AAIB
Air Accidents Investigation Branch

AAIB Bulletin 1/2015

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Published: 8 January 2015

Cover picture courtesy of Richard Ross

ISSN 0309-4278

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

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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:	ATR 72-212 A, EI-FCY
No & Type of Engines:	2 Pratt & Whitney Canada PW127M turboprop engines
Year of Manufacture:	2013 (Serial no: 1139)
Date & Time (UTC):	15 May 2014 at 1923 hrs
Location:	Manchester Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 48
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	6,263 hours (of which 5,028 were on type) Last 90 days - 147 hours Last 28 days - 40 hours
Information Source:	AAIB Field Investigation

Synopsis

On final approach to Manchester Airport, both multifunction computers (MFC) failed, resulting in the nosewheel steering system becoming inoperative. After landing, the aircraft deviated to the left side of the runway before the pilots brought it to a halt. After resetting the MFCs, they were able to taxi the aircraft to the terminal without further incident. Both the manufacturer and the operator have taken safety action because of this incident.

History of the flight

The aircraft was on a scheduled passenger flight from Cork Airport to Manchester Airport and had made an uneventful approach to Runway 23R. The co-pilot was PF and, after carrying out a normal landing, the aircraft started to deviate to the left of the runway centreline. The commander took control from the co-pilot in accordance with the normal procedure, and initially applied some rudder and then attempted to use nosewheel steering (NWS) to correct the deviation but the aircraft continued to turn left. The commander applied brakes and stopped the aircraft on the left side of the runway. The co-pilot noticed that the Multifunction Computer (MFC) modules 1B and 2B switch lights on the overhead panel were both indicating FAULT. The pilots reset the MFC modules and all systems were restored, allowing them to taxi the aircraft to its stand without further incident. Subsequently the commander reported that the NWS was ineffective during the landing roll and that no master cautions or warnings were observed, but that she noticed several engine indications were missing from the engine and warning display (EWD).

Multifunction computers (MFC)

The MFC system consists of two independent computers, MFC 1 and MFC 2; each has two independent modules (A and B). The functions of the MFC system are to monitor, control and authorise various aircraft systems and to manage system failures and command associated warnings in the Flight Warning System (FWS). The MFCs are switched on and off by four pushbuttons (one for each module) on the overhead panel. These pushbuttons also contain FAULT lights.

Various aircraft systems are controlled through a variety of combinations of MFC modules. A significant number of electrical services are listed in the QRH as unavailable in the event of a failure of MFC 1B and 2B modules, including:

- FWS Master Warning
- FWS Master Caution
- FWS Aural alerts
- FWS Amber alerts on EWD
- Nosewheel steering[1]
- Anti-skid[2]

Although the FWS master warning and caution systems are unavailable, the manufacturer stated that, in the event of an MFC 1B and 2B failure on this aircraft variant, the MFC 1B and MFC 2B switch light alerts illuminate on the overhead panel and the master caution lights flash.

Flight crew documentation

The Flight Characteristics section of the FCOM, for takeoff, states:

> *'For take-off, use of nose wheel steering guidance is only recommended for the very first portion of the take off run as rudder becomes very rapidly efficient when airspeed increases (~40 kts) and ATR 72 exhibits a natural tendency to go straight.'*

For landing, it states:

> *'-as speed reduces, and not later than about 40 kt (estimated) Capt takes NWS control, co-pilot hold control column fully forward.'*

Footnote

1 NWS is unavailable because the weight-on-wheels system becomes inoperative.

2 The manufacturer elaborated that only the touchdown protection element of the anti-skid system becomes inoperative. The touchdown protection system is designed so that, at main gear compression, the braking action is inhibited when wheel spin-up is below 35 kt or for 5 seconds, in order to preclude inadvertent brake application prior to wheel spin-up.

The minimum equipment list (MEL) allows for aircraft dispatch with NWS inoperative and there are no additional limitations on aircraft operation in this situation.

