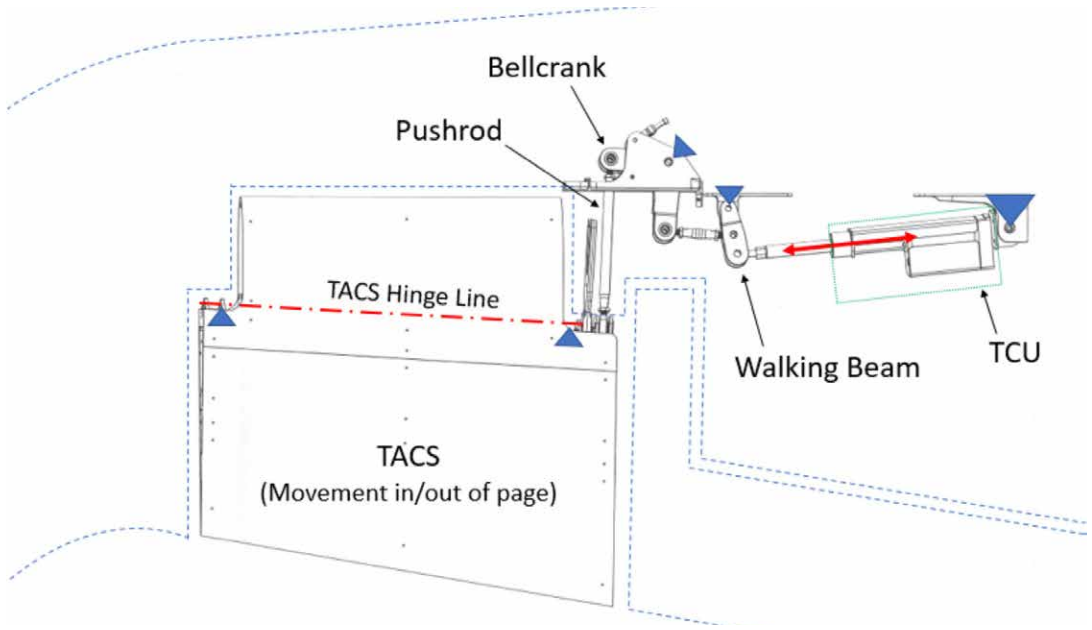


Figure 8

Top view of mechanical linkages of ATLAS.
Note: blue triangles indicate hinge points

Two linear variable differential transducers (LVDTs) in each TCU feedback actuator position to the ACU. The system is designed to activate the TACSs symmetrically (both up or both down), but if there is a difference between the LVDT readings, a difference between the commanded position and the recorded position of either TCU, or an asymmetry between the TCUs the system de-powers the actuators.

The TACSs are designed to travel above and below the neutral point (faired) to relieve both positive and negative wing loads (Figure 9) and will travel to these positions in 0.1 seconds when commanded. The actuators can be back driven by hand when de-powered.

In normal operation, the travel of a TACS is limited electronically within its respective TCU motor controller. Mechanical stops within the actuator limit the travel of the TACS if the TCU is de-powered. Additional mechanical stops are incorporated into the bellcrank to prevent large TACS deflections if the TCU experiences a mechanical failure.

If there are any faults with the system, such as a LVDT mismatch, a fault latch within the ACU will be triggered and the instrument panel mounted ATLAS INOP push button will illuminate. When this is illuminated the actuators are de-powered. Pressing the ATLAS INOP button once clears the ACU fault latch and the system will resume normal operation. The light will go out if the reset is successful, if it is not, the light will remain on. Pressing it three times within three seconds will initiate a built-in test schedule to further attempt to rectify any faults.

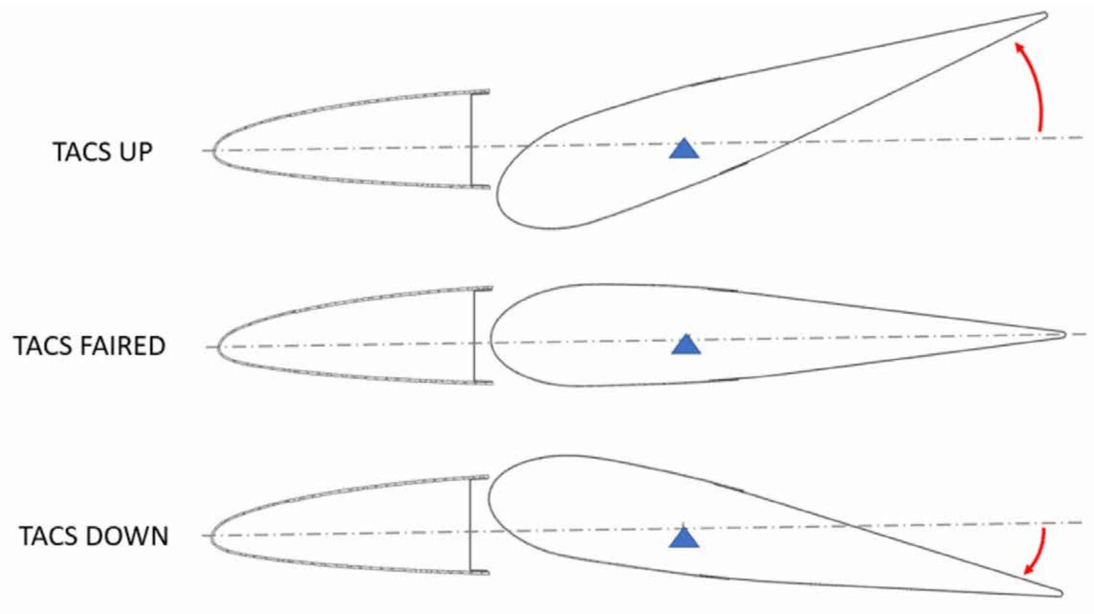


Figure 9
Section view of TACS positions

Under normal circumstances the ATLAS system is powered when the aircraft master switch is ON. The control system utilises analogue electronic control and has no means to record any faults that occur during operation. There are three CBs associated with the ATLAS system, one to isolate it entirely and two to isolate the emergency bus power for the ATLAS INOP push button light.

The TACSs are mass balanced and their leading edges are ahead of their hinge line to reduce aerodynamic loads and improve the TACS response time. As a result, a TACS could be aerodynamically forced to its mechanical stops if it were de-powered while unfaired[15] in flight.

Aircraft examination

Trouble shooting of N680KH was carried out at a maintenance facility before the AAIB was notified about the serious incident. The maintenance engineers were in contact with the ATLAS manufacturer and had established that a fault with the left TACS was suspected as the cause of the event. This troubleshooting revealed that when the system was initially powered up, the ATLAS warning light was ON and the TACSs could be moved by hand. Further power cycling caused the left TACS to move to full upward deflection, where it remained. Manipulation of the main ATLAS CB then caused the left TACS to translate to full downward deflection where it locked and would not move from this location, even when de-powered. Examination of the TACS and the drive mechanisms associated with them revealed no fault or breakage. It was therefore determined that the left TCU was likely to

Footnote

15 The term 'unfaired' means the TACS is not in its faired position, either trailing edge up or down.

have caused the uncommanded roll to the left. Both TCUs were removed from the aircraft and shipped to the TCU manufacturer for assessment. The ACU remained installed on the aircraft.

TCU examination

The TCU examination was conducted at its manufacturer's facility with representatives from the system manufacturer and the pilot also present. This occurred before the AAIB was informed.

The right TCU (s/n 1014) passed all functional test and was therefore not subjected to any further assessment. Figure 10 shows an image of TCU s/n 1014.

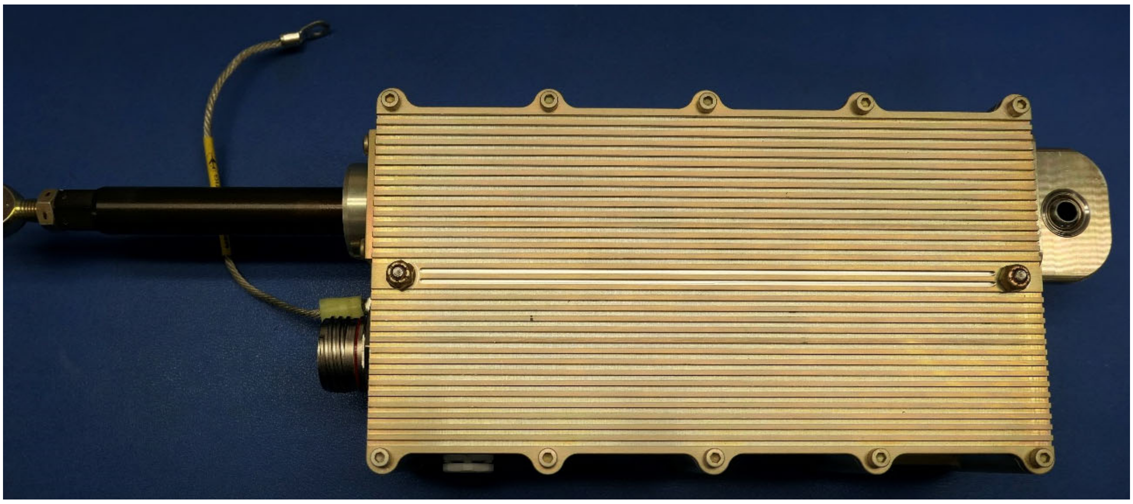


Figure 10
TCU s/n 1014 after initial assessment

The left TCU (s/n 1015) was received with the actuator arm fully retracted and could not be moved by hand. This is consistent with the TACS being trailing-edge down at the end of the troubleshooting. The unit passed an electrical insulation resistance test, but it indicated an open circuit. As the actuator arm was seized no functional testing could be conducted and the unit was prepared for stripping.

When the unit was shaken, before removing the cover, something rattled inside. Opening the unit revealed that the screw and washer which attached and earthed the electrical connector printed circuit board to the unit's chassis were missing. Both the screw and washer were found within the chassis[16] (Figures 11 and 12).

Footnote

16 As the screw and washer will have moved within the unit since the event, their observed locations would not have been representative of where they were at the time of the incident.

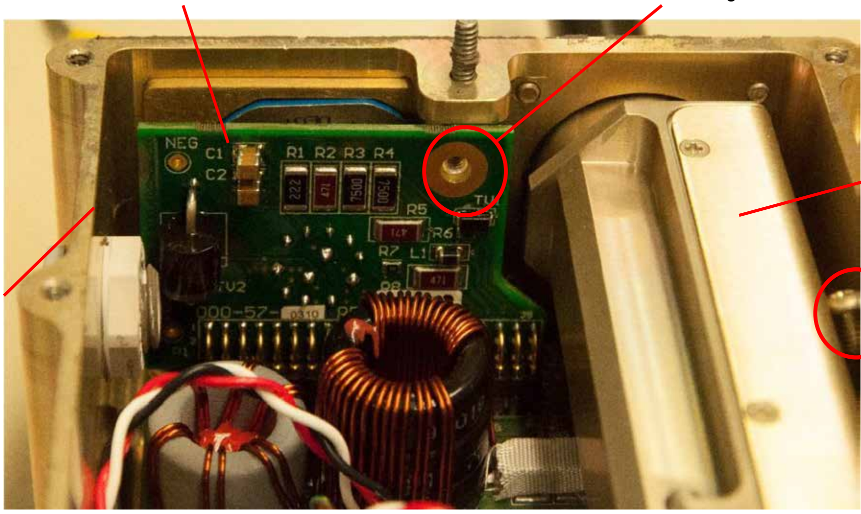


Figure 11

TCU s/n 1015 showing where the crew should have been, and where it was found.

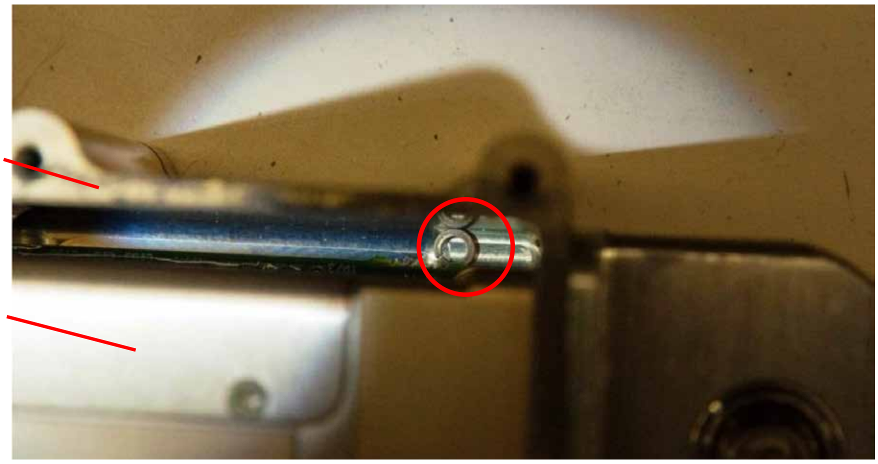


Figure 12

TCU s/n 1015 showing location missing washer was found

Damage in the actuator retract end stop (Figure 13) and thrust pack carrier was consistent with them being struck by the ball nut that travels with the actuator arm. There was some resistance when the ball nut was separated from the thrust pack carrier, which was determined to be the cause of the actuator being locked in the retract position. The impact marks on the retract end stop, and witness marks on the thrust pack carrier, indicated that the ball screw nut had struck the stop and thrust pack carrier with some force. The impact marks in the stop were 0.012 inch deep. This damage probably occurred during the trouble shooting activity when the aircraft was on the ground.

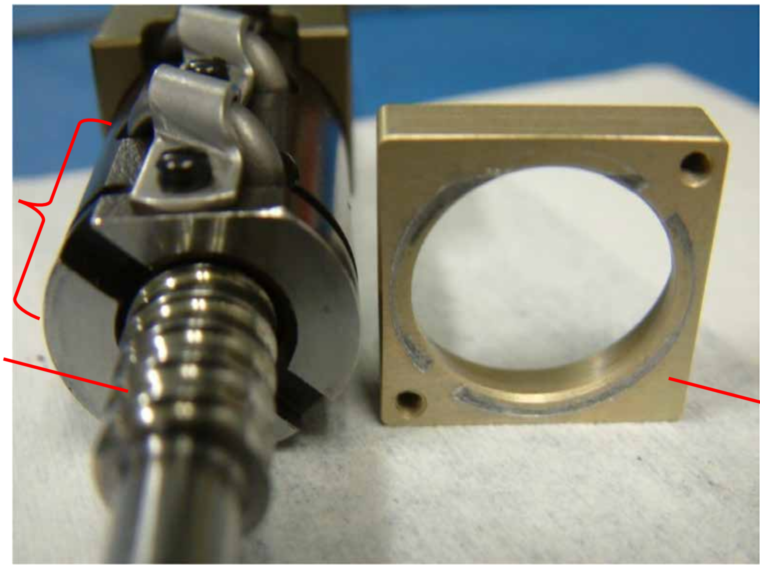


Figure 13

TCU s/n 1015 impact marking from actuator ball screw against retract end stop (retract end stop turned to show impact mark next to contact point on ball nut)

The main printed circuit board (PCB) within the unit was removed and examined to identify the cause of the reported faults. Initially the PCB was slaved to an undamaged actuator assembly and when powered up the actuator immediately retracted to its hard stop. The PCB was then removed and elements of the PCB were tested in isolation. It was found that one of the microchips was not functioning correctly and was producing a continuous +11 VDC. This set the actuator motor drive circuit to full speed in the retract direction. This was probably a result of permanent damage to the chip arising from a short circuit caused by the loose screw or washer within the unit. This would have driven the left TACS to the trailing-edge down position, which is not consistent with uncommanded roll to the left in flight and was probably the cause of the retraction during troubleshooting.

The manufacturer conducted a failure assessment of the actuator to establish what might cause the left TACS to deploy trailing-edge up (actuator extended), and determined that a short between two pins within the connector head could drive the TCU arm to the extend hard stop. Testing this scenario confirmed that the TCU arm could extend momentarily before being de-powered. This may have been sufficient for the TACS to extend to the mechanical stops under aerodynamic load during flight when the TCU was de-powered by the fault detection circuitry within the ACU.

Aircraft flight manual

Operating procedures

The aircraft's 'Airplane Flight Manual'[17] (AFM) *'SECTION III – OPERATING PROCEDURES'* contained procedures in the following order: *'White message'*, *'Amber message'*, *'Red message'*[18], *'Emergency/Abnormal'*[19] and *'Normal'.*

Emergency and abnormal procedures

The *'Emergency and abnormal procedures'* section stated:

> *'A red box around the title denotes an emergency procedure. Some emergency situations require immediate corrective action. These numbered steps are printed in double-lined boxes in the Emergency/Abnormal Procedures sections and are intended to be accomplished without the need to refer to the AFM or checklist.'*

As an example of their layout, the following is an excerpt from the AFM *'Jammed elevator trim tab (cruise)'* procedure.

4 ■ **Jammed Elevator Trim Tab**

● **Cruise**

The procedure required will vary with the airspeed at the time the jammed condition occurs. It is best to maintain the trimmed speed as long as possible without exceeding 263 KIAS or approximately 10 pounds elevator force. When nearing the airport or when more than 10 pounds of force is required, regardless of altitude, initiate the following procedures:

1. Throttles . . . . **IDLE**
2. Speedbrakes . . . . **Deploy**
3. Landing Gear . . . . **Down** (below 186 KIAS)
4. Airspeed . . . . **Reduce** (elevator force will reduce as airspeed is reduced)
5. Flaps . . . . **TAKEOFF AND APPROACH** (below 200 KIAS)
6. Speedbrakes . . . . **Retract** (below 120 KIAS speedbrakes can be used as desired; elevator force will increase slightly).
7. Airspeed . . . . **120 KIAS**
8. Flaps . . . . **LAND** (elevator force will increase slightly when flaps LAND is selected)

Footnote

[17] Cessna Airplane Flight Manual, Citation CJ1+ Model 525 (525-0600 thru -0799), Revision 3, 27 March 2012.
[18] Aircraft messages were colour coded as white, amber and red in increasing severity.
[19] Procedures grouped by system for malfunctions which don't necessarily generate an aircraft message.

Following is an excerpt from the *'Elevator trim runaway'* AFM procedure.

2 ■ Elevator Trim Runaway

1.	AP/TRIM DISC Button	**Push**
2.	Throttles	**As Required**
3.	Speedbrakes	**As Required**
4.	Manual Elevator Trim	**As Required**
5.	PITCH TRIM Circuit Breaker (LP-C13R4)	**Pull**

Pilot's checklists

The aircraft manufacturer published two 'Citation CJ1+ Pilot's Checklist' documents[20] entitled *'Normal Procedures'* and *'Emergency/Abnormal Procedures'*, which replicated AFM procedures but excluded systems descriptions. The first page stated:

> *'The Pilots' Checklist… should not be used until the flight crew has become familiar with the airplane, its systems and the FAA approved Airplane Flight Manual. Should any conflict exist between the checklist and the checklist in the FAA approved Airplane Flight Manual, the Flight Manual shall take precedence. All Airplane Flight Manual Normal, Emergency and Abnormal Procedure items must be accomplished regardless of which checklist is used.'*[21]

Basic AFM supplements

The AFM was approved by the FAA and published by the aircraft manufacturer. The introduction to *'SECTION V SUPPLEMENTS'* stated

> *'The supplements in this section contain amended operating limitations, operating procedures, performance data and other necessary information for airplanes conducting special operations and for airplanes equipped with specific options. Operators should refer to each supplement to ensure that all limitations and procedures appropriate for their airplane are observed…*
>
> *A non-FAA Approved Log of Supplements is provided for convenience only. This log is a numerical list of all the supplements published for this airplane…'*

The log it referred to was a list headed *'Log of Approved Supplements'.*

Footnote

20 The manufacturer's checklist referred to these as *'Current with model 525 Citation CJ1+ (525-0600 thru -0799) FAA approved Airplane Flight Manual Rev. 3, 27 March 2012 (part number 525FMB-03)'.*

21 The original quoted text was in upper case.

ATLAS AFM supplement

The ATLAS AFM supplement (AFMS)[22] was approved by EASA[23] and published by the Design Organisation (DO). As an STC, it was not included in the basic AFM but was provided to ATLAS purchasers for them to install in their AFM.

Information from ATLAS AFM Supplement

General

The title page of the ATLAS AFMS stated: *'This supplement is part of, and must be placed in, the basic FAA Approved Flight Manual…'.* The top of each subsequent page was labelled '*SECTION V – SUPPLEMENTS'*.

ATLAS inoperative procedure

The relevant parts[24] of the *'ATLAS inoperative procedure'* were as follows.

The following items should be added to the applicable position in the Cessna AFM.

1 ■ **ATLAS INOPERATIVE (ATLAS INOP BUTTON LIGHT ON)**

The ATLAS INOP Button light will illuminate if the ATLAS system ACU detects a failure condition within the system.

● **ATLAS Inoperative in Flight**

WARNING

Large aileron input may be required if an ATLAS failure at high indicated airspeed includes a TACS runaway.

Speed reduction is the first priority in these failure conditions.

1. Throttles .... **IDLE**
2. Speed Brakes .... **Extend**
3. AP/TRIM DISC Button .... **Push**
4. Maintain lateral control.
5. Airspeed .... **Reduce to 140 KIAS or Less**
6. ATLAS INOP Button .... **Press to Reset**

☐ **If ATLAS INOP Button Light Remains Illuminated**

7. ATLAS INOP Button .... **Press 3 times within 3 seconds**
   ATLAS INOP Button light will flash 3 times while system goes through BIT (Built In Test).

Footnote

[22] *'Airplane Flight Manual Supplement CA/DD/M038 TAMARACK® - ACTIVE TECHNOLOGY LOAD ALLEVIATION SYSTEM (ATLAS™) WINGLETS Issue B'.*

[23] The 'ATLAS winglet certification' section of this report explains EASA's involvement during the certification process.

[24] After the main procedure title, the AFMS detailed the 'ATLAS inoperative on the ground' before the 'In-flight' procedure.

The AFM defined a *'Warning'* (in the context of a procedure) as *'Operating procedures, techniques, etc., which can result in personal injury or loss of life if not carefully followed.'*

It defined a *'Caution'* as *'Operating procedures, techniques, etc., which can result in damage to equipment if not carefully followed'.* The AFMS did not provide fuel and flight planning information for TACS deployed failure conditions, which would include flying at 140 KIAS.

N680KH's documents

After the serious incident, N680KH's AFM was found at the rear of the aircraft, rather than the flight deck. It contained pages five to eighteen[25] of the ATLAS winglet AFMS, in reverse order, in the section entitled *'White message procedures'*[26]. Those ATLAS AFMS pages included the sections on normal and emergency procedures.

AFM *'SECTION VI WEIGHT AND BALANCE DATA'* contained an updated *'Airplane Weighing Form'*, an FAA *'Major Repair and Alteration'* document and an *'Equipment List Amendment'*[27] relating to the ATLAS winglets, along with a copy of the STC.

Two sets of the *'Normal'* and *'Emergency/Abnormal'* Pilot's Checklists were in the flight deck, one set each side. The pilot indicated that when the incident occurred he was aware of the presence and basic functioning the ATLAS winglets but not the extent to which they could affect the aircraft's controllability, or the existence of its AFM supplement.

Regulatory information

The FAA Code of Federal Regulations (CFR)[28] 91.505[29] stated:

> *'Each pilot in command of an airplane shall, before beginning a flight, become familiar with the Airplane Flight Manual for that airplane…'.*

CFR 91.7 stated:

> *'The pilot in command of a civil aircraft is responsible for determining whether that aircraft is in condition for safe flight...'.*

EASA Part NCO.GEN.105:

> *'Pilot-in-command responsibilities and authority', states: 'The pilot-in-command shall be responsible for… recording… all known or suspected defects in the aircraft at the termination of the flight, or series of flights, in the aircraft technical log or journey log for the aircraft.'*

Footnote

25 The complete AFMS was around 190 pages.
26 White messages – advisory in nature, sometimes requiring future action.
27 Those three documents were dated 20 November 2017.
28 Under which N680KH was operated.
29 CFR Part 91 *'General Operating and Flight Rules'*, Subpart F [accessed October 2020].

The EASA described a TACS fault as a '*defect that hazards seriously the flight safety'* and indicated that on that basis it would expect the condition to be reported.

The EASA requires manufacturers to submit 'Operational Suitability Data' when applying for a change to a type certificate (TC) or for an STC. It stated:

> *'Annex I to Regulation (EU) 748/2012 (Part-21) requires an applicant for a change to a TC or for an STC to assess the impact of design changes to the Operational Suitability Data* [OSD]*. This latest requirement, as implemented with amending Regulation (EU) 69/2014, requires that all such applications filed from 19 December 2016, include an approval of the associated changes to the OSD FC* [30]*, when applicable. Part of this approval are pilot training elements associated to a specific design, when such elements are identified in the certification process.'*

Additional information from the pilot and passenger

The pilot reported that during the upset he intended to follow the instruction marked on the ATLAS button to reduce airspeed, but he was "fighting" to control the aircraft. Although he was trying to raise the aircraft's nose to slow down, at one stage he accepted the increased rate of descent because he was concerned about losing control and considered landing on the sports field. He reflected that he didn't have time to consider using speedbrake or aileron trim, but also that he needed both hands on the control column. He found controlling the aircraft easier at lower airspeeds.

The passenger in the front right seat reported that the pilot "…tried to regain control of the aircraft using his full weight on the control [column] pulled towards him and hung to the right, giving full feet to the rudder. He actually hung half over my lap… and I heard him say… several times 'come on', which I assume meant that the aircraft had to respond to his actions".

The pilot reported being unsure if the ATLAS INOP light was actually a button, but he intuitively pressed it, and re-set the related CB, hoping to disable the system. He was able to reach the CB because he was already leaning across the flight deck.

Additional information from air traffic control

Following are some relevant parts of the transcript contained in Bournemouth ATC's investigation report[31] for the event[32].

> *'14:19:02 N680KH Bournemouth* (The aircraft starts turning sharply left and descending)

Footnote

30 Flight Crew.
31 Submitted to the CAA as a Mandatory Occurrence Report.
32 The original document's text colours and italicisation has been preserved as far as practical, with black ellipses representing gaps between excerpts. The different colours represent different individuals or communication methods: blue – ATCO; red – the pilot; green, orange – ATC internal communications.

14:19:09	*N680KH Bournemouth*
14:19:14	*N680KH Bournemouth radar do you read…*
14:19:18	*Readability five* (breathing heavily) *we have a problem*
14:19:26	*N680KH Bournemouth Roger what's the nature of your problem*
14:19:31	*We have erm a .....* (breathless)
14:19:36	*.....a failure of the......of the of the erm tamaracks*
14:19:45	*Roger I don't understand that system Sir do you wish to return to Bournemouth to land*
14:19:50	*I wish to..*(garbled)*...Bournemouth to land yes*
14:19:51	(On intercom to Tower) *answer the phone quick*
	yep
	right he sounds really panicked we don't know what the problem is, he's coming back in…
14:19:53	*N680KH roger join downwind left hand visually for runway 08 I have traffic on final approach at err 5 miles I can break him off…*
14:20	…the tower controller contacts AFS[33] and instigates a full emergency stage 1[34].
14:20:35	*N680KH report final runway 08 if you are able there is traffic on final approach at one mile.*
14:20:42	*Copied err a ..*(Inaudible)*..680KH*
14:20:47	*680KH just say again the nature of your problem*
14:20:51	*tamarack failure for the...680KH tamarack failure roger winglets* (this transmission from the pilot of N680KH was mainly indecipherable)*…*
14:21:15	*…break N680KH you are cleared to land runway 08 the surface wind 150 degrees 10 knots*
14:21:25	*Cleared to land err....'*

The ATCO described the aircraft entering a "last minute dive" followed by a "very unstable landing".

The report stated *'…the pilots voice suggested that he was exerting a high level of physical effort in controlling the aircraft'.* The event was defined by their safety management system as *'Hazardous'*, which was the second most serious of five risk levels, because it *'narrowly avoided a collision…'.*

Footnote

[33] Aerodrome fire service.
[34] Stage 1 – For aircraft with a passenger carrying capacity of 20 or less.

ATLAS winglet certification

Introduction

The original design and manufacture of the ATLAS system was completed in the USA, but at that time FAA workload meant it was not possible to certify the system quickly in the USA. The manufacturer therefore identified an organisation in the UK with Design Organisation Approval which worked with the manufacturer to certify the STC in Europe to EASA CS-23[35], the certification specification for *'Normal, Utility, Aerobatic, and Commuter Category Aeroplanes'.*

Initial certification of the STC by EASA was granted on 22 December 2015 as STC 10056170 and revision 2 was published on 27 June 2016. N680KH was modified to incorporate the ATLAS system under import STC SA03842NY, approved by the FAA in December 2016[36].

Flight testing

General information

The DO's *'Flight test report'*[37,38] for the ATLAS modification purposed to demonstrate compliance with relevant EASA Certification Specifications (CS-23)[39], and some special conditions. It did this by reviewing and approving the winglet manufacturer's documentation including its *'Flight test report'* and its *'ATLAS dual asymmetry flight test report'* – which were included in the main flight test report as Annexes A and C, respectively. Annex D contained EASA's certification flight tests.

The winglet manufacturer tested the following TACS failure cases[40]. (The test procedure is described in the 'Additional flight testing' section below).

- Maximum[41] symmetric deflection
- Maximum dual[42] asymmetric deflection left (left TACS up and right TACS down)
- Maximum dual asymmetric deflection right (right TACS up and left TACS down)

The EASA indicated that individual technical failures were tested for certification, rather than multiple failures, and assumed predicted failure rates of components. Therefore, it flight tested single[43] asymmetric deflections because a dual TACS failure was considered *'extremely improbable'*.

Footnote

35 The equivalent FAA document is CFR 23.
36 The FAA has a bilateral agreement with EASA, which allowed for issuance of an FAA STC.
37 CA/DD/TSR063, October 2015.
38 Produced in association with other documents, including *'Flight test analysis report', 'Functional hazard assessment' and 'System safety assessment'.*
39 CS-23 Amendment 3, 20 July 2012.
40 Flight tests were performed at critical weights and centres of gravity.
41 Maximum deflection for TACS up was 18°, and for TACS down was 8°.
42 Dual asymmetry – both TACSs are deflected in opposite directions.
43 Single asymmetry – one TACS is deflected and the opposite one is faired.

The EASA stated that TACS failure modes were tested on all occasions using what it considered "industry standard" reaction times of three seconds during cruise with autopilot engaged, and one second for takeoff, climb and landing phases (when it was assumed a pilot may be monitoring more actively)[44].

CS-23 *'Flight characteristics', section 'CS 23.141 General'* stated

> *'The aeroplane must meet the requirements of CS 23.143 to 23.253 at all practical loading conditions and all operating altitudes, not exceeding the maximum operating altitude… for which certification has been requested, without requiring exceptional piloting skill, alertness or strength.'*

Unless otherwise stated, the following flight testing information pertains to dual TACS failures, the results for associated single TACS failures being consistent and less critical in load and controllability.

<u>Controllability and manoeuvrability</u>

The TACS failure procedure required the test pilot to:

> *'record… ability to safely control and maneuver the airplane with the most adverse TACS position without the use of exceptional pilot skill and with the normal use of controls.'*

Flight test report Annex A section 3.6.16 *'General – all flight phases'* stated:

> *'Controllability and maneuverability were satisfactory at all test points and there were no marginal conditions with regard to required pilot strength…*
>
> *For all failure scenarios tested… there were no hazardous flight path deviations and it was also demonstrated that the aeroplane is safely controllable and that a pilot can perform all manoeuvres and operations necessary to effect safe flight and landing in case of failure.'*

<u>Trim</u>

Flight test report section 3.35.2.5, *'…Trim'*, stated:

> *'The ability to adequately trim the aircraft for the three TACS failures conditions was assessed. The tests were conducted for a high speed cruise configuration at VH[45], for an approach with Flap 0°, and in the landing configuration.'*

Footnote

[44] These reaction times are specified in FAA AC 23-17C *'Systems and equipment guide for certification of part 23 airships and airplanes'* (accessed 24 July 2020).

[45] V_h was tested at 237 KIAS.

Flight test report Annex A, section 3.6.23 *'Trim'* stated:

> *'All trim requirements were met in both* [normal] *and asymmetric TACS conditions with the trim system always capable of reducing roll control force to less than 5 lb.'*[46]

Reference approach landing speed

Flight test report section 3.35.2.2 *'Reference Approach Landing Speed'* (V_{REF}) stated:

> *'Simulated approaches in the landing configuration… were flown at the AFM-derived V_{REF} and with the aircraft trimmed to account for the failures. In all cases the aircraft behaviour was acceptable and no unsafe characteristics were detected.'*

Flight test report Annex A section 3.6.12 *'Reference Approach Landing Speed'* stated:

> *'Once the aileron trim was set for an asymmetrical TACS failure condition, the aircraft behaves as would be expected of a trimmed aircraft.'*

Flight test report Annex D, *'Control during landings'*, for single asymmetry, stated that the pilot completed the landing *'without using any exceptional skill or control force, with sufficient travel remaining in each surface to compensate for the conditions.'*

Autopilot

Flight test report section 3.44 *'Automatic Pilot System'* described the effect of ATLAS failures on the autopilot as follows:

> *'The aircraft was flown at a variety of speeds up to 240 KIAS and various standard manoeuvres were performed for each condition. In all cases, even when the autopilot disconnected, aircraft loads were acceptable and there was negligible deviation from the flight path.*
>
> *… the asymmetric failure conditions caused rolls followed (for the 180 KIAS and 240 KIAS test speeds) by autopilot disconnect when bank angle limits were reached. At 180 KIAS, autopilot disconnect typically occurred at 5 to 7 seconds from ATLAS failure. At 240 KIAS, the time was typically 2 seconds.*
>
> *The rolls and the subsequent autopilot disconnect are readily discernible to the pilot, therefore it will quickly become obvious if there has been a system failure, even if the ATLAS INOP Button light is missed. Given a pilot reaction time of 1*[47] *second, it has been assessed that no unsafe conditions can subsequently result.'*

Footnote

[46] 5 lbf was the CS-23 (amendment 3) limit for prolonged application in roll. Force limits were not specified in later amendments of CS-23.

[47] The winglet manufacturer reported this should state *'or 3'* seconds.