Analysis

Failure of both MFC 1B and 2B causes the weight-on-wheels system to be unavailable, which results in the NWS becoming inoperative. When the commander realised that the NWS was inoperative, she concentrated on stopping the aircraft but also noticed that there were unusual indications on the EWD. The pilots diagnosed and rectified the dual MFC failure after they observed the FAIL lights on the overhead panel. They were unaware of the failure until after the aircraft had stopped.

After landing, the commander applied some rudder before attempting to use the NWS to keep the aircraft straight. The FCOM indicates that the rudder is effective in maintaining directional control above 40 kt. However, when the commander took control, it is likely that the aircraft speed was such that rudder authority alone was insufficient to correct the deviation from the centreline.

Safety actions

The manufacturer has issued a Service Bulletin that recommends the installation of MFC computers modified to S5 standard to address the cause of the dual MFC failure experienced by this crew. At the time of publication of this report, the implementation of the Service Bulletin has been delayed pending resolution of technical issues associated with it.

The manufacturer has identified some inaccuracies in the FCOM, which it will amend.

The operator has introduced dual MFC failure scenarios into flight crew recurrent training.

ACCIDENT

Aircraft Type and Registration:	Cessna 525A Citation CJ2+, N380CR	
No & Type of Engines:	2 Williams FJ44-3A-24 turbofan engines	
Year of Manufacture:	2010 (Serial no: 525A0465)	
Date & Time (UTC):	31 December 2013 at 1100 hrs	
Location:	5.7 nm north-west of Coventry, Warwickshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Structural damage to left and right wings, broken HF antenna, dent to fin leading edge	
Commander's Licence:	FAA Private Pilot's Licence	
Commander's Age:	69 years	
Commander's Flying Experience:	3,900 hours (of which 600 were on type) Last 90 days - 16 hours Last 28 days - 5 hours	
Information Source:	AAIB Field Investigation	

Synopsis

As the aircraft approached its cruising altitude of FL430, the pilot was not monitoring the indicated airspeed and the aircraft stalled, departing from controlled flight in a series of five 360° rolls to the right. The pilot briefly regained control before the aircraft stalled again and in the following recovery, the aircraft's wings were damaged in overload. The pilot made a successful landing and examination of the aircraft's recorded data revealed that the angle of attack (AOA) sensing system had 'stuck' in flight and the aircraft's stall warning system did not operate prior to the stall onset. Two Safety Recommendations are made, relating to the continued airworthiness of the AOA sensing system.

History of the flight

The aircraft was kept in a heated hangar at Leeds Bradford Airport. On the day of the accident the owner planned to fly, with one passenger, from Leeds Bradford Airport to Palma de Majorca, Spain. He occupied the left cockpit seat and the passenger sat towards the middle of the cabin on the right side, wearing a three-point harness. Three small dogs were in the cabin, unrestrained, on and around the passenger's lap. Before flight the owner had conducted a pre-flight inspection, noting no defects. The pitot and static heat were selected ON before departure and the takeoff and initial climb were without incident. The aircraft followed a southerly track, climbing continuously towards the planned cruising level of FL430.

The pilot later reported one brief icing encounter, which he described as a "flash" of frost across an unheated area of the windscreen. The engine anti-ice had been selected ON earlier in the climb and the pilot then selected the wing and tail de-ice ON as a precaution, although no ice was seen on the wing at any time. The engine, wing and tail ice protection systems were selected OFF later in the climb.