Flight test report Annex A section 3.6.39 *'Automatic Pilot System'* stated:

> *'…At higher speeds, control forces to arrest roll due to an asymmetric TACS condition approached the temporary control force limit of 50 lb[48]. That force was immediately relieved with any application of counter trim.'*

Flight test report Annex D *'Automatic pilot system'* found, for single asymmetry, the 240 KIAS right hand turn was critical, achieving 40° angle of bank and airspeed increase of less than 10 KIAS without automatic autopilot disengagement. The pilot response to a straight and level flight test point was *'not strictly per the procedures'* in the AFMS: *'… the pilot first responded to the lateral upset, then reduced speed once the upset had been countered'.* The report stated:

> *'…the procedural order is critical: power reduction and speed brake deployment are higher priority than responding to the roll upset. This is unusual when compared to other roll upset recovery procedures (e.g., autopilot roll axis or lateral trim runaway). Other recovery procedures (e.g., unusual attitude recovery from a nose down position[49]) are similar in that power reduction to minimize speed increase is prioritized.'*

<u>Hazard classification</u>

Using definitions from FAA AC 23.1309-1E[50] (shown in Table 1), dual asymmetric TACS deflection was classified 'Hazardous', and single deflection 'Major'[51]. The allowable quantitative probability of a hazardous event was less than 10^{-7} per flying hour, which was qualified by analysis of predicted failure rates of the system.

Hazard classification	Description
Major	Failure conditions that would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be a significant reduction in safety margins or functional capabilities. In addition, the failure condition has a significant increase in crew workload or in conditions impairing crew efficiency; or a discomfort to the flight crew or physical distress to passengers or cabin crew, possibly including injuries.

Footnote

48 From CS-23 (amendment 3).
49 Detailed in the aircraft's operating manual, Citation CJ1+ 525OMB-01.
50 'System Safety Analysis and Assessment for Part 23 Airplanes'.
51 The five severity classifications for failure conditions were: no safety effect, minor, major, hazardous and catastrophic.

Hazard classification	Description
Hazardous	Failure conditions that would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be the following: (a) A large reduction in safety margins or functional capabilities; (b) Physical distress or higher workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely; or (c) Serious or fatal injury to an occupant other than the flight crew.
Catastrophic	Failure conditions that are expected to result in multiple fatalities of the occupants, or incapacitation or fatal injury to a flight crewmember normally with the loss of the airplane.

Table 1

FAA AC 23.1309-1E Hazard classifications

Additional flight testing

Flight test report section 3.44 *'Automatic pilot system'* stated:

> *'Further flight testing, as shown in Annex C, was conducted to provide quantitative data in justifying the hazard classification for the TACS dual asymmetric failure case as Hazardous and not Catastrophic... The results demonstrate that the failure condition does not meet any of the Catastrophic classification criteria…'*

Flight test report Annex C section 1.6 described the *'Test procedure'* as follows.

> *'Once the autopilot was set, the [pilot in command (PIC) and Safety Pilot] both removed their hands and feet from the controls... The PIC depressed the Recognition Button and… After the flight crew announced they were ready, the* [flight test engineer (FTE)] *used the TACS Manual Control Box to inject a sudden dual asymmetric failure without warning… Immediately upon recognizing the failure, the PIC released the Recognition Button, starting the automatic countdown*[52]*. At the end of* [this] *the Reaction Light illuminated…*

Footnote

[52] Reaction time.

the PIC immediately removed his hands from his lap and initiated recovery procedures per the ATLAS AFMS… Once the airplane had returned to level roll attitude, the FTE removed the failure, returning the TACS to neutral positions.'

Flight test report Annex C included the following *'Flight test results interpretation matrix'* and *'Review of critical test parameters'* (Figures 14 and 15).

Characteristic	Major	Hazardous	Catastrophic
Maximum bank angle	< 60°	> 60°	Unrecoverable
Maximum control force	Pitch: ≤ 50 lbf Roll: ≤ 25 lbf	Pitch: ≤ 75 lbf Roll: ≤ 50 lbf	Pitch: > 75 lbf Roll: > 50 lbf
Load factor	(None specified)	Neg: < 0.0g	Neg: < -1.52g Pos: > 3.6g
Maximum speed	>263 KIAS	≥ 284 KEAS	≥ 305 KEAS
Maximum altitude loss	(None specified)	(None specified)	>2000 feet

Figure 14

'*Flight test results interpretation matrix'* from *Flight test report* Annex C

Table 4 Composite Critical Test Point

RESULTS: 240 KIAS RH TURNING FLIGHT TACS ASYMMETRIC RIGHT – COMPOSITE CRITICAL PARAMETERS							
	Max Bank Angle (deg)	Max Pitch Force (lb)	Max Roll Force (lb)	Max KIAS	Min Nz	Max Nz	Alt Loss (ft)
DAS:	7,8	12	8	14	8	14	13
	115	69.48	48.44	252*	0.8	2.75	1160

*KIAS values less than Major

Figure 15

'*Review of critical test parameters'* from *Flight test report* Annex C

Additional organisation information

The DO reflected that a pilot's instinctive tendency to correct sudden roll using opposite aileron[53] precipitated the *'Warning'* in the *'ATLAS inoperative in flight'* AFMS procedure to address speed reduction first[54]; and that the warning related to the high speed case.

The regulator stated that it is instinctual for pilots to respond to roll rate. Therefore, the *'ATLAS Inoperative in flight'* procedure must be followed immediately (in other words, contrary to a pilot's instincts to control roll first).

A member of one of the test flying teams explained that the dual asymmetric TACS failure was "severe" but that they were able to control the aircraft. They confirmed that after the initial handling of it, the remainder of its associated test flying assumed the use of roll trim.

Footnote

53 Example of a 'skill-based response' – highly practiced, largely physical, with almost no conscious monitoring.
54 Example of a 'knowledge-based response' – almost completely conscious, for novel or new situations.

Information from the winglet manufacturer

The manufacturer produced a product information document for prospective buyers entitled *'Unlock the Beauty and Performance of Your Jet – ATLAS® Active Winglets for Cessna Citation CJ, CJ1 and CJ1+'.* It stated:

> *'…Failure modes are benign and the only required pilot action in the event of a failure is to slow to the indicated airspeed shown on the cockpit annunciator.'*

A customer testimonial in that document stated:

> *'…The benign nature of the installation requires no structural modifications and the fail-safe mode simply allows the active surfaces to trail on failure.'*

The winglet manufacturer's *'ATLAS Active Winglet Delivery Checklist: CJ, CJ1, CJ1+, M2'*[55] for new customers advised:

> *'…ATLAS annunciations are rare; however, if ATLAS INOP button is illuminated, slow to 140 KIAS and follow the ATLAS INOP procedure – speed reduction is first priority in failure conditions.*
>
> *NOTE: Significant aileron input may be required if an ATLAS failure at high indicated airspeed includes a TACS asymmetric deployment. Like other unlikely system failures, it may produce increased control forces which are diminished with reduced airspeed, as per normal upset training.'*

The delivery checklist contained items relating to the content of the AFMS, including an *'Emergency procedures'* section, which summarised the ATLAS inoperative in flight procedure. It did not give guidance on installing the AFMS in an aircraft's existing AFM.

The winglet manufacturer reported that it, and its dealer network, conducted a 'handoff procedure' for anyone collecting a newly modified aircraft from them using the delivery checklist. That including a briefing on the AFMS and its procedures. There was no such provision for subsequent owners of aircraft with this equipment installed.

The winglet manufacturer stated that it intends to offer its product *'For commercial airliners, military aircraft, UAV and UAS applications…'.*[56]

FAA airplane flying handbook

The FAA's *'Airplane flying handbook'*[57] provides *'basic… skills and knowledge which are essential for flying airplanes'*.

Footnote

55 The winglet manufacturer reported having a document control process, for standardisation and revision tracking. At the time of the incident, the delivery checklist was not included that process.
56 https://tamarackaero.com/technology/commercial-military-jet-winglets [accessed November 2020].
57 FAA-H-8083-3B (2016).

Its chapter on *'Maintaining aircraft control: Upset prevention and recovery training'* stated:

> *'An unusual attitude is commonly referenced as an unintended or unexpected attitude in instrument flight… the term "upset" is inclusive of unusual attitudes. An upset is defined as an event that unintentionally exceeds the parameters normally experienced in flight or training. These parameters are:*
>
> - *Pitch attitude greater than 25°, nose up*
> - *Pitch attitude greater than 10°, nose down*
> - *Bank angle greater than 45°*
> - *Within the above parameters, but flying at airspeeds inappropriate for the conditions.'*

It summarised upset recovery procedures as follows.

> 1. *Disconnect the wing leveller or autopilot*
> 2. *Apply forward column or stick pressure to unload the airplane*
> 3. *Aggressively roll the wings to the nearest horizon*
> 4. *Adjust power as necessary by monitoring airspeed*
> 5. *Return to level flight'*

CAA flight crew human factors handbook

In Civil Aviation Publication (CAP) 737 - *Flightcrew human factors handbook*[58]*,* published by the UK CAA, the chapter entitled *'Workload'* states:

> *'Very high workload (particularly fast onset) and feelings of not coping with the workload can cause high arousal or stress… Under a high workload task, a pilot may not have the capacity to search and assess other areas, problems and alternatives.'*

The chapter entitled *'Surprise and startle'*[59] includes the following:

> *'The fight or flight response is an innate reaction… All mental capacity becomes focussed on the threat and/or the escape from it…* [It] *is accompanied by an urge to be engaged in the active solution.*
>
> *…example: an unusual attitude. While easy enough normally, when experiencing extreme fight or flight, a pilot may glance at the attitude indicator but be unable to make sense of it… because the brain does not want to dwell on assessment…*

Footnote

[58] https://publicapps.caa.co.uk/docs/33/CAP%20737%20DEC16.pdf [accessed November 2020].

[59] 'Startle reflex' – the first response to a sudden, intense event; 'Surprise' – results from a disparity between a person's expectations, and what is perceived.

> *…in a severe upset situation or with a primary control or display problem, the 'aviate' task may not be resolvable when in the fight or flight state, and the pilot(s) could get stuck trying to 'aviate.'*[60]

Other events

During initial introduction of the STC into service the manufacturer was made aware of several TCU failure events, listed in Table 2. The DO was informed of the first two events immediately and reported them using the European Aviation Safety Reporting on-line portal. On entering the website, the DO reported the events on the UK register not knowing that, as the STC had been certified though the EASA, they should have issued the safety reports to the EASA[61] by clicking on the EASA link shown in Figure 16. Although the UK regulator forwarded the occurrence reports via an automated transmission to the European Central Repository, the EASA did not become aware of them immediately. The EASA was made aware of the first event by other means and the occurrence report was provided to them by the UK CAA. An EASA risk assessment of the single event did not identify an unsafe condition and therefore no action was considered necessary

The winglet manufacturer reported the events that occurred in January and March 2019 to the FAA but did not inform the DO or EASA until after the N680KH serious incident. The DO subsequently formally notified the EASA once they had been made aware.

The certifying authority was therefore only aware of one event involving the ATLAS system prior to the serious incident involving N680KH.

Date	Reported Event
February 2018	Aircraft banked to the right in cruise achieving approximately 30° of bank as the pilot recovered. ATLAS would not reset in the air.
August 2018	Left Seat was being trained by Right Seat. "Right Seat" told "Left Seat" to recover and "Left Seat" did without "Right Seat" touching controls. "Left Seat" reported full aileron input for recovery. "Right Seat" reports that he "was never out of training mode".
January 2019	Pilot reported a violent roll input. Passenger didn't notice the event until landing.
March 2019	Pilot reported a roll input he assumed was autopilot hardover. Less than 45° bank during recovery, using 1/4 to 1/3 roll input.

Table 2

Other TCU events

Footnote

60 'Aviate, navigate, communicate' – a task prioritisation rule commonly used by pilots.
61 EU Regulation 376/2014 Article 4 requires that *'…each organisation established in a Member State which is certified or approved by the Agency [EASA] shall report to the Agency the details of occurrences …. as soon as possible, and in any event no later than 72 hours after becoming aware of the occurrence.'*

Figure 16

Aviation reporting home screen

On 30 November 2018, a Cessna 525A, N525EG, with ATLAS winglets installed, crashed shortly after takeoff near Memphis, Indiana, USA, fatally injuring the three occupants onboard. The US National Transportation Safety Board (NTSB) stated that while climbing through 6,000 ft amsl, the aircraft turned left and descended, then disappeared from radar. The NTSB investigation is ongoing.

Service Bulletins

The system manufacturer's investigation into the reported events revealed that in some of the events the PCB attachment screw had come loose. It found that at the limits of tolerance of the hole, the spring washer could move into the hole. This reduced the clamping load in the joint, loosening the screw and eventually allowing it to become dislodged. Service Bulletin (SB) CAS/SB1467 issue A, was issued by the DO on 25 April 2018 and revised to issue B on 1 August 2018, instructing operators to remove both TCUs and replace them with units that had been modified to incorporate improved connector PCB earthing and securing screw retention. It stated that an inflight system failure of the ATLAS system had been reported, resulting in a TACS *'hard over'*. The modification was issued as '*Category 2: Do as soon as possible without effect on service or by 150 flight hours or 1 year from the date of receipt of this service bulletin, whichever occurs first.'* It was therefore a recommended embodiment, and was not mandated by the relevant airworthiness authority. At the time of the incident, the SB had not been embodied on N680KH. The aircraft had accumulated 107 flight hours and it was less than a year since the SB had been released.

Another SB, CAS/SB1475 issue A, issued by the DO on 1 March 2019, introduced the fitment of "centering strips" (Figure 17) to the trailing edges of both TACSs:

> *'1) Return the TACS to faired when TCU power is removed and 2) Return the TACS to the faired position if they are "blown" out of position if ATLAS power is removed.'*

The modification documentation stated that there had been three uncommanded roll events relating to system failures. Due to the aerodynamic overbalance of the TACSs, it was possible for them to remain deployed if they were not faired when the TCUs were de-powered.

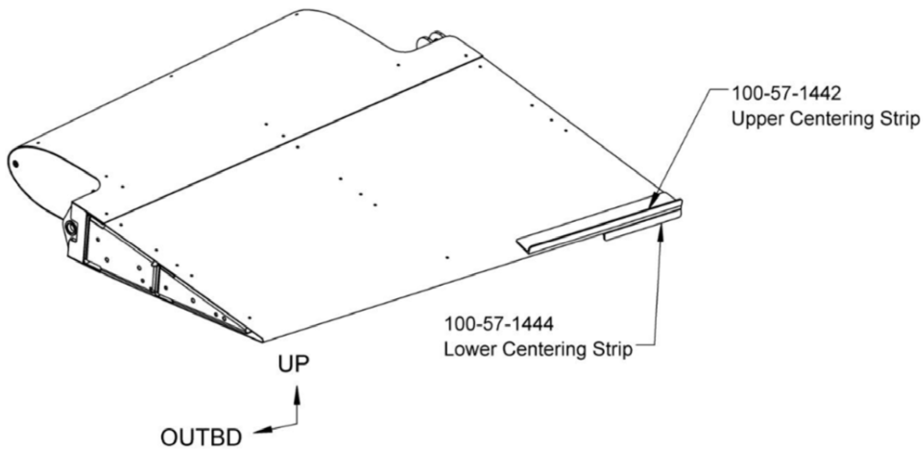


Figure 17

Centering strips introduced via Service Bulletin CAS/SB1475 issue A

The system manufacturer described aircraft response to an uncommanded and stuck TACS deployment as "benign", and as such the embodiment requirement of the SB was *'Category 7: Do at customer convenience.';* effectively an optional SB. At the time of the incident, N680KH had not embodied CAS/SB1475 issue A, but the modification pack had been provided to the pilot.

Airworthiness Directives

On 19 April 2019, when the EASA was made aware of the serious incident involving N680KH, and subsequently the other events, it immediately issued an Emergency Airworthiness Directive (EAD) 2019-0086-E. This EAD required that all ATLAS equipped aircraft have their ATLAS deactivated and restrict the movement of the TACSs by applying *'Speed Tape over the gaps around the each TACS, on both upper and lower surfaces, to ensure the free movement is not possible'.* Flight envelope limitations were also set to reduce wing loading, by limiting the aircraft to 140 kt, and to avoid icing conditions. It allowed operation of the aircraft with the ATLAS system disabled for 100 hours in accordance with the EASA approved master minimum equipment list (MMEL).

On 24 May 2019, the FAA issued an Airworthiness Directive (AD) 2019-08-13. This AD was applicable to all aircraft with the ATLAS system installed and was in response to the EASA EAD 2019-0086-E. It prohibited operations of the aircraft with the ATLAS system installed and was effective on the day of issue. The FAA AD prohibited further flight with the ATLAS system installed until '*a modification has been incorporated in accordance with an FAA-approved method*.'

At the time of the EASA EAD, the FAA did not have an approved MMEL for ATLAS operations, so the FAA AD did not allow operations with the ATLAS system disabled.

On 4 July 2019 SB CAS/SB1480 was issued by the DO, which mandated the embodiment of SBs CAS/SB1467 and CAS/SB1475: improving screw retention within the TCU and introducing centering strips on the TACS trailing edges respectively. The SB also introduced changes to improve TCU reliability.

On 10 July 2019, the FAA issued an alternate means of compliance (AMOC) which, if complied with, removed the flight restrictions put in place by the FAA AD. The AMOC required operators to follow instructions identified in SB CAS/SB1480.

On 9 August 2019, EASA issued a revision to EAD 2019-0086-E, which was effective on 23 August 2019. The revision removed the restrictions put in place by the EASA EAD if the instructions identified in SB CAS/SB1480 were complied with. The original STC was also revised to include the appropriate modifications outlined in SB CAS/SB1480.

Purchasing process

Prior to purchasing N680KH from a private owner an *'Aircraft Pre-Buy Survey Report'* was produced by the aircraft manufacturer for the pilot[62]. The pre-buy inspection was intended to give the buyer an independent assessment of the condition of the aircraft prior to purchase, but stated that it:

> *'does not: (a) ensure the total integrity of the Aircraft; (b) represent that the aircraft is airworthy; (c) satisfy the Inspection requirements for continued airworthiness of the aircraft....'*

In addition to assessing the aircraft physically, the inspection reviewed available maintenance data in CESCOM[63], to identify any Advisory Circulars, SBs and ADs that may be applicable to the aircraft.

The Pre-Buy report for N680KH, which was issued on 28 February 2019, indicated that the Tamarack ATLAS system had been installed on 20 November 2017 and that the Equipment List had been updated, the flight manual supplement had been installed in the Manual and relevant instructions for continued airworthiness were up to date. CAS/SB1467 issue B, issued on 1 August 2018, recommending the replacement of the TCUs, was not mentioned in the document. The aircraft manufacturer stated that it relied upon data provided by the seller within a CESCOM 'Aircraft Status report', printed on 21 February 2019, to identify any outstanding SBs. No ATLAS related SBs were listed in this report. All the ATLAS SBs were available on the ATLAS manufacturer's website, but the scope of this Pre-Buy report did not extend to searches of individual STCs.

Footnote

62 The aircraft manufacturer stated that the scope of a pre-buy inspection is set by the purchaser of the aircraft.

63 CESCOM is a third party maintenance tracking service which integrates with the aircraft manufacturer's Product Support, Parts Distribution, Service Facilities, Reliability Engineering and Maintenance Engineering systems.

The *'Offer to purchase agreement'* necessitated aircraft delivery *'with all documents required to be maintained with respect to the Aircraft, original, complete and continuous… up to date and maintained in accordance with FAR*[64]*, and all flight manuals, manuals and subscriptions up to date…'.*[65] The *'Aircraft purchase and sale agreement'* noted the presence of *'Tamarack winglets'* under *'modifications/conversions'.*

Additional information

In 1997, the FAA published two studies on general aviation pilot responses to autopilot malfunctions, which used a fixed-base simulator configured as a Piper Malibu single propeller aircraft[66]. The paper stated:

> *'Cooling and Herbers (1983) noted, in their discussion of human factors, that "...there are no studies available to support the FAA certification standard of a three second delay (enroute) or a one second delay (on approach) before initiation of recovery by the pilot from an autopilot malfunction." However, it has been suggested that the data were actually derived from an examination of airline pilots' responses collected during a study performed at Wright-Patterson AFB in the 1960s (ACE-110, 1996).'*

It found that pilot response times for a *'commanded roll'*[67] malfunction ranged from 1.8 seconds to 107.1 seconds, with a mean[68] response time of 16.5 seconds, and a median[69] response time of 8.5 seconds.

On 16 June 2020 a bill was introduced in the USA to reform the FAA's aircraft certification process for transport category aircraft[70], cited as the *'Aircraft Safety and Certification Reform Act of 2020'.* The Act intends to:

> *'…review existing assumptions on pilot recognition and response, including response to safety-significant failure conditions, as part of the certification process… validate such assumptions with applicable human factors research and the input of human factors experts, and as necessary modify the existing assumptions… ensure that when carrying out the certification of a new aircraft type, including an amended or supplemental type, the cumulative impact that new technologies may have on pilot response are properly assessed through system safety assessments or otherwise… ensure that any action carried out under this section accounts for the necessary adjustments to system safety assessments, pilot procedures and training needs, and design requirements... notify other international regulators that certify transport-category airplane*

Footnote

64 US Federal Aviation Regulations.
65 The aircraft manufacturer stated that the condition of the documents was the responsibility of the seller.
66 DOT/FAA/AM-97/24 *'Automation in general aviation: two studies of pilot responses to autopilot malfunctions'* (1997).
67 The commanded-roll failure emulated an AP-commanded roll that exceeded the target bank angle.
68 Mean – average pilot response time.
69 Median – middle value in range of pilot response times.
70 Operated under CS-25.

type designs of the review and encourage them to evaluate any regulatory changes to their processes and address any changes, if applicable.'

The EASA indicated that it did not require representative operational pilots to participate in the ATLAS winglet certification process.

Analysis

Engineering analysis

The uncommanded roll of N680KH on 13 April 2019 was caused by failure of the left TCU, which caused it to move the left TACS away from the faired position with its trailing edge up. The system recognised the positional error, either by identifying a discrepancy between the left and right TACS or a difference between the commanded and actual position. On identifying the error, the system was de-powered. This allowed the left TACS, which was now subject to aerodynamic loads, to move to the trailing-edge up mechanical stop. This resulted in the uncommanded left roll input. Once de-powered, the left TACS was aerodynamically locked in the fully deflected position for the remainder of the flight.

<u>Cause of the short circuit</u>

The cause of the TCU failure was probably a short circuit within the TCU caused by a loose screw or washer within the unit. The screw and spring washer had become loose because the spring washer had lost load, allowing the screw to unwind and eventually become loose within the unit.

The TCU was returned to the manufacturer's facility in the fully retracted position, corresponding with the TACS trailing edge being down. It had been driven into the hard stop during troubleshooting and is likely to have been as a result of a short circuit in the TCU across a set of terminals of a microchip. This short circuit did not explain the cause of the fault which occurred in flight, but it is likely the same screw or washer caused a short circuit, albeit a different one, in that case as well. Analysis by the manufacturer identified the terminals that may have been affected. There was no evidence to suggest that the TACS had been mechanically locked in the up position during the serious incident.

The ATLAS caution light probably illuminated on the instrument panel as soon as the system detected a fault, but with the TACS *aerodynamically* locked in the trailing-edge up position, pressing the ATLAS caution light would not have caused the TACS to move to the faired position.

<u>Service bulletins</u>

Service bulletin CAS/SB1467, recommending the replacement of TCUs to change the screw retention system, had been available for nearly a year, but had not been embodied on N680KH. The embodiment of the SB was recommended rather than mandatory, so it was not compulsory for any operators or owners to implement it.

Under the previous ownership this SB had not been embodied and the pre-buy survey did not identify that it needed to be carried out. The pilot probably put significant weight on the pre-buy report and may not have been aware that the report would not highlight any outstanding SBs associated with the STCs fitted to the aircraft. Had the SB been mandatory, rather than recommended, and issued with an associated AD it is more likely that it would have been embodied.

The manufacturer also issued service bulletin CAS/SB1475 issue A to introduced centering strips to aerodynamically centre the TACSs were they to be deflected when de-powered. The service bulletin was issued only shortly before the serious incident, so there had been little opportunity to embody the SB before the event. Had the centering strips been fitted, the TACS would have floated to the faired position as soon as the TCUs were de-powered. When the SB was introduced it was optional.

Following the occurrence involving N680KH, both EASA and the FAA took safety action in issuing ADs restricting the operation of aircraft with ATLAS installed. The closing action and AMOC for the ADs, SB CAS/SB1480, mandated the embodiment of SBs CAS/SB1467 and CAS/SB1475, ensuring that the TCUs were the latest standard and that centering strips had been installed on the trailing edge of each TACS.

If all the events involving the ATLAS system that had occurred before the serious incident involving N680KH had been reported to the EASA, the Agency may have determined that the reliability was not achieving continued airworthiness requirements. This could have prompted the EASA to issue an AD before the occurrence flight. At the time of the serious incident the EASA was only aware of one event involving a TCU failure. The risk assessment completed at that time did not show it as an unsafe condition.

Had the CAA identified that the events were associated with an EASA certified STC, it might have presented an opportunity to inform them. As all of the reported events prior to the serious incident involving N680KH occurred in the USA, and involved aircraft that are certified in the USA, it may not have been obvious to associate the reported events with the EASA certified STC. It is therefore unlikely the CAA would have determined that the report had been submitted to the wrong authority. Considering this finding the UK CAA intends to create data validation rules in ECCAIRS[71] to identify reports that should be shared with other authorities based on State of Occurrence, Registration and Design, including those regarding STCs. It also intends to agree with the EASA any additional criteria that will be included in validation rules.

AFM supplements

Applicable regulations state that pilots should be familiar with their aircraft's AFM, which includes information contained within AFM supplements.

Emergency and abnormal procedures for the basic aircraft are contained in Section 3 of the AFM, whereas procedures for supplementary equipment are contained in a separate

Footnote

[71] ECCAIRS is the European Coordination Centre for Accident and Incident Reporting Systems.

supplementary section. Consequently, it is foreseeable that supplementary procedures are less obvious than those in the main body of the AFM. This may be particularly significant if they are required in high workload situations. Being an STC, the ATLAS AFMS was not published in the basic AFM *'Section V - supplements'*. Aircraft owners in receipt of newly purchased ATLAS winglets were required to install the accompanying AFMS into their aircraft's AFM Section V.

Section V was indexed by a *'Log of Approved Supplements'*. The log itself was not FAA approved but the introductory paragraph described it as a numerical list of *'all the supplements published'* for that aircraft. Therefore, installing the ATLAS AFMS also required the log to be manually updated in order to maintain its validity. Consequently, if a modified aircraft's AFM Section V and its log were not being updated properly, the AFMS might be absent but the log still be described as complete.

After the serious incident N680KH's AFM was found at the rear of the aircraft containing a small number of pages from the ATLAS AFMS. Those pages resided in an unrelated part of Section III, with no other indication they were present. The pilot was an experienced owner of Citations and used the pilot's checklist documents. He knew N680KH had winglets installed but hadn't appreciated the significance of the system or that an AFMS existed for it. Therefore, it is unlikely that easier access to the AFM would have affected the incident outcome.

Original purchasers of new ATLAS winglets were in a better position to have working knowledge of the system, to receive the delivery checklist and handoff briefings, and to receive the AFMS to install themselves. Subsequent purchasers of an ATLAS-modified aircraft would need to research the system, and the nuances of its' AFMS installation, independently. It is likely that the absence of N680KH's ATLAS AFMS entry from its AFM Section V was missed by the pre-buy survey which, along with the expectation that aircraft delivery required a fully updated AFMS, masked its existence. This highlights the importance of pilots familiarising themselves with the equipment on each airframe they operate even when flying a familiar type.

After initial ATLAS purchase, subsequent owners and pilots are less likely to be aware of the presence and characteristics of the system. Accordingly, the winglet manufacturer:

- has undertaken safety action to add a signature page to the ATLAS winglets delivery checklist to identify who has conducted each handoff briefing. It intends to incorporate that checklist into its document control process
- intends to add an item to the ATLAS winglets delivery checklist requiring the AFMS to be installed in the AFM and the log of approved supplements to be updated during the handoff briefing
- intends to promote awareness of the AFMS to ATLAS pilots and improve its overall availability, for example, by making it easier to find and download on its website.

TACS failure cases discussion

Introduction

ATLAS winglets were not modelled by aircraft simulators so the single TACS failure at 258 KIAS in this incident was compared with the test flying involving single and dual asymmetric TACS failures at airspeeds of up to 240 KIAS.

Pilot preparedness and response

The test pilot[72] operated as 'single pilot', with a safety pilot alongside, and was conversant with the winglet system. He expected a significant rolling moment, caused by TACS failure, and was primed to apply the procedure detailed in the AFMS after a defined delay. Having to repeat the procedure on several test points meant he had the opportunity to practice handling the failure. Nevertheless, on one single asymmetry test point, he instinctively controlled roll, rather than the knowledge-based prioritisation of airspeed reduction. The failure was temporary and controlled in a pre-determined flight condition, thereby minimising startle presented by a real system failure.

The pilot of N680KH was experienced on type but was unfamiliar with the AFMS. From his perspective the event was a sudden, significant and uncommanded roll, opposite to the intended direction of turn during departure. The aircraft entered an 'upset' situation (exceeding a 'normal' bank angle), which disengaged the autopilot, generated a bank angle alert, and produced control forces which the pilot believed he might not sustain. The passenger's description of the pilot straining, vocalising his frustrations, and ATC perceiving him as so panicked that they instigated emergency procedures, indicate his stress.

The pilot was in a 'fight or flight' state, with his physical and mental capacity focussed on escaping the threat; using the skill-based response of countering the roll with aileron and rudder, and then reducing thrust. He did not have the capacity to assess alternative actions such as using speedbrake and aileron trim. Instead he attempted to disable the system and flew closer to the ground, considering an emergency landing.

His incomplete and indistinct radio transmissions suggest his attention was focussed on 'aviating and navigating' rather than communicating. The novel method of controlling the aircraft laterally by modulating right rudder pressure was a knowledge-based, rather than skill-based, response and added to his workload.

While a single TACS failure was considered a 'major' event in the certification context, the physical distress and workload experienced by the pilot corresponded with the AC 23.1309 definition of 'hazardous'.

Footnote

[72] Different test pilots tested TACS failures for the DO's and the regulator's flight testing, but for ease of reference this report uses the singular 'he'.

Recognition and reaction times

The test pilot's preparedness for the TACS failure removed any need to diagnose it, thus minimising his recognition time. The reaction delay incorporated into the testing process was intended to account for an operational pilot assessing their course of action, then recalling and applying the AFMS procedure.

The ATLAS INOP button assisted the pilot at some level to identify that system as being the cause of the roll. The flight test report cited autopilot disengagement as another recognition cue which, in the event on 13 April 2019, occurred 11 seconds after the roll began and around the same time power was reduced. This indicates that the pilot's 'recognition plus reaction time' was probably around 11 seconds, which is between the mean and median response times to the commanded roll malfunction assessed in the FAA study (see *Additional information*).

This incident and evidence from the FAA study indicate that the one and three second certification reaction times may not be a satisfactory standard. The forthcoming *'Aircraft Safety and Certification Reform Act of 2020'* provides an opportunity to address this, and some of the other differences highlighted between the circumstances of the actual TACS failure and those demonstrated or assumed during flight testing.

To the extent the EASA applies FAA-specified pilot reaction times, any associated FAA regulatory reform may be adopted by the EASA automatically. While the Act refers to CFR 25 aircraft, given that the same regulatory reaction times are currently applied to both CFR 23 and CFR 25 aircraft, and that CFR 23 already applies to some aircraft permitted to carry fare paying passengers, the Act's human factors review should apply to both. Regarding the winglet manufacturer's aspiration to install its product on *'commercial airliners'*, it would be required to comply with CFR 25 in that case.

Lateral control

The flight test report stated that the autopilot disconnected after approximately 2 seconds in the case of a dual TACS failure at 240 KIAS, producing maximum roll and pitch forces approaching the applicable regulatory limits, and 115° angle of bank. The corresponding single failure produced 40° angle of bank; not enough to disengage the autopilot.

The incident aircraft's airspeed was nearly 20 KIAS faster than during test flying, at the point its single TACS failed. While the roll rate was 4 to 7° per second, the pilot's startle from a significant flight path deviation meant he perceived it as very quick. He instinctively controlled the roll first. The maximum bank angle encountered was 75°, which corresponds with 'hazardous' using the flight test results interpretation matrix.

Flight testing did not determine control forces for failures above 240 KIAS, or beyond the reaction time. The ATCO's perception of the pilot's physical effort, characterised by the passenger as his "full weight" and full control authority, indicate that control forces higher than the 'major' classification were present, or at least perceived, during that single TACS failure. It is likely that the higher roll rate and control forces associated with a dual TACS failure would have met the 'catastrophic' classification.

Due to the aircraft's abnormal flight path, ATC staff believed it would not reach the runway. The pilot used right aileron and rudder inputs until landing. He did not use aileron trim. Flight testing assumed the use of aileron trim after a TACS failure, relieving roll forces and resulting in normal approaches, but it was not included in the ATLAS inoperative procedure. Accordingly, the winglet manufacturer intends to include aileron trim in the ATLAS inoperative in flight procedure. This is planned to occur before the end of 2020.

Airspeed

At 258 KIAS, N680KH airspeed corresponded with the high speed case critical for the ATLAS inoperative procedure *'Warning'*. The pilot reported that he saw the 'LIMIT 140 KIAS' message on the illuminated annunciator; when he reduced throttles to idle the airspeed began to decrease. However, he experienced high workload controlling the aircraft and, in the circumstances he described, faced a choice between slowing down and reducing altitude. Control forces reduced as the aircraft decelerated to 220 KIAS. The altitude loss from roll onset was around 700 ft in 27 seconds.

During tests representing failure of a single TACS at 240 KIAS, the maximum airspeed increase was 10 KIAS. The corresponding dual asymmetry airspeed increase was 12 KIAS, with altitude loss of 1,160 ft. Flight testing assumed throttles were retarded to idle 3 seconds after failure recognition, for the dual case resulting in control forces and bank angle near the 'hazardous' classification limits. Thus, delayed airspeed reduction could result in exceeding those limits; and TACS failures below 1,000 ft could have more serious implications.

The control forces generated in both the dual failure test flying and the incident required both hands on the control column. Therefore, the pilot found he did not have spare capacity to use the speedbrake.

The ATLAS inoperative procedure appears tailored to the high speed case. However, immediate airspeed reduction might not be the most appropriate first action in other flight conditions, such as in a nose-high attitude or at other airspeeds. By comparison, flight control procedures for the unmodified aircraft, such as the *'Jammed elevator trim tab (cruise)'* and *'Elevator trim runaway'* procedures consider flight conditions such as airspeed and control forces.

More comprehensive guidance would assist pilots in responding appropriately in the other flight conditions in which the ATLAS can become inoperative and would be consistent with the philosophy of procedures for the unmodified aircraft. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2020-027

It is recommended that Tamarack Aerospace Group amend the ATLAS inoperative in flight procedure to ensure actions are specified that are relevant in all anticipated flight conditions.