The climb was conducted with the autopilot engaged in vertical speed (VS) mode with a selected rate of climb of 2,000 ft/min and the thrust levers, for the FADEC-controlled engines, in the Maximum Continuous Thrust (MCT) detent. As the aircraft climbed, the selected rate was reduced in 500 ft/min decrements and, passing FL 410, the aircraft was climbing at 1,000 ft/min. At this point (1057:38 hrs) recorded aircraft data shows that the indicated airspeed reduced below 150 kt. The indicated airspeed continued to decrease, reducing below 140 kt, 46 seconds later. The pilot noted that the indicated airspeed was lower than he had expected, with the green 'donut' marker on the speed tape (indicating V_{REF})[1] being slightly faster than his actual airspeed. He therefore reduced the rate of climb to 500 ft/min. The recorded data suggests that this occurred around 1059:17 hrs, when the indicated airspeed was 128 kt. Based on his experience, the pilot considered that the selection of a vertical speed of 500 ft/min should have managed the aircraft's energy sufficiently to achieve FL430 without incident. However, recorded data shows that over the next 50 seconds, the speed gradually reduced by a further 10 kt.

At some point between FL420 and FL430 the pilot noted the upper wind, displayed on the primary flight display (PFD), and decided to check the forecast winds chart that he had saved on his tablet-style portable electronic device (PED). He therefore looked down to the PED, located on the unoccupied right cockpit seat for what he believed to be a second or two. The pilot later recalled being "head down" looking at the PED when, without warning, he heard a 'click' and the aircraft pitched severely nose-down and rolled to the right. He thought that the stick shaker may have activated once as the aircraft pitched down; data shows that this occurred at 1100:08 hrs.

The pilot then recalled a violent and very confusing rolling departure from controlled flight. The aircraft almost immediately entered high cirrus cloud, obscuring the horizon. The pilot was unable to interpret the PFD attitude indicator, which he described as presenting information that he could not recall having seen before. He did not recall exactly how long this persisted but he did recall checking both the left and right PFD displays, which were similar in appearance.

The pilot made several attempts to recover the aircraft, although he could not later recall what control inputs he made. He recalled selecting idle thrust and achieving almost level flight at one point but, he had not increased thrust and the aircraft slowed rapidly and again departed from controlled flight. During the period that the aircraft was out of control it descended into clearer air between cloud layers, with a visible external horizon allowing the pilot to regain control.

Footnote

[1] V_{REF} is defined as 1.3 x stall speed.

The pilot re-established communications with ATC who instructed him to maintain FL280. He believed that he had re-engaged the autopilot, but when he released the yoke the aircraft immediately adopted a nose-up attitude and climbed approximately 2,000 ft before he regained control. He then noted that the pitch trim was in the fully nose-up position and the autopilot had not engaged.

Having set an appropriate trim position and now in a stable flight regime, the pilot confirmed that his passenger was uninjured. He noted damage to the upper surface of the left wing and his passenger reported similar damage to the right wing.

Given the damage to the aircraft, the pilot did not want to exceed 1,000 ft/min during descent and therefore he estimated that it would take 25 to 30 minutes to land. This placed Leeds Bradford Airport within the available options and, as he had only recently left that airport, was certain of the weather and was familiar with the airport, he considered this the best option with the lowest risk. He informed ATC of his decision and the remainder of the flight was without further incident. The pilot stated that the aircraft handling appeared unchanged by the damage it had sustained.

The pilot, passenger and the dogs were uninjured.

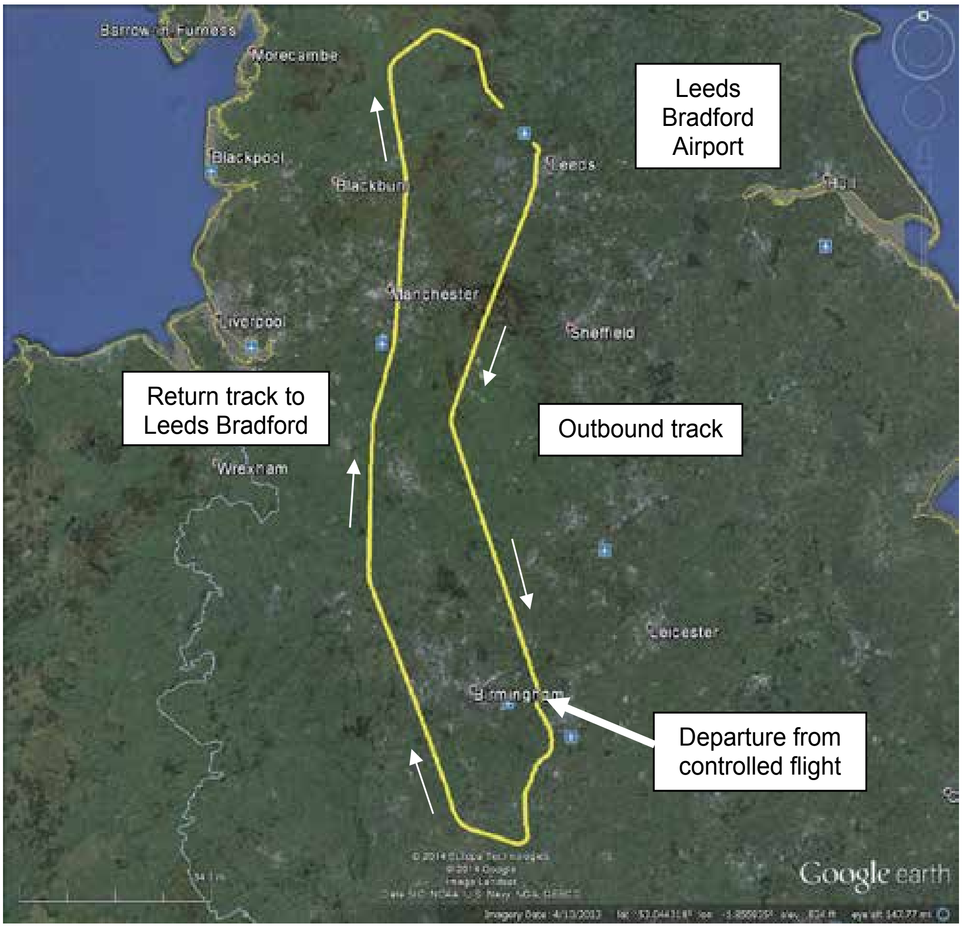

Figure 1

N380CR track

Aircraft examination

Inspection after the accident flight showed that the aircraft's wings were damaged in a manner consistent with overload in positive symmetrical bending. Five ribs in the outboard wingbox of the left and right wings were damaged by buckling in a manner similar to that shown in Figure 2, and the bonded joints between the ribs and the upper and lower wing skins had failed in overload. The upper and lower outboard wing skins of both wings were permanently deformed with a significant loss of aerofoil shape. Despite the disruption to the wing structure, which on this aircraft type forms an integral fuel tank, no fuel had leaked from the wings and the wing skins remained firmly attached to the front and rear spars. The upper wing skins above the main wheel wells, at the inboard end of the wing close to the fuselage, were also found buckled due to overload. The damage was consistent with symmetrical 'pullout' manoeuvre loads between +3.6g ('limit' load) and +5.4g ('ultimate' load).

Figure 2

Right wing internal damage at WS255.25, at approximately mid-span of the aileron

Both ailerons showed evidence of skin wrinkling along the trailing edge on their upper and lower surfaces.

The aircraft's HF (high-frequency band) antenna had broken at its connection to the top of the vertical fin and the antenna's spring tension unit was missing. The antenna had remained attached at its forward mounting on the upper fuselage skin, and flailing of the antenna during flight had caused a dent on the left side of the fin leading edge, close to the fin root rib.

A review of the weight and balance calculations for the flight showed that the CG and aircraft weight were within flight manual limits at all stages of the flight.

Weather

The UK Met Office provided an aftercast of the weather conditions likely to have been encountered during the accident flight. It reported that there was occasional stratus cloud at 600 ft agl with tops at 1,000 ft, leading to broken cumulus and stratocumulus between 2,000 ft and 8,000 ft with alto-cumulus and alto-stratus above these heights. The freezing level was at about 4,300 ft.