Reporting of technical faults

Reporting a technical fault provides an opportunity for it to be rectified. The EASA described a TACS fault as a '*defect that hazards seriously the flight safety'* and indicated that on that basis it would expect the condition to be reported.

The implications of a TACS failure had been described by the ATLAS manufacturer as *'benign'*. The other material it provided did not highlight the system's capacity to influence the aircraft's flight path or the implications of a pilot responding instinctively to uncommanded roll caused by its failure.

Following the previous event involving N680KH on 16 March 2019, in which the symptoms were transient and ceased without any intervention, the pilot determined that the aircraft was in a safe condition for flight because there was no evidence of a persisting fault. Had it been reported, it is unlikely that the cause of the fault would have been identified unless the TACS unit was inspected internally.

Level of detail provided in the ATLAS inoperative procedure

Familiarity with the ATLAS inoperative procedure and its memory actions could have assisted the pilot because, as stated in CAP 737, *'Under a high workload task, a pilot may not have the capacity to search and assess other areas, problems and alternatives'.*

Both on the incident flight and during test flying, the pilots were aware they should reduce airspeed. Without knowing the documented procedure, the pilot accomplished all the relevant actions except applying speedbrake, although in a different order because he instinctively made control inputs to counter the uncommanded roll. The flight test report described the order of the ATLAS inoperative procedure as unusual when compared to other roll upset recovery procedures, and on one test point the test pilot inadvertently (and probably instinctively) responded to the lateral upset first.

The ATLAS inoperative in flight procedure included a 'warning' that large aileron input may be required, and that airspeed reduction must be prioritised, but did not explain why. Providing this information might assist pilots to appreciate why a potentially counter-intuitive response was required, and to understand how quickly the handling difficulties might escalate in the absence of immediate airspeed reduction, making the circumstances less surprising when encountered.

The warning did not fully describe the escalating nature of TACS failures, possibly leading to aircraft upset; the possibility for high control forces and altitude loss; the expected reaction time for thrust reduction; and the possibly counter-intuitive nature of the required response, the first actions of which differ from conventional jet upset training. By comparison, the opening paragraph of the original aircraft's *'Jammed elevator trim tab procedure'* explained the intent of the procedure. It provided guidance on airspeed and control forces, and related these to throttle and speedbrake use.

The procedure 'caution' associated with an ATLAS failure in flight indicated that resulting performance decrements would require a pilot to *'Fuel and flight plan with caution'.* It is not clear how that should be achieved considering such planning normally occurs before departure.

Accordingly, the following Safety Recommendation is made.

> **Safety Recommendation 2020-028**
>
> It is recommended that Tamarack Aerospace Group expand the information within the ATLAS inoperative in flight procedure to provide a level of detail consistent with other AFM procedures and to enable pilots to understand the significant and potentially escalating nature of TACS failures.

Training

Modifications to the system reduce the probability of a TACS failure resulting in asymmetric deployment but don't eliminate it completely. During the investigation the AAIB did not identify any other emergency condition with similar potential for aircraft upset that did not also require specific training. Training may be particularly valuable if a required response differs from other training or from a foreseeable instinctive response, or if it needs to be particularly prompt.

The EASA stated that regulations coming into force after the ATLAS STC was approved have the effect of requiring manufacturers to consider the impact of design changes on the pilot training required. However, it is not clear that those regulations will result in adequate training in the case of the ATLAS or similar systems.

In the absence of such training, and given the benign qualities described in the manufacturer's literature, there was little to alert pilots, particularly those other than the original purchasers of the system, to the potential seriousness and nature of the failure and associated response. Accordingly, the winglet manufacturer:

- will ensure that the information it provides in its manuals, marketing material and other media, is clear about the consequences of ATLAS fault conditions;
- has undertaken safety action to provide a laminated single-page informal abbreviated ATLAS checklist to ATLAS purchasers, which lists the actions from the AFMS ATLAS inoperative in flight procedure. It intends to include that checklist in its document control process;
- intends to undertake safety action to create a page on its website containing advisory information about likely failure modes, including relevant cockpit video, and the related emergency procedure using excerpts of the AFMS. It plans to promote awareness of the webpage to ATLAS pilots, and to create a mechanism for pilots to contact them with queries relating to the ATLAS inoperative procedure;

- intends to include the ATLAS as a knowledge topic in the FAA's 'WINGS Pilot Proficiency Program'.[73]

In order to give general effect to these measures, the following Safety Recommendations are made:

Safety Recommendation 2020-029

It is recommenced that the European Union Aviation Safety Agency determine the additional training it requires pilots to undertake in order to operate aircraft fitted with supplementary systems that influence flight path, where training on the original aircraft would not adequately prepare pilots for operating the modified aircraft in normal, abnormal or emergency situations.

Safety Recommendation 2020-030

It is recommended that the Federal Aviation Administration determine the addition training it requires pilots to undertake in order to operate aircraft fitted with supplementary systems that influence flight path, where training on the original aircraft would not adequately prepare pilots for operating the modified aircraft in normal, abnormal or emergency situations.

Conclusion

The uncommanded left roll occurred because a short circuit in the left ATLAS Control Unit caused the associated control surface to fail in the fully deflected up position.

The pilot, who had recently purchased the aircraft already modified with the ATLAS winglets, was not aware of the associated aircraft flight manual supplement, which was absent from the relevant section of his aircraft's flight manual.

The pilot's instinctive response to the aircraft upset was different to that assumed by certification flight testing and the ATLAS inoperative emergency procedure. Some of those differences may be addressed by the *'Aircraft Safety and Certification Reform Act of 2020'* which is underway in the USA.

Safety Recommendations and actions

Four Safety Recommendations are made:

Safety Recommendation 2020-027

It is recommended that Tamarack Aerospace Group amend the ATLAS inoperative in flight procedure to ensure actions are specified that are relevant in all anticipated flight conditions.

Footnote

[73] A voluntary program intended to help pilots improve their skills and knowledge.

Safety Recommendation 2020-028

It is recommended that Tamarack Aerospace Group expand the information within the ATLAS inoperative in flight procedure to provide a level of detail consistent with other AFM procedures and to enable pilots to understand the significant and potentially escalating nature of TACS failures.

Safety Recommendation 2020-029

It is recommended that the European Union Aviation Safety Agency determine the additional training it requires pilots to undertake in order to operate aircraft fitted with supplementary systems that influence flight path, where training on the original aircraft would not adequately prepare pilots for operating the modified aircraft in normal, abnormal or emergency situations.

Safety Recommendation 2020-030

It is recommended that the Federal Aviation Administration determine the additional training it requires pilots to undertake in order to operate aircraft fitted with supplementary systems that influence flight path, where training on the original aircraft would not adequately prepare pilots for operating the modified aircraft in normal, abnormal or emergency situations.

The winglet manufacturer has taken, or intends to take, the following safety actions:

- It intends to include aileron trim in the ATLAS inoperative in flight procedure.
- It has added a signature page to the ATLAS winglets delivery checklist to identify who has conducted a particular handoff briefing. It intends to incorporate that checklist into its document control process.
- It intends to add an item to the ATLAS winglets delivery checklist requiring the AFMS to be installed in the AFM and the log of approved supplements to be updated during the handoff briefing.
- It intends to promote awareness of the AFMS to ATLAS pilots and improve its overall availability, for example, by making it easier to find and download on its website.
- It will ensure that the information it provides in its manuals, marketing material and other media, is clear about the consequences of ATLAS fault conditions.
- It has published a laminated single-page informal abbreviated ATLAS checklist, which it provides to ATLAS purchasers. The checklist includes the actions from the AFMS ATLAS inoperative in flight procedure. It intends to include that checklist in its document control process.

- It intends to create a page on its website containing advisory information about likely failure modes, including relevant cockpit video, and the related emergency procedure using excerpts of the AFMS. It plans to promote awareness of the webpage to ATLAS pilots, and to create a mechanism for pilots to contact them with queries relating to the ATLAS inoperative procedure.

- Intends to include the ATLAS as a knowledge topic in the FAA's *'WINGS – Pilot Proficiency Programme'.*

- The EASA and the FAA issued ADs restricting the operation of aircraft with ATLAS installed. The closing action and AMOC for the ADs and SB CAS/SB1480 mandated the embodiment of SBs CAS/SB1467 and CAS/SB1475, ensuring that the TCUs were the latest standard and that centering strips had been installed on the trailing edge of each TACS.

- The UK CAA has taken an action to create data validation rules in ECCAIRS to identify occurrence reports that should be shared with external authorities based on State of Occurrence, Registration and Design. It has also intends to agree with the EASA any additional criteria that will be included in validation rules.

Published: 3 December 2020.

AAIB Correspondence Reports

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

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

The accuracy of the information provided cannot be assured.

SERIOUS INCIDENT

Aircraft Type and Registration:	Agusta A109E, G-ETPJ
No & Type of Engines:	2 Pratt & Whitney Canada PW206C turboshaft engines
Year of Manufacture:	2004 (Serial no: 11173)
Date & Time (UTC):	2 July 2020 at 1510 hrs
Location:	Boscombe Down Airfield, Wiltshire
Type of Flight:	N/A
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Localised overheating and burning
Commander's Licence:	N/A
Commander's Age:	N/A
Commander's Flying Experience:	N/A
Information Source:	Aircraft Accident Report Form and further enquiries by the AAIB

Synopsis

The helicopter landed after a routine flight during which a circuit breaker (CB) tripped. While an engineer was investigating the cause, the next flight crew noted a burning smell in the rear baggage bay during their walk-around checks. The operator's investigation found evidence of a fire in the aft equipment bay[1], and a chaffed electrical cable. The cable was part of a design change that was made whilst the helicopter was on the UK military register before being approved by a Supplementary Type Certificate (STC) when the helicopter was transferred to the civil register. A protective strip should have been installed as part of the design change, but this was missing when the helicopter was examined after the incident. The strip would have prevented the cable from chaffing against the adjacent structure.

History of the flight

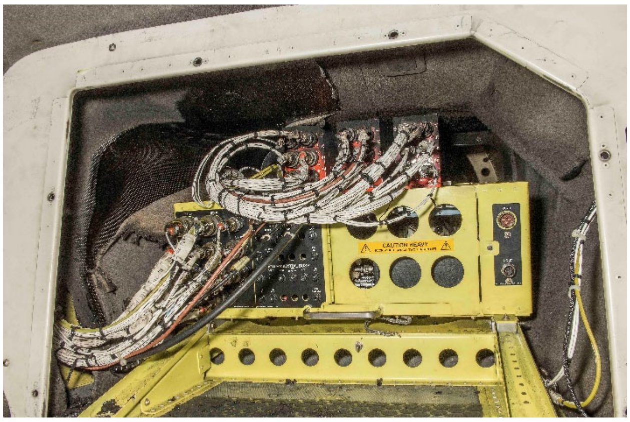
The helicopter was on a routine flight when the main Flight Test Instrumentation (FTI) circuit breaker (CB) tripped. The crew did not reset the CB and the flight continued as normal with the helicopter landing after approximately 20 minutes.

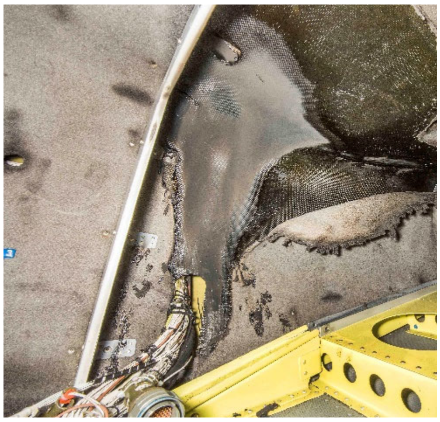
A ground engineer attended the helicopter and with the batteries on, reset the CB, which tripped again almost immediately. Whilst the engineer investigated the fault, the next flight crew commenced a walk-around check of the helicopter in preparation for the next flight.

Footnote

[1] The aft equipment bay is behind the baggage bay. It is accessed by removing a lightweight panel between the two bays.

Upon opening the baggage bay the crew noticed a burning smell and, with the assistance of the engineer, they removed the panel to access the rear equipment bay. They found a '*smouldering fire*', which self-extinguished before the arrival of the airfield fire service (Figures 1 and 2).





(Images courtesy of the operator)

Figures 1 and 2

Overheat damage before and after FTI crate removal
(Note: the panel between the baggage bay and
rear equipment bay has been removed)

Investigation

Cabling

The damage was most severe where electrical cables entered the equipment bay through an aperture in the adjacent structure. A single cable was found to be chaffed and it was apparent that the exposed conductor had been arcing with the equipment bay liner, which was manufactured from a composite material. The cable connected the battery and FTI busbars and the circuit was protected by a 10 Amp CB. This was the CB that tripped in-flight.

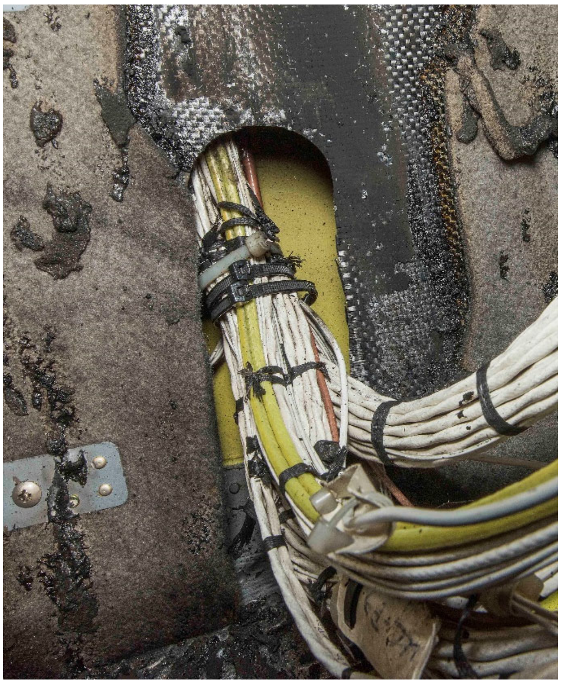
Flight Test Instrumentation

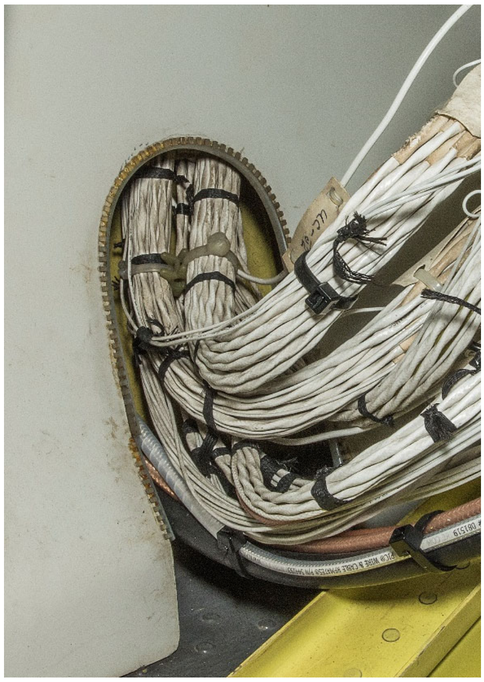
The FTI was designed and installed several years before the incident when the helicopter was on the UK military register. When the helicopter moved onto the civil register the design was reviewed by an approved organisation and a STC was issued by the UK CAA.

The installation drawings depicted a protective strip around the periphery of the aperture to ensure that the cables did not chafe against the adjacent structure. When the helicopter was examined after the incident it was apparent that the protective strip was missing.

Operator's fleet check

The operator owned another Agusta 109 (G-ETPI), which was equipped with a similar FTI installation. This helicopter was checked, and the protective strip was found correctly embodied (Figures 3 and 4).





(Images courtesy of the operator)

Figures 3 and 4

Note: lack of protective strip on G-ETPJ (left image)
and protective strip as fitted to G-ETPI (right image)

Conclusion

The investigation established that the electrical power supply cable between the battery busbar and the FTI busbar chaffed against the equipment bay liner causing a short-circuit, arcing, and the CB to trip.

The equipment bay liner was melted and burned, and the operator concluded that it was probable that fire damage occurred in-flight, assisted by airflow entering the bay through the cable aperture. If a protective strip had been installed, as required by the design change, this should have prevented the cable damage.

SERIOUS INCIDENT

Aircraft Type and Registration:	Beech 200 Super King Air, G-FSEU
No & Type of Engines:	2 Pratt & Whitney Canada PT6A-41 turboprop engines
Year of Manufacture:	1978 (Serial no: BB-331)
Date & Time (UTC):	28 February 2020 at 1415 hrs
Location:	Doncaster – Sheffield Airport
Type of Flight:	Commercial Air Transport
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Flap motor burnt out
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	856 hours (of which 393 were on type) Last 90 days - 18 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

While climbing through 8,800 ft after departing Doncaster-Sheffield Airport, the pilots noticed an electrical smell on the flight deck followed by a build-up of grey smoke in the cabin. A MAYDAY was declared and on the approach the flaps were selected down but remained in the retracted position. The aircraft landed without further incident.

The smoke was caused by overheating of the flap motor. The flaps UP limit switch had not operated due to wear in the system and so electrical power continued to be supplied to the motor after the flaps reached the retracted position prior to takeoff. The flap motor Circuit Breaker was found to be intermittent and had not initially tripped to protect the motor from overload.

History of the flight

Prior to a flight from Doncaster-Sheffield Airport to Wick Airport, the commander checked the flap system by operating the flaps through their full range and visually comparing each position against the flap indicator. The flaps were returned to the retracted (UP) position and the aircraft made a flapless take off from Runway 20.

As the aircraft climbed through 8,800 ft, the pilots noticed an electrical burning smell in the cockpit and decided to return to Doncaster. There was no obvious source for the smell and none of the circuit breakers (CB) had operated. Grey smoke was then seen in the cabin. The commander declared a MAYDAY to Scottish ATC(C) and requested an ILS approach for Runway 20, while the co-pilot searched for the origin of the smoke in the cabin. However, the source could not be identified.

On the approach to Doncaster, the commander selected the flaps to the APPROACH position but there was no movement. An inspection of the CB panel found that the CB for the flap motor had tripped.

The aircraft made an uneventful landing at Doncaster and was met by the airport Rescue and Fire Fighting Service who used thermal imaging equipment to search for hot spots. A hotspot was detected on the left of the fuselage, below the floor near the centre of the cabin where the flap motor was located. There was no evidence of fire.

Flap control system

Two flaps are mounted on each wing and are driven by an electric motor and gearbox located below the floor to the left of centre of the cabin. The gearbox drives four flexible drive shafts each connected to a jackscrew via a flap actuator, which moves the flaps to the position selected by the pilot.

The flap selector has three positions: UP, APPROACH and DOWN. When the pilot selects one of these positions, electrical power is supplied to the motor to move the flaps. Once the flaps reach the selected position, a cam connected to the right inboard flap by a link-arm assembly operates a limit switch to disconnect electrical power to the motor. At the same time a second winding in the motor is activated which causes the motor to act as a brake to prevent the flaps from travelling past their selected position.

Maintenance

The manufacturer changed the maintenance schedule of the flap system from phased based maintenance to flap cycles in January 2019, which reflects the actual usage of the flaps.

The flap motor, gearbox and flap actuators were replaced during the Phase 3 maintenance carried out on 17 January 2020 and had operated for 56 flap cycles prior to this event.

Maintenance actions

Examination of aircraft

Examination of the aircraft, by the operator's engineers, discovered evidence of heat damage and a burnt smell from the flap motor (Figure 1). A check of the flap motor CB was carried out and was found to be intermittent in operation.

Figure 1
Flap motor showing evidence of damage due to overheating

Cause of the smoke in the cabin

The maintenance organisation believed that wear in the flap cam and link-arm assembly prevented the flap UP limit switch from operating when the flaps retracted. As a result, electrical power was continuously supplied to the motor, which overheated, emitting fumes and smoke into the cabin. Normally, the CB would operate to protect the motor; however, it is likely that an intermittent fault meant it did not initially trip.

ACCIDENT

Aircraft Type and Registration:	Aeroprakt A22-LS Foxbat, G-FXBA
No & Type of Engines:	1 Rotax 912iS piston engine
Year of Manufacture:	2018 (Serial no: LAA 317B-15534)
Date & Time (UTC):	10 August 2020 at 1515 hrs
Location:	Holmbeck Farm Airfield, Buckinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nosewheel, propeller, wings and tailplane
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	335 hours (of which 166 were on type) Last 90 days - 41 hours Last 28 days - 19 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The accident occurred while landing at Holmbeck Farm Airfield, Buckinghamshire. At the time Runway 11 was in use, the weather was good with a light wind from the southeast and a temperature of 33°C.

Shortly before landing, at about 5-10 ft agl, the aircraft unexpectedly climbed approximately 10 ft. It then descended rapidly, landed firmly, and bounced before landing again. The second landing was on the aircraft's nosewheel, which collapsed and dug into the grass. The aircraft then pitched forward and came to rest inverted (Figure 1). The pilot isolated the aircraft's systems and exited the aircraft unhurt with assistance from onlookers.

The pilot stated that he made no conscious control input during the unexpected climb, but witnesses thought he may have instinctively pitched the nose down to counteract it.

The pilot thought the unexpected climb was caused by a gust of wind or a thermal effect caused by the high temperature. He commented that the hard landing was a result of him not initiating a go-around promptly in the short time available, adding that he has learned to be prepared to initiate a go-around at the first sign of anything untoward.

Figure 1

G-FXBA after the accident
(Used with permission)

ACCIDENT

Aircraft Type and Registration:	Cessna 172N, G-BUJN
No & Type of Engines:	1 Lycoming O-320-H2AD piston engine
Year of Manufacture:	1979 (Serial no: 172-72713)
Date & Time (UTC):	30 July 2020 at 1520 hrs
Location:	Coventry Airport
Type of Flight:	Private
Persons on Board:	Crew -1 Passengers -1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose landing gear collapsed, propeller and structural damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	119 hours (of which 5 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After joining a busy circuit at Coventry Airport, the pilot maintained a height of 1,000 ft. After turning onto the final approach, the pilot observed that the aircraft was high on the approach path. The pilot continued the approach believing that, making use of the length of the runway a successful landing was possible. Late in the approach the aircraft experienced an updraft, but the approach was continued. The aircraft then descended rapidly, struck the runway and the bounced three times before the nose landing gear collapsed.

History of the flight

The aircraft was abeam Gloucester Airport (Staverton) when the passenger started to feel unwell. The pilot decided to curtail the flight and return to Coventry Airport. The circuit was busy when the aircraft arrived at Coventry Airport. The pilot reported that he was visual with several aircraft in the circuit including a helicopter to the left of the Cessna and at the same height and a twin-engine aircraft that was turning onto the base leg. The pilot maintained a height of 1,000 ft, and when he turned onto the final approach four white lights were visible on the PAPI and the twin-engine aircraft was carrying out a touch-and-go on the runway. The pilot asked ATC if he should "go-around" but was told that he could land at his discretion. He decided to continue the approach "knowing that Coventry was a long runway and with all the traffic it was better to be high than low". Approaching the runway, the aircraft experienced an updraft from a local road feature, but with "reds starting to appear on the

PAPI" the pilot continued the approach as he thought that the landing would be successful. He recalled adjusting for a wind from the left before the aircraft descended rapidly, hitting the runway and bouncing. Eyewitnesses reported that the aircraft bounced three times and the nose landing gear collapsed. The aircraft came to rest with the engine running; both occupants were uninjured.

The pilot considered that he was too high on the approach and overloaded with the workload in the circuit. He believed that, in hindsight, he should have gone around to give himself more time.

ACCIDENT

Aircraft Type and Registration:	Jodel D112, G-INNI
No & Type of Engines:	1 Continental Motors Corp A65-8 piston engine
Year of Manufacture:	1956 (Serial no: 540)
Date & Time (UTC):	22 August 2020 at 1400 hrs
Location:	Old Hay Airfield, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to aileron
Commander's Licence:	Private Pilot's Licence
Commander's Age:	67 years
Commander's Flying Experience:	350 hours (of which 40 were on type) Last 90 days - 7 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was carrying out a local flight from Old Hay Airfield and on return he made a heavy landing and bounced. He selected full power and carried out a go-around but noticed that the ailerons were stiff and widened his circuit in order to make more gentle turns. He thought that an aileron control pulley wheel may have buckled as a result of the heavy landing. He completed his landing but once on the ground, and during his taxi back to the main hangar, he noticed that the aileron control was normal.

A subsequent investigation by an LAA inspector was not able to identify any structural damage but there were abrasion marks on both ailerons contacting the wing. The wing skin was removed and a check made of the main spar to see if there was any damage that may have contributed to the stiff aileron control, but none was identified.

Discussions with the LAA regarding the potential dangers of heavy landing damage were illustrated in an AAIB report into an accident to Pierre Robin DR400/180, G-DELS, in July 1996[1].

ACCIDENT

Aircraft Type and Registration:	Jodel DR250/160, G-BUVM
No & Type of Engines:	1 Lycoming O-320-D2A piston engine
Year of Manufacture:	1966 (Serial no: 54)
Date & Time (UTC):	11 August 2020 at 1900 hrs
Location:	Crosland Moor Airfield, Huddersfield, West Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - None
Nature of Damage:	Extensive damage
Commander's Licence:	Other
Commander's Age:	59 years
Commander's Flying Experience:	464 hours (of which 159 were on type) Last 90 days - 3 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was flying this tail-dragger aircraft with its co-owner to increase his currency and proficiency after a period of reduced flying activity due to public health restrictions. The flight had been uneventful, and the choice of Runway 25 for landing considered a 5 kt tailwind, upslope, and a hedge before the threshold of the reciprocal runway.

The pilot reported that they encountered buffeting and windshear at about 50 ft, which he attributed to an adjacent quarry[1]. He thought that the flare was normal, but the aircraft slewed left in the turbulent air and he overcorrected using right rudder. He reported that "subsequent oscillations required full rudder deflection with braking" and the aircraft departed the right side of the runway onto the grass. The right wing struck a metal gate post approximately eight feet from a raised embankment at the airfield perimeter, and the aircraft came to rest inverted. The passenger sustained serious injuries, but both occupants were able to exit through the left cockpit window, which had broken.

The pilot cited that the tail wind conditions during the approach, along with the local topography, combined with the lack of recent flying practice were factors that led to the accident.

Footnote

[1] Pooleys Flight Guide 2019 includes a warning to expect turbulence on approach to Runway 25 from quarry working to the north of the airfield.

ACCIDENT

Aircraft Type and Registration:	Piper PA-24-180 Comanche, N5839P
No & Type of Engines:	1 Lycoming O-360-A1A engine
Year of Manufacture:	1959 (Serial no: 24-920)
Date & Time (UTC):	13 September 2020 at 1630 hrs
Location:	Compton Abbas Airfield, Dorset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to propeller, engine, exhaust and underside of fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	214 hours (of which 117 were on type) Last 90 days - 12 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

N5839P was being positioned via an overhead join for an approach to land on Runway 26. When the landing gear was selected down there was a sudden smell of burning. The pilot, believing there was a fire or an imminent risk of fire, immediately made an emergency call to ATC and positioned the aircraft for a shortened approach. The aircraft touched down normally and rolled on its landing gear for around 80 m before it collapsed and the aircraft slid along on its belly. Once the aircraft came to a halt, the occupants vacated the aircraft with the fire service in attendance. Initial enquires suggested the landing gear failed to lock down due to a burnt-out electrical gear motor.

When the burning smell became apparent to the pilot, he made sure that he was positioned to land as soon as possible, informed ATC of his emergency and asked for the fire truck to attend. Having completed the landing, both he and his passenger evacuated the aircraft as quickly as they could. The aircraft landed safely and neither occupant was injured. The aircraft suffered damage to the propeller, engine, exhaust and underside.

SERIOUS INCIDENT

Aircraft Type and Registration:	Sportstar Max, G-TMAX
No & Type of Engines:	1 Rotax 912ULS2 piston engine
Year of Manufacture:	2010 (Serial no: 2010 1305)
Date & Time (UTC):	25 May 2020 at 1340 hrs
Location:	White Ox Mead Farm Airstrip, near Bath, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Propeller damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	73 years
Commander's Flying Experience:	287 hours (of which 120 were on type) Last 90 days - 5 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, and further enquiries by the AAIB

Synopsis

A propeller blade detached from the propeller hub during the initial climb out, causing a high level of vibration and the engine to stop. The pilot made a successful forced landing in a field. The detached blade was not recovered, and the cause of the failure was not identified.

History of the flight

The aircraft departed from Runway 20 at White Ox Mead Airstrip in fine weather conditions. Towards the end of the takeoff run the pilot reported feeling a distinct high-frequency vibration, but as he was beyond the point on the runway where the aircraft could safely be stopped, he continued with the takeoff. The vibration continued as the aircraft became airborne so the pilot reduced power and started a left turn, with the intention of returning to the airstrip if the vibration continued. As the aircraft climbed through 250 ft agl the vibration increased and the pilot reported hearing a loud bang and observed a propeller blade passing over the canopy. The vibration increased significantly after the propeller blade detached, causing the forward-hinged canopy to open and be sucked upwards into the airflow. The engine also stopped, which the pilot subsequently determined was due to the carburettors detaching from the inlet manifolds.

At approximately 200 ft agl the pilot selected a crop field, which was into wind and had an upslope, and made a successful forced landing (Figure 1). No additional damage was incurred during the landing. Despite a search of the area that the aircraft had overflown, the detached propeller blade was not located.

Figure 1

G-TMAX following the propeller blade detachment (missing blade position circled in red)

Aircraft information

The aircraft was fitted with a three-bladed Woodcomp Klassic 170/3/R propeller and the blades were numbered 1, 2 and 3, with Blade 2 being the blade which failed in flight. The propeller blades are moulded from carbon and glass fibres embedded in a polymer matrix and are clamped between two aluminium alloy half-hubs to form the propeller assembly (Figure 2). The blade pitch may be adjusted by rotating the blade roots within the hub, when the hub screws are suitably loosened. The propeller is attached to the engine reduction gearbox drive flange by six bolts.

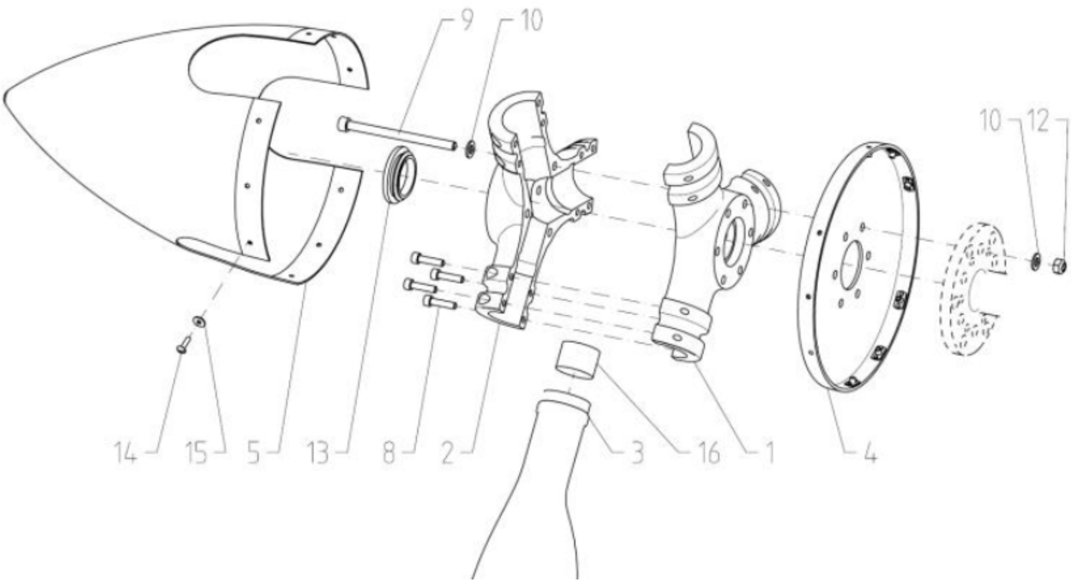


Figure 2

Propeller assembly (courtesy Woodcomp)

The propeller, when new, was installed on the aircraft in 2017 and had accumulated 215 hours when it was then removed following a propeller strike in August 2018. The propeller was overhauled by the manufacturer and was reinstalled on the aircraft in July 2019. The propeller accumulated a further 80 hours and the aircraft owners stated that they had not experienced any abnormal vibration when flying the aircraft prior to the incident. They were also not aware of any pre-existing damage to the propeller.

Propeller examination

The propeller was removed from the engine by an engineer and no abnormalities were noted with the attachment bolts. The propeller was disassembled by the AAIB for an initial examination, and the components were then sent to the manufacturer for a further examination.

AAIB initial examination

The hub screw torques were checked by unscrewing the screws with a calibrated torque wrench. Three of the 12 hub screws were found to be marginally below the required torque value of 10 Nm, with the lowest screw torque measured at 7 Nm. The other screw torque values were in the range 10-14 Nm. It is possible that the vibration experienced in the incident may have loosened the screws that were found below the prescribed torque figure.

The propeller blade pitch angles of the remaining two blades (Blades 1 and 3) were measured in accordance with the procedure in the Propeller User Manual. The results showed pitch angles of 18.9° for Blade 1 and 19.3° for Blade 3.

Examination of the internal faces of the hub bores showed only normal contact marks made from the clamping of the propeller blade roots, and no visible evidence of rotation of the blade roots within the hub. The clearance between the hub halves when assembled was also within prescribed limits.

Visual examination of the retained root section of Blade 2 showed that it had failed by overload in forward bending, in the propeller thrust direction, in combination with the propeller centrifugal loading (Figure 3). There was no evidence of dirt or contamination on the fracture surfaces that might be present had progressive cracking occurred over a number of flights.

Cracks were evident in the trailing edge root section of Blade 3, and the leading edge root section of Blade 1 (Figure 4). It is likely that these cracks were the result of the high propeller vibration experienced following the release of Blade 2. A leading edge crack was also evident at approximately mid-span on Blade 3. This may have been caused by the excessive propeller vibration, or alternatively could have been caused by contact with Blade 2 following its release (Blade 3 follows Blade 2 in the rotation sequence).