Above this it was likely that there was no cloud up to about FL290, above which cirrus was likely. The absolute cloud tops were probably in the region of FL350. Data above those levels was sparse but the profile showed no significant wind shear at any level. There were no rapid or unusual changes in temperature relative to the normal ISA lapse rate but there was a slight rise, from -57°C to -55°C, between FL400 and FL430.

Recorded information

A number of data sources were available to the investigation, including ground-based radar and data stored in on-board avionics components. The aircraft was not fitted with a flight data or cockpit voice recorder, nor was it required under airworthiness regulations.

The aircraft was, however, fitted with a system known as AReS (Aircraft Recording System) by the aircraft manufacturer. This was fitted as a system diagnostic and troubleshooting tool but in this instance was also available for accident investigation purposes. The system installed on N380CR recorded 6 channels of ARINC 429 data, sourced from various avionics components of the Rockwell Collins Pro Line 21 Avionics System.

Review of the AReS data confirmed that the accident flight had been recorded along with eight preceding flights, with over 3,000 parameters available. As this data recorder was fitted by the aircraft manufacturer voluntarily, it was not subject to the rigours of flight data recorders fitted to aircraft by regulation, which have a minimum parameter list. A large number of useful parameters for this investigation were therefore not available[2].

A key parameter for this investigation that was recorded was 'normalised' angle of attack (AOA)[3]. This parameter was sourced from the AOA computer and converted into a digital signal by the Pro Line 21 avionics. If the AOA signal was detected as invalid, the Pro Line 21 system would 'freeze' the normalised AOA at the last known value but would also provide an 'invalidity' marker of when this had occurred. The aircraft AOA system is described in further detail in the 'Aircraft description' section of this report.

In addition to the AReS data, the Enhanced Ground Proximity Warning System (EGPWS) recorded a number of events, which were also downloaded.

Footnote

2 This included AOA validity, AOA heater status, roll rate, control column and rudder pedal positions, control surface positions, stick shaker and pitch trim parameters.
3 Normalised AOA is the ratio of actual angle of attack to stalling angle of attack.

Previous flights of N380CR

Flights, dating back to 4 October 2013, had been retained in the AReS system and were analysed to review aircraft operations during the climb and the corresponding AOA activity. On 7 December 2013, four flights prior to the accident flight, the aircraft flew from Palma de Majorca, Spain, to Leeds Bradford Airport. At the top of the climb, the recorded normalised AOA remained static for approximately 90 seconds despite changes in pitch attitude. The recorded static air temperature (SAT) at the time was -61°C although not the minimum of -66°C which occurred just over 20 minutes later.

Analysis of the recorded normalised AOA data confirmed that the Pro Line 21 system had declared this data as 'valid' throughout the entire flight. No other static AOA activity was noted during any recorded flight, apart from the accident flight and that on 7 December. A summary of the minimum SAT encountered during each of the flights is shown in Table 1:

Date of flight	Minimum static air temperature	Maximum altitude
4 October 2013	-58°C	FL430
25 October 2013	-61°C	FL430
5 November 2013	-58°C	FL430
29 November 2013	-64°C	FL430
7 December 2013	-66°C	FL430
17 December 2013	-43°C	FL280
17 December 2013	-23°C	FL200
17 December 2013	-50°C	FL320
31 December 2013 (accident flight)	-57°C	FL420

Table 1

Summary of minimum static air temperature encountered by N380CR during nine flights recorded on the AReS system

Accident flight

Analysis of the recorded normalised AOA data during the accident flight again confirmed that the data was always deemed 'valid' by the aircraft system.

Climb to FL420

Figure 3 shows that at 1044:02 hrs, the recorded AReS data shows the normalised AOA remaining static as the aircraft climbed through FL197 at a SAT of -22°C. Despite recovering intermittently, as the aircraft climbed and the SAT reduced, periods of static normalised AOA were recorded.