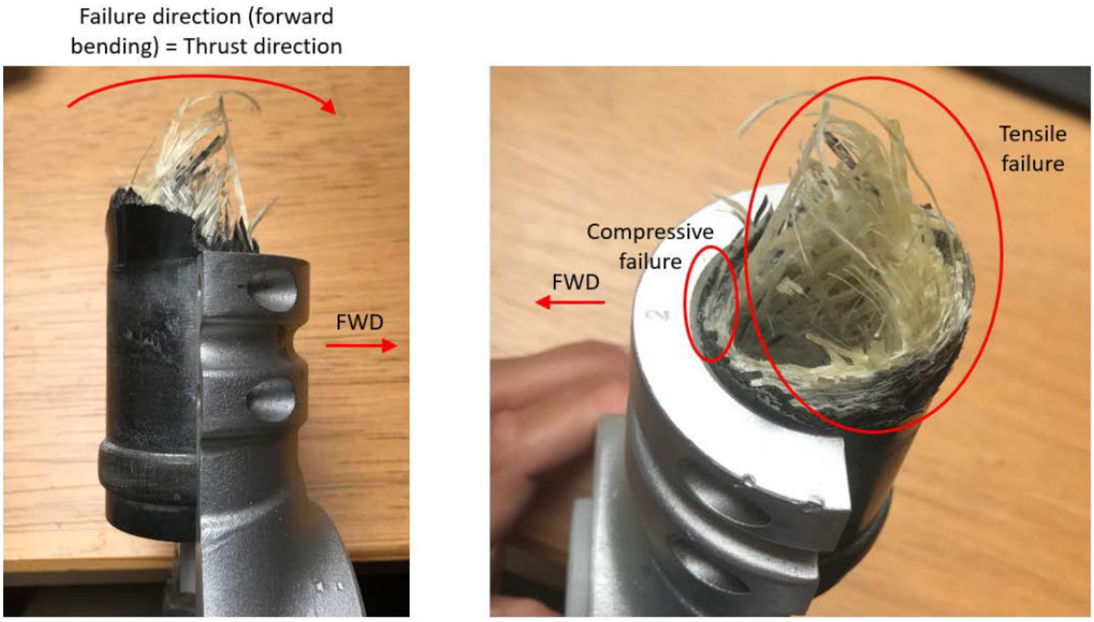


Figure 3

Blade 2 fracture surfaces

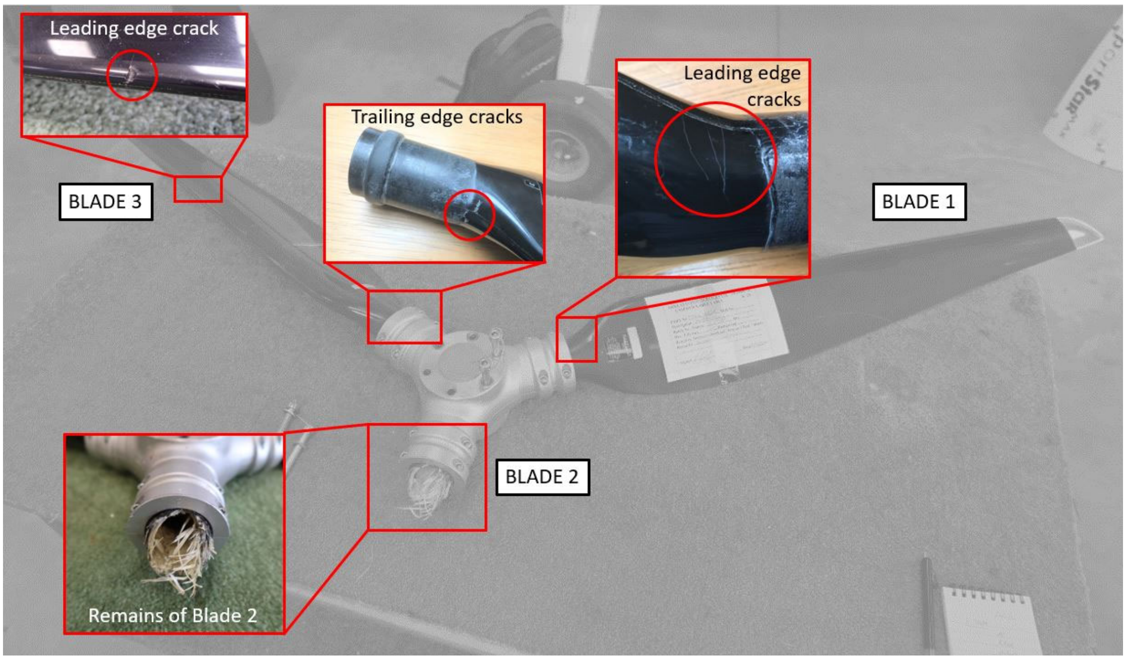


Figure 4

Propeller damage observations

Manufacturer's examination

The manufacturer noted that the failure appeared to be similar to previous blade releases that had occurred following a propeller strike with the ground or a foreign object. They also observed that the outer surface of the root section of Blade 2 did not show any evidence of visible changes in the polymer matrix, such as whitening or small cracks, that would indicate a progressive failure.

Analysis

The propeller blade detached under the combination of centrifugal and thrust loads during normal operation in the initial climb out from White Ox Mead Airstrip. The absence of any evidence of progressive cracking prior to the blade's release indicates that the propeller was weakened prior to the failure, possibly due to contact with the ground or a foreign object. The increasing level of vibration experienced during the latter stages of the takeoff roll is consistent with a change in the stiffness or mass of a propeller blade during the takeoff roll. As the released blade was not recovered, it was not possible to identify the cause of the failure.

SERIOUS INCIDENT

Aircraft Type and Registration:	Westland Scout AH1, G-CIBW
No & Type of Engines:	1 Rolls-Royce Nimbus MK 10501 turboshaft engine
Year of Manufacture:	1966 (Serial no: F9632)
Date & Time (UTC):	17 September 2020 at 1510 hrs
Location:	West Dean, Salisbury, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - None Passengers - None
Nature of Damage:	Rubber retaining grommet perished, allowing the window in the door to fall out in flight
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	4,950 hours (of which 190 were on type) Last 90 days - 54 hours Last 28 days - 14 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB

The helicopter was flying straight and level at approximately 100 KIAS when the pilot heard a loud bang. It immediately became apparent that the fixed upper window in the left door had fallen out, leaving the rubber retaining grommet in place. The helicopter was above fields at the time of the event and the pilot carried out a brief airborne search of the area but was unable to locate the window. The helicopter returned to Middle Wallop Airfield without further incident.

The subsequent examination of the door and window frame found that the rubber window retaining grommet had perished. The grommet incorporates ridges and channels designed to attach and hold the window into its frame. Approximately 200 mm of the central ridge on the grommet had separated allowing the window to be 'loosened by the airflow', causing it to fall out of its frame. No other damage to the helicopter was reported.

ACCIDENT

Aircraft Type and Registration:	Mainair Blade 912, G-BZNS
No & Type of Engines:	1 Rotax 912UL piston engine
Year of Manufacture:	2001 (Serial no: 1263-1000-7-W1057)
Date & Time (UTC):	17 September 2020 at 1530 hrs
Location:	Athey's Moor Airfield, Northumberland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damaged beyond economic repair
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	85 hours (of which 55 were on type) Last 90 days - 41 hours Last 28 days - 19 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The right drag link connection failed while the aircraft was taxiing, causing the landing gear to rotate backwards and the propeller to partially sever the landing gear struts. The BMAA published an article in their December 2020 *Microlight Flying* magazine reminding owners to check drag link connections carefully during pre-flight checks.

History of the flight

After returning from a visit to East Fortune Airfield in Scotland, the pilot landed on Runway 14 without incident. He backtracked along the runway towards the airfield hangar. As he cleared the runway, travelling at approximately 5 mph, the right main landing gear collapsed. The landing gear rotated rearwards into the arc of the rotating propeller which partially sliced through the landing gear struts and spat (Figure 1).

Visual inspection revealed the right drag link bar ear connection to the fuselage pod had failed. Cracks were also found on the left drag link bar ear connection, (Figure 2).

The front drag link assembly is designed to allow movement of the rear suspension around the mounting bolt and to enable changes in the landing gear geometry when the trike unit is folded. Checking the security of drag links is a pre-flight check in Section 6 of the Mainair Blade 912 aircraft manual.

Aircraft examination

Figure 1

G-BZNS showing collapsed right landing gear
and damage caused by propeller

A BMAA article by Roger Pattrick (2020) *'Now see ear', Microlight Flying*, December 2020 briefly describes this incident and reminds owners to check the drag link connections carefully during their pre-flight checks.

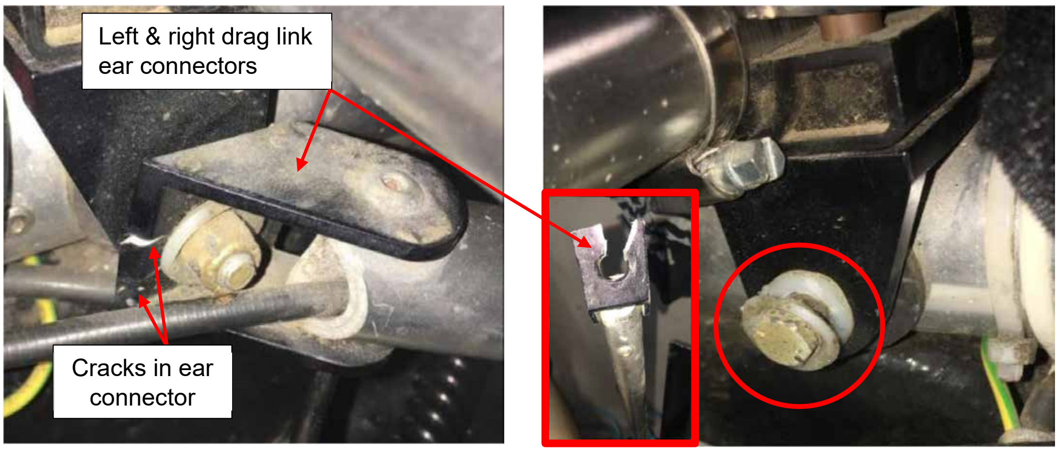


Figure 2

Left drag link ear connection showing cracks
and the failed right drag link ear connection

ACCIDENT

Aircraft Type and Registration:	Mignet HM-1000 Balerit, G-MRAM
No & Type of Engines:	1 Rotax 582 piston engine
Year of Manufacture:	1999 (Serial no: 134)
Date & Time (UTC):	31 August 2020 at 1615 hrs
Location:	Coleman Green Airstrip, Hertfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nose landing gear
Commander's Licence:	Private Pilot's Licence
Commander's Age:	84 years
Commander's Flying Experience:	4,700 hours (of which 457 were on type) Last 90 days - 23 hours Last 28 days - 14 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Shortly after takeoff, the engine stopped abruptly. The aircraft landed straight ahead but, on touchdown, the nose landing gear dug into the ground and the aircraft tipped forwards and came to a halt.

History of the flight

The pilot was intending to carry out a local area flight from a private airstrip, with a runway orientated 060°/240°M, which was 450 m long and had a grass surface with a recently ploughed field at the upwind end of Runway 06. The weather was good with the wind light and variable, visibility in excess of 10 km, cloud estimated as above 2,000 ft and an OAT of about 20°C. All the normal pre-flight and cockpit checks were carried out including the power check, which was normal with no rough running, and the water check of the fuel, which was clear. The aircraft was lined up on Runway 06. The acceleration and takeoff roll was normal, and it became airborne at about the usual position. At the end of the runway and at about 50 ft, with no rough running or any other abnormal indications, the engine suddenly stopped. The only possible action was to land straight ahead, and on touchdown the nose landing gear dug into the soft earth and the aircraft tipped forward, bringing it to an abrupt stop. The pilot and passenger were able to release their restraint harnesses and recover the aircraft back to the strip, but with difficulty due to the soft ground. No cause for the engine failure was identified and the nose landing gear was the only damage.

ACCIDENT

Aircraft Type and Registration:	Savannah VG, G-CGTV
No & Type of Engines:	1 Jabiru 2200 piston engine
Year of Manufacture:	2011 (Serial no: BMAA/HB/609)
Date & Time (UTC):	25 June 2020 at 2010 hrs
Location:	Scurf Dyke Farm, near Driffield, Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	78 hours (of which 78 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During takeoff the aircraft struck a bump causing the pilot's knee to touch the flap lever, which then moved from the 20° to the 40° position. Shortly after takeoff the pilot felt the left wing start to stall, and the aircraft subsequently struck a stack of hay bales.

History of the flight

The pilot had prepared for a local evening flight from his home farm strip to Beverley Airfield and after completing the pre-flight checks, he lined the aircraft up on an easterly heading to take off into a light wind. The farm strip was approximately 220 m long, dry, cut-grass pasture with power lines at the eastern end and farm buildings to the north (Figure 1). With the flaps set to the normal takeoff configuration of 20°, he commenced the takeoff roll. Approximately two thirds along the ground roll, the pilot reported that he felt one of the main wheels strike a bump which caused his knee to touch the flap lever. The flaps then deployed to full flaps of 40°. The aircraft started to climb at very low speed and was close to stalling. To avoid a stall, the pilot lowered the nose, but was conscious that he needed to maintain enough height to avoid the power lines at the end of the strip. Having cleared the power lines he reported that he felt the left wing starting to stall and so applied left rudder and lowered the nose further. The aircraft veered to the left and struck a stack of hay bales at approximately 10 m above the ground. It then struck the ground tail first before coming to rest. The pilot was able to turn off the fuel before exiting the aircraft with only minor injuries.

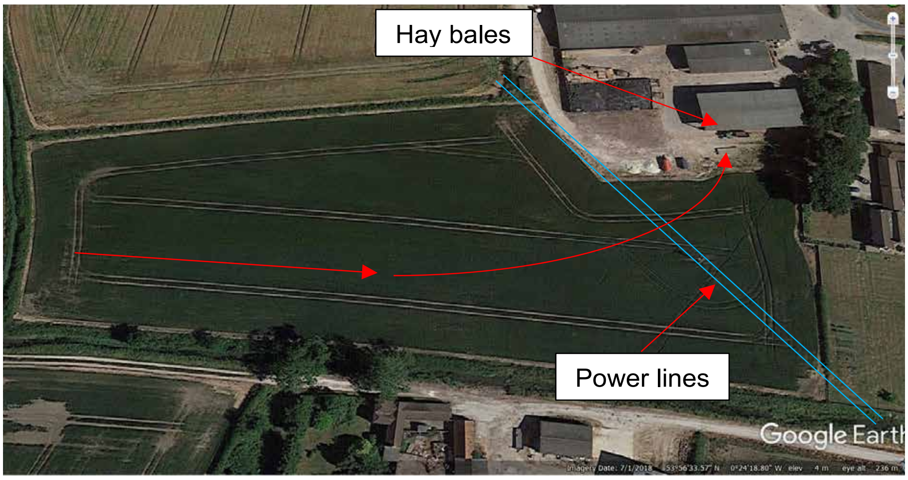


Figure 1
Accident site

Flap system

The Savannah VG is fitted with full wingspan trailing edge flaperons with 0°, 20° or 40° settings. They are operated by a lever on the cockpit floor between the legs of the left seat pilot (Figure 2). The lever has a locking button on the top which engages with a detent for each setting. The Pilot's Operating Handbook (POH) states that with the standard take off procedure with flaps 20° the aircraft lifts off between 26 to 30 kt and the Take Off Distance Required (TODR) to clear a 50 ft obstacle is 228 m. The pilot had practiced a full-flap take off once before with an instructor and in the POH is noted: "*The short take off procedure* [Flaps 40°] *is a very delicate manuver* [sic]*. It is suggested to practice it with an instructor before attempting it.*" The stall speed is 26 kt with flaps fully extended and 30 kt with flaps retracted. The pilot stated that in flight when extending the flaps, it is necessary to overcome the aerodynamic loads, however on ground, the flaps will fully extend under their own weight.

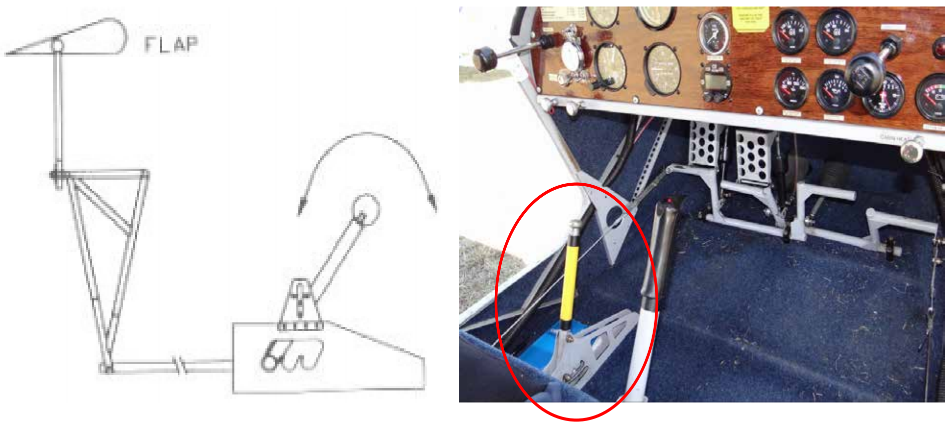


Figure 2
Flap system – lever and linkage

Discussion

During the takeoff ground roll with the aircraft approaching flying speed, the pilot stated that the aircraft struck a bump and he inadvertently moved the flap lever. No defect was identified in the flap mechanism and due to the low aerodynamic loads, they deployed to flaps 40°. This would have created a sudden increase in lift and drag and reduced the stall speed. The manufacturer has highlighted in the POH that taking off with flaps 40° should be handled delicately and that the lift off and stall speeds are very similar. The pilot had practiced rejected takeoff manoeuvres to the right and straight ahead, but not to the left. The sensation of a left-wing stall resulted in the pilot turning to the left and he realised he would strike the hay bales or the farm buildings (Figure 3).

The POH states that 228 m is required to clear a 50 ft obstacle. The strip length was approximately 220 m and the height of the power lines was approximately 20 ft. However, in this case, due to the orientation of the power lines, the Take Off Run Available (TORA) decreased as the aircraft turned to the left after takeoff. The CAA "SafetySense leaflet 12 Strip Flying" highlights the hazards of flying from private strips.