At 1053:43 hrs while climbing through FL356, the indicated airspeed stabilised at 180 kt as the vertical speed reduced from approximately 1,750 ft/min to 1,400 ft/min. This airspeed was maintained for a minute after which it began to reduce. At 1056:41 hrs, the vertical speed reduced further to 1,000 ft/min as the aircraft climbed through FL395 at an indicated airspeed of 158 kt.

At 1059:17 hrs, at FL420 and 128 kt, a further reduction in the vertical speed to 500 ft/min was recorded but this did not stop the decay in airspeed. Nine seconds later, a 'step' change in the normalised AOA was recorded, from 0.46 to 0.61 units, where it remained for the next 45 seconds, despite a reducing airspeed and increasing pitch attitude. This step change (and others noted above FL300) were considered by the aircraft manufacturer to be characteristic of the AOA vane momentarily breaking loose from its static position. At 1100:01 hrs, the indicated airspeed reduced to below 120 kt with a recorded normalised AOA of 0.61 units and pitch attitude of 10.8° pitch-up.

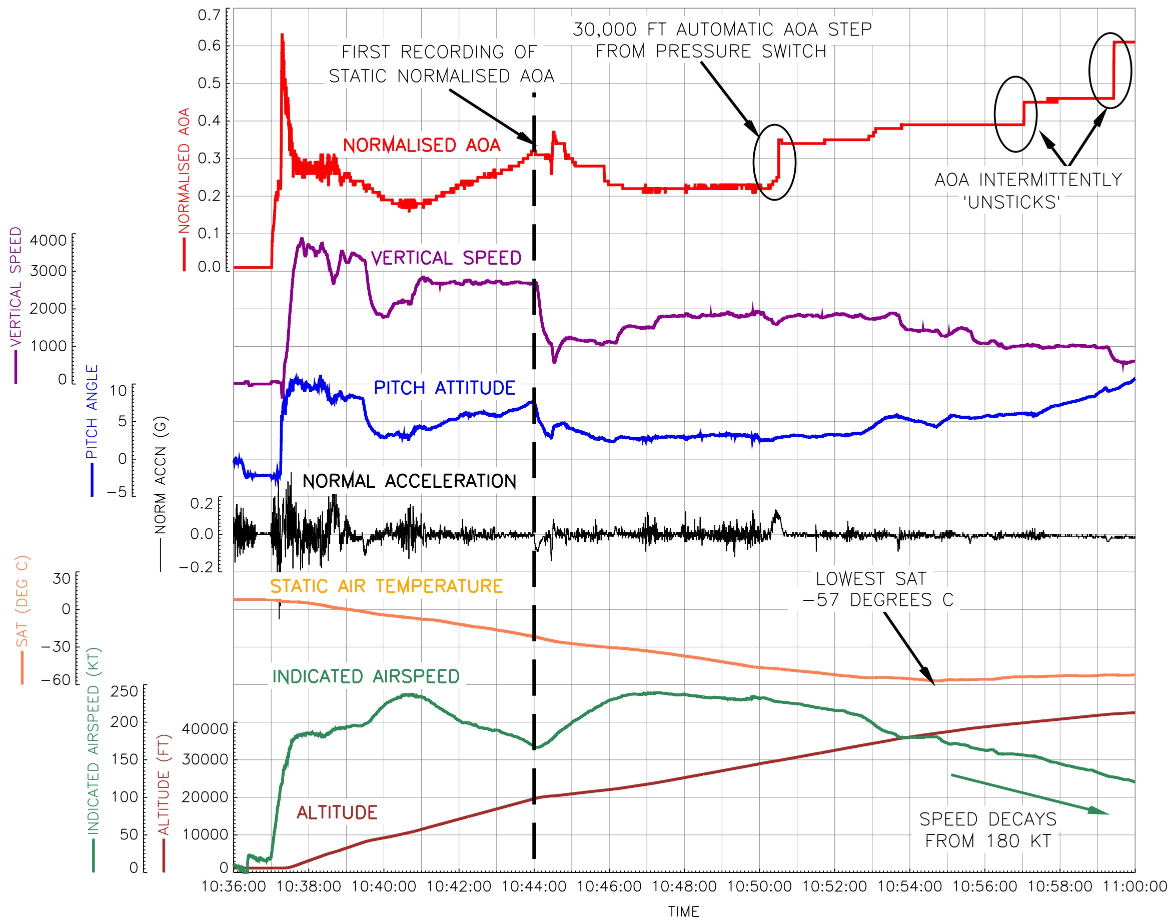

Figure 3

N380CR AReS data during climb

Departure from controlled flight

At 1100:08 hrs, while climbing through FL426 with a pitch attitude of 11.5°, the aircraft rolled right to 57° over a period of four seconds (Figure 4). No buffet vibration could be identified prior to this from the recorded accelerations. This roll attitude should have triggered the PFD 'declutter'[4] mode and an EGPWS bank angle warning[5]. During this time, the aircraft pitched down to -9°, the autopilot disengaged[6], the aircraft reached an indicated airspeed of 116.7 kt but the recorded normalised AOA remained at 0.61 units prior to reducing to 0.27 units.

The aircraft then rolled back to the left during which the normalised AOA increased to above the threshold required to activate the stick shaker (0.87) for approximately 0.5 seconds before again sticking at a value of 0.78. Control column and rudder pedal positions were not recorded, so it was not possible to establish the control inputs being made by the pilot.

After rolling to the left to -66°, the aircraft rolled back to the right and between 1100:12 hrs and 1100:35 hrs completed five 360° rolls to the right. The derived roll rates[7] increased progressively from 111°/sec to 120, 152, 153 and finally to 181°/sec. During this, the EGPWS download confirmed a further 12 bank angle warnings and the aircraft oscillated in pitch and slowly pitched down to a minimum of -68°, before then pitching up to -3.6° with a normal acceleration of a 3.25g[8]. The outcome of this was not to arrest the descent but to reduce the airspeed significantly.

Engine power was reduced to IDLE at 1100:34 hrs and remained there for the next 72 seconds. During the fourth complete roll, the recorded normalised AOA became unstuck and increased to 1.0 for six seconds. No further static AOA behaviour was noted for the remainder of the recording.

After the 3.25g pull-out, the aircraft pitched down again and appeared to turn through a further 360° roll to the right while pitching down almost vertically to a minimum pitch attitude of -89.7°. The Attitude Heading Computer (AHC) manufacturer indicated that at such pitch attitude, the roll and heading values "are not well defined".

Pitch attitude then increased, and there followed two oscillatory pitching manoeuvres over the next minute and a half (Figure 5). During the first of these, the aircraft rolled to 115° right, the indicated airspeed reached its maximum of 295 kt (Mach 0.77) and an overspeed warning was recorded.

Footnote

4 'Declutter' mode is defined in the Aircraft Description section.
5 When the EGPWS senses a bank angle in excess of ±50 degrees, an audio callout of 'BANK ANGLE' is triggered.
6 The autopilot will automatically disengage if the roll attitude exceeds 45º.
7 Roll rate was not recorded by the AReS system.
8 AReS records normal acceleration with the acceleration due to gravity removed. As such, when stationary on the ground, normal acceleration is recorded as 0g instead of 1g. Normal acceleration figures quoted in this report are the recorded value plus 1.