Figure 3
G-CGTV and accident site

ACCIDENT

Aircraft Type and Registration:	Skyranger Swift 912S(1), G-CFIA
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2008 (Serial no: BMAA/HB/561)
Date & Time (UTC):	2 October 2020 at 0937 hrs
Location:	Baxby Airfield, Husthwaite, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Significant airframe damage
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	316 hours (of which 65 were on type) Last 90 days - 8 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft adopted a steep nose-high attitude immediately after lift-off. The pilot closed the throttle and applied forward pitch control in an attempt to land back on the runway, but the aircraft stalled, dropped a wing and struck the ground. The pilot considered it likely that the trim lever had been left in the nose-up setting used for the previous landing.

History of the flight

The pilot had planned an early morning flight from Baxby Airfield to Beverley Airfield. Weather conditions were CAVOK with the wind calm and Runway 05 in use, which is 420 m long with a grass surface. The pilot had ensured that a small amount of luggage was secured within the luggage hammock and there were no loose articles in the cockpit. The engine start-up and taxi to the holding point were normal, with the usual checks completed, and the pilot made a radio check with another aircraft.

The runway was clear and the pilot lined up, applying full power. The aircraft accelerated with the pilot counteracting the minimal yaw to the right. At 40 kt, the pilot rotated the aircraft, which climbed too abruptly and with a very high nose up attitude. He decided to abandon the takeoff, closing the throttle and simultaneously applying forward control stick, but the aircraft stalled and dropped the right wing. It made a descending turn to the right through about 90° and struck the ground in a nose down attitude. The engine stopped on impact and the pilot switched off the fuel and electrical systems. He was injured in the accident but was able to exit the aircraft and crawl clear before phoning the emergency services, and an air ambulance took him to hospital.

He considered that in his haste to depart, due to a significant workload and jobs he had planned for the rest of the day, he omitted to set the trim lever to neutral for takeoff leaving it in the nose up position from the previous landing. This had the effect of raising the nose significantly on lift off. In his attempt to abandon the takeoff, the aircraft stalled resulting in the accident. He considered that being restrained by his properly adjusted four-point harness prevented more severe injuries.

Comment

The pilot considered it likely that day-to-day distractions meant he did not set the trim correctly for takeoff and that this led to the aircraft adopting a high nose attitude at lift-off. It is possible that closing the throttle with the nose above the horizon caused a more rapid reduction in airspeed than might otherwise have been the case, thereby making a stall more likely.

ACCIDENT

Aircraft Type and Registration:	Aeryon SkyRanger R60 (UAS, registration n/a)
No & Type of Engines:	4 electric motors
Year of Manufacture:	2019 (Serial no: SR 5074049)
Date & Time (UTC):	17 June 2020 at 0057 hrs
Location:	Maidenbower Pond, Crawley, West Sussex
Type of Flight:	Emergency Service Operations
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	Not applicable
Commander's Age:	33 years
Commander's Flying Experience:	6 hours (of which 4 were on type) Last 90 days - 2 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The UA fell from a height of about 70 ft into a pond when the emergency cut-out was accidentally operated by the pilot. The pilot stated he had not recognised the emergency cut-out function icon which had appeared on the flight controller screen. In attempting to clear it he unintentionally activated the function, stopping the UA motors.

History of the flight

The UAS was being used to search for a missing person in the area of a large pond surrounded by trees. The search was being conducted at night and was using a thermal camera to search areas hard to access by foot. The weather at the time was good with only a light breeze.

The UAS pilot reported that during the flight he became aware of a message on the screen of the flight controller which he did not recognise. He did not realise the message was a warning and attempted to clear it but in doing so the aircraft motors cut out, causing the UA to fall from a height of about 70 ft into the pond below.

Aircraft information

The SkyRanger UAS includes a quadcopter UA powered by four electric motors with a maximum takeoff weight of 3.5 kg. Using the DROPS analysis tool[1] a dropped object of this weight is capable of causing fatal injuries to an individual wearing a hard hat from a height of only 4 m.

The UA is controlled remotely by a pilot using a flight controller containing a small screen to input commands and to receive information. A stylus has to be used to make selections on the screen.

The UAS has an emergency cut-out function which cuts power to all four UA motors. It is accessed by holding the stylus over an icon on the flight controller screen showing a white aircraft on a black background. This causes the aircraft shadow under the icon to flash red. By tapping the icon three times within three seconds the emergency cut out function is activated.

Aircraft examination

Data from the UAS was sent to the manufacturer for analysis. This confirmed that the cut-out screen icon had been activated three times within three seconds, causing all four electric motors on the UA to stop.

Organisational information

Two neighbouring police forces had combined the management and oversight of their UAS operations. Between them they operated a number of UAS with about 150 officers being qualified to use them.

In order to qualify as a UAS pilot, personnel were sent on a five-day course with a civilian training company to gain the necessary CAA recognised qualification, during which time they were required to fly a UA for a minimum of two hours. This was followed by further internal training working alongside a more experienced qualified UAS pilot within the relevant police unit for a period of time until the trainee was considered ready for assessment. This assessment was carried out by one of a small number of assessors within the two police forces. The assessment covered various aspects of operating the UAS, including role specific requirements and more general aircraft requirements.

The two police forces used a number of different types of UAS, including the SkyRanger. Pilots operating the SkyRanger were required to undertake a two-day specific course, designed by the manufacturer but run internally. The course included the management of different aircraft warnings and failures, with pilots needing to pass an assessment at the end of the training.

Footnote

1 See AAIB Bulletin: 7/2020 DJI M600 Pro AAIB-26314. The analysis tool was developed as part of a dropped object prevention scheme (DROPS) introduced as part of a safety initiative by the UK Oil and Gas industry in the 1990s.

Pilots were required to maintain a minimum currency, as required by the CAA, of two hours flying in 90 days. Where they fell below this requirement pilots were required to be re-assessed before they could operate again.

Pilot information

The pilot had completed his initial training in 2018 to gain his UAS pilot's qualification. Due to an unexpected lack of availability of UAS in his police unit he had then not operated further until undertaking a SkyRanger course in February 2020. The pilot had passed his assessment with no apparent issues.

At the time of the accident he had accumulated a total of 6 hours 15 minutes flying time, of which 4 hours 15 minutes were on the SkyRanger.

Analysis

The pilot had not recognised the significance of the icon that he had inadvertently selected on the flight selector and his attempt to clear the message from the screen had the unintended consequence of activating the emergency cut-out function. This had shut down the motors and caused the UA to fall into the pond below.

CAA requirements currently allow a person with no previous experience to gain a commercial UAS pilot's qualification in a relatively short period of time, often in less than a week. The high level of automation available also makes many UAS relatively easy to operate. These points have the benefit of making this important area of aviation more widely available. They however also present the potential for people operating UAS to do so without the benefit of the experience gained over the longer and more extensive training required for more traditional routes into manned aviation. Recent AAIB investigations reveal a lack of understanding by some UAS pilots of fundamental operational factors such as weather limitations and the handling of aircraft warnings and failures.

The potential for such UAs as that involved in this accident to cause serious or fatal injuries when falling from even relatively low heights highlights the need for UAS pilots to be capable of understanding all aspects of their operation. This in itself requires careful management where an operator has a number of different pilots and systems under their control, with a need to carry out effective training and assessments, as well as keeping pilots properly current.

Safety Action

The police forces involved had been increasingly investing in the training and assessment of those officers using UAS. They were already in the process of introducing a new system of pilot assessment which will require pilots to undergo an assessment every six months, incorporating an annual day's training. Since the accident they have also allocated an officer working full time in the training role to compliment the assessors already in place.

ACCIDENT

Aircraft Type and Registration:	Wingcopter 178 Heavylift (UAS, registration n/a)	
No & Type of Engines:	4 Scorpion SII-4035 560 KV brushless DC motors	
Year of Manufacture:	2020 (Serial no: SN-0084)	
Date & Time (UTC):	4 September 2020 at 1415 hrs	
Location:	Mayfield Farm, Ilsley Road, Compton, Newbury	
Type of Flight:	Training	
Persons on Board:	Crew - N/A	Passengers - N/A
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Damaged beyond economical repair	
Commander's Licence:	Other	
Commander's Age:	24 years	
Commander's Flying Experience:	108 hours (of which 13 were on type) Last 90 days - 14 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

Whilst the unmanned aircraft (UA) was climbing, in hover mode, one of the rear electronic speed controllers (ECSs) overheated causing a loss of control of its associated motor and propeller. Control of the aircraft was lost and it fell into a crop field, damaging it beyond economical repair. The manufacturer is looking to re-design the rear propellers to reduce the likelihood of the ESCs overheating.

History of the flight

The Wingcopter 178 Heavylift, (Figure 1) is an unmanned electric Vertical Takeoff and Landing (eVTOL) aircraft with a maximum takeoff weight of 18 kg. It can take off and land vertically like many multirotor unmanned aircraft but can transition to wing-borne flight by rotating its two forward propellers to a horizontal position and folding its rear propellers to reduce drag. In 'fixed wing mode' the aircraft is capable of ranges of up to 75 miles and speeds up to 150 mph, dependent on payload. The aircraft has a 1.78 m wingspan and is 1.32 m long.

The UA was conducting a test flight to verify its performance at its maximum takeoff mass (MTOM), using an automated mission profile that it had successfully completed five times before.

Figure 1

Wingcopter 178 Heavylift with propellers positioned in 'hover mode'

After conducting the pre-flight and mission checks the remote pilot (RP) armed the aircraft, confirmed that the motors had spooled up correctly and initiated the automatic flight by switching the radio control transmitter to 'mission' mode. The aircraft lifted off successfully and began to climb in 'hover mode' towards its target height of 110 m agl at which point the aircraft would transition to 'fixed wing mode'.

Recorded data from the aircraft shows that it initially climbed vertically to approximately 35 m agl before continuing a programmed translational climb in 'hover mode' to the south west (Figure 2). After 72 seconds, whilst approaching 100 m agl, and having travelled 188 m, the aircraft rolled and pitched to the right and became temporarily inverted. It righted itself, but was unable to maintain control, descending rapidly whilst spinning in a clockwise direction. The RP reported that it was evident that one of the motors had lost propulsion. He attempted to gain control of the aircraft by switching to manual control, but this was unsuccessful.

As the aircraft descended some thrust was still produced by the operating motors prolonging the descent. The UA travelled approximately 80 m downwind before striking the ground in a harvested crop field. There were no injuries, although the aircraft was destroyed.

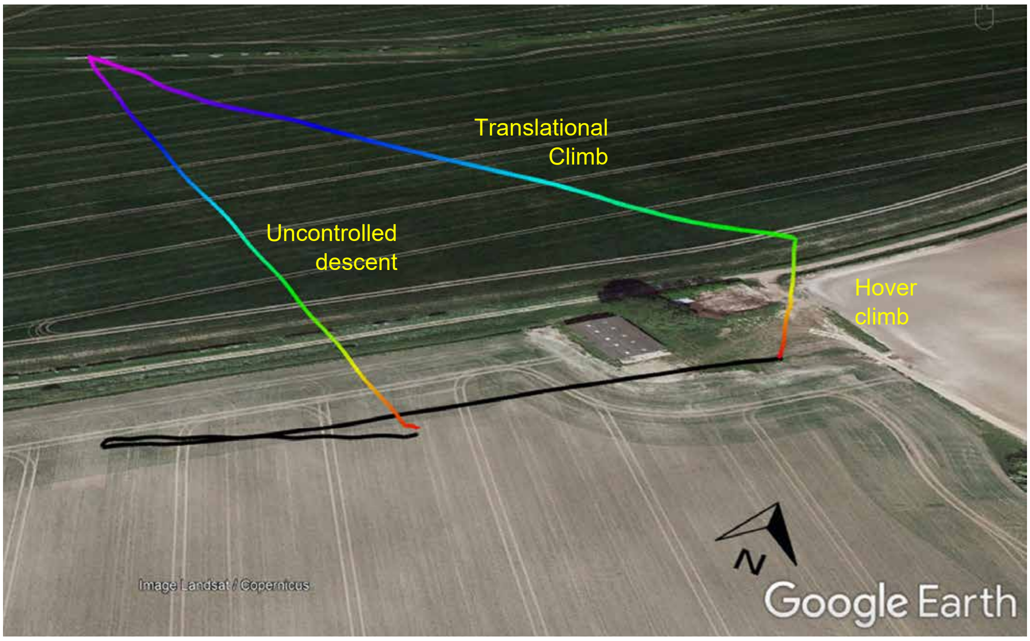


Figure 2

Oblique view of the aircraft's flight profile
© Google 2020, Image © Landsat / Copernicus

Aircraft examination

Assessment of the aircraft by the operator, in conjunction with the manufacturer, identified that a rear ESC had overheated resulting in the loss of control of its associated motor. This issue had been previously identified by the manufacturer and a hover time limitation of 120 seconds, to prevent the overheating, had been imposed. It is considered that the ESC overheated due to the increased load produced as a result of the combination of the duration of the translational climb and operation close to MTOM.

The manufacturer is currently working on resolving this issue by introducing re-designed rear propellers to the aircraft type.

AAIB Record-Only Investigations

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

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

The accuracy of the information provided cannot be assured.

Record-only UAS investigations reviewed October - November 2020

28-Jul-20 **Yuneec Typhoon H520** Faringdon, Oxfordshire

During the flight, the UA became erratic and descended. The operator activated the return to land function and the UA landed without further incident. The UK agent has identified that the issue was caused by the battery which had developed a high level of internal resistance.

13-Sep-20 **DJI Matrice 210 V2** Bath Racecourse, Somerset

At the end of an otherwise normal flight the UA fell onto grass from 21 ft causing substantial damage.

15-Sep-20 **Raptor X4** Stranraer, Wigtownshire

The UAS was being operated at sea when it entered a spiral dive and dropped into the sea. One of the four speed controllers was believed to have failed. The UA was not recovered.

18-Sep-20 **Mavic Pro** Huntingdon, Cambridgeshire

The UAS reported compass and Inertial Measurement Unit errors, and drifted off course. It struck a tree and fell to the ground. It could not be located.

24-Sep-20 **Evolve Dynamics Skymantis** Dundry, Somerset

At a height of 15 m the UAS suffered a propulsion failure and fell to the ground, there were no injuries. The manufacturer traced the cause of the power loss to a faulty crimp connection on a signal wire to an electronic speed controller. The manufacturer is addressing the quality issue with the third-party cable supplier.

29-Sep-20 **Intel Falcon 8+** Rough Field, North Sea

Whilst undertaking an inspection of the underdeck of North Sea platform the UA lost its link with the controller. The UA landed in the sea and was not recovered.

7-Nov-20 **DJI Inspire 2** Anglesey

The UA became entangled in a suspended telephone cable which the UA pilot had not seen. To allow recovery of the UA the pilot switched off the UA's motors allowing it to fall to the ground. The UA was severely damaged when it struck the ground.

10-Nov-20 **Parrot Anafi** Brighouse, West Yorkshire

During night operations the UA lost power and collided into trees. The UA was not recovered.

Record-only UAS investigations reviewed October - November 2020

17-Nov-20 **Sky Mantis** Grantham, Lincolnshire

Approximately 15 minutes into the flight the UA performed an uncommanded tumble without warning. It was located in a rural area and was substantially damaged.

19-Nov-20 **Phantom 4 Pro Quadcopter** Colchester, Essex

The UA suddenly dropped to the ground during an aerial photography flight. It was substantially damaged.

Miscellaneous

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

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

BULLETIN CORRECTION

Aircraft Type and Registration:	Colibri MB2, G-BUDW
Date & Time (UTC):	15 December 2019 between 1228 and 1328 hrs
Location:	Northfield Farm, Spilsby, Lincolnshire
Information Source:	AAIB Field Investigation

AAIB Bulletin No 11/2020, page 55 refers

After publication it was noted that the captions for figures 9 and 10 were incorrectly assigned.

The correct captions are shown below.

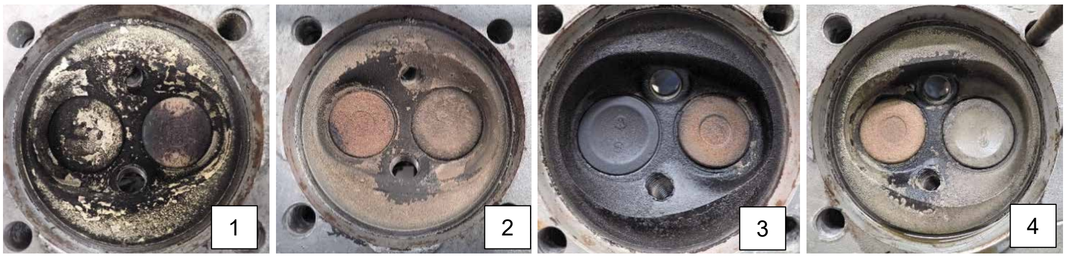


Figure 9
Cylinder heads

Figure 10
Piston crowns

The online version of this report was corrected on 19 November 2020.

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

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

Published September 2014.

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

Published July 2015.

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

Published August 2015.

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

Published October 2015.

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

Published March 2016.

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

Published September 2016.

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

Published March 2017.

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

Published March 2018.

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

Published November 2018.

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

Published March 2020.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

aal	above airfield level
ACAS	Airborne Collision Avoidance System
ACARS	Automatic Communications And Reporting System
ADF	Automatic Direction Finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
AOM	Aerodrome Operating Minima
APU	Auxiliary Power Unit
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European 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