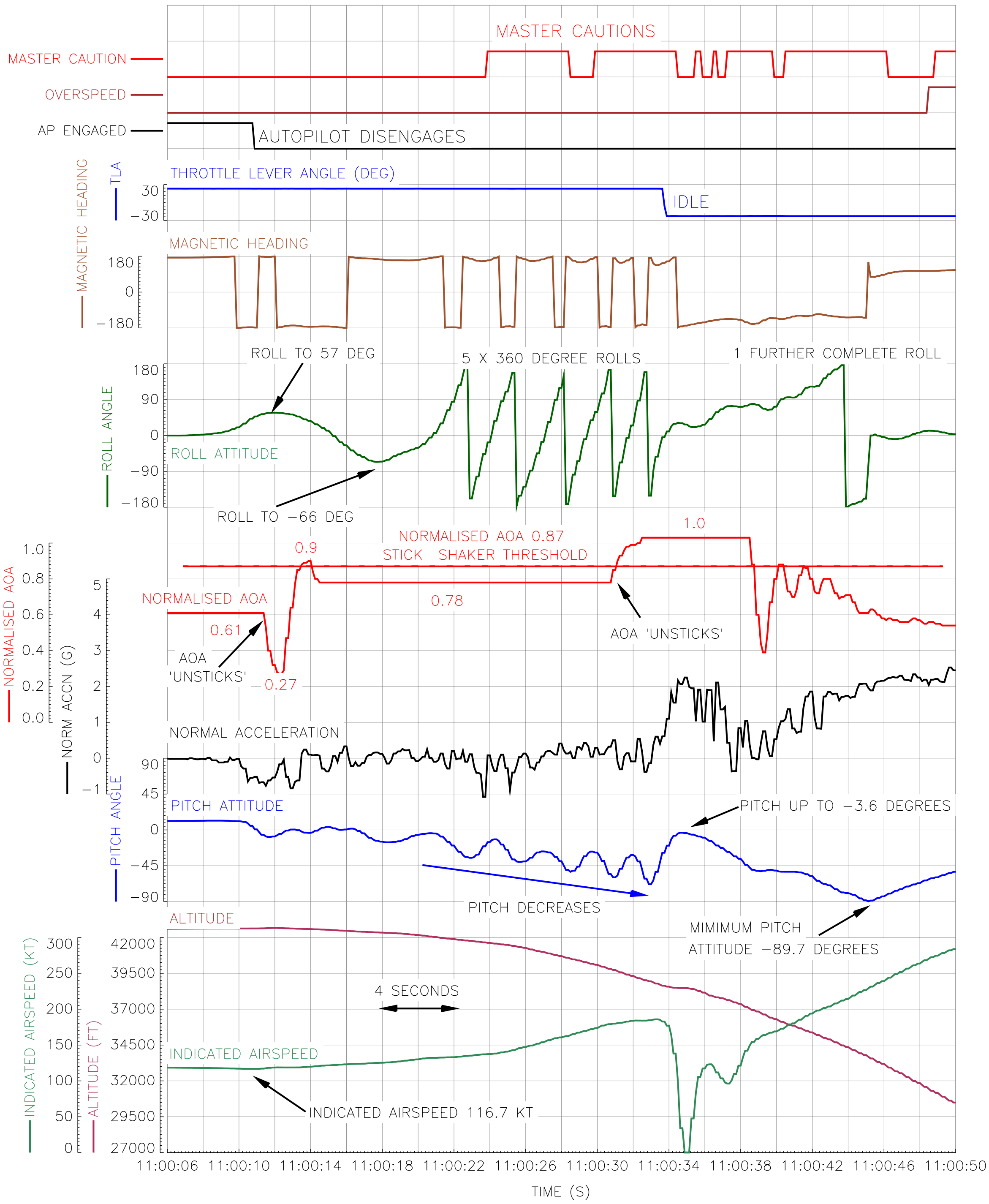

Figure 4

AReS parameters during loss of control

At 1100:58 hrs, as the pitch attitude increased, the descent was arrested at FL270, which also corresponded with the peak normal acceleration of 4.48g. The descent of 15,662 ft over 46 seconds equated to a vertical speed of approximately 20,000 ft/min. Ten seconds prior to reaching the maximum pitch attitude of 70° during this pitching manoeuvre, the normalised

AOA increased to above 0.87 (peaking at 1.0) and remained there for the next 33 seconds. The minimum indicated airspeed as the aircraft began to pitch down again was 44 kt.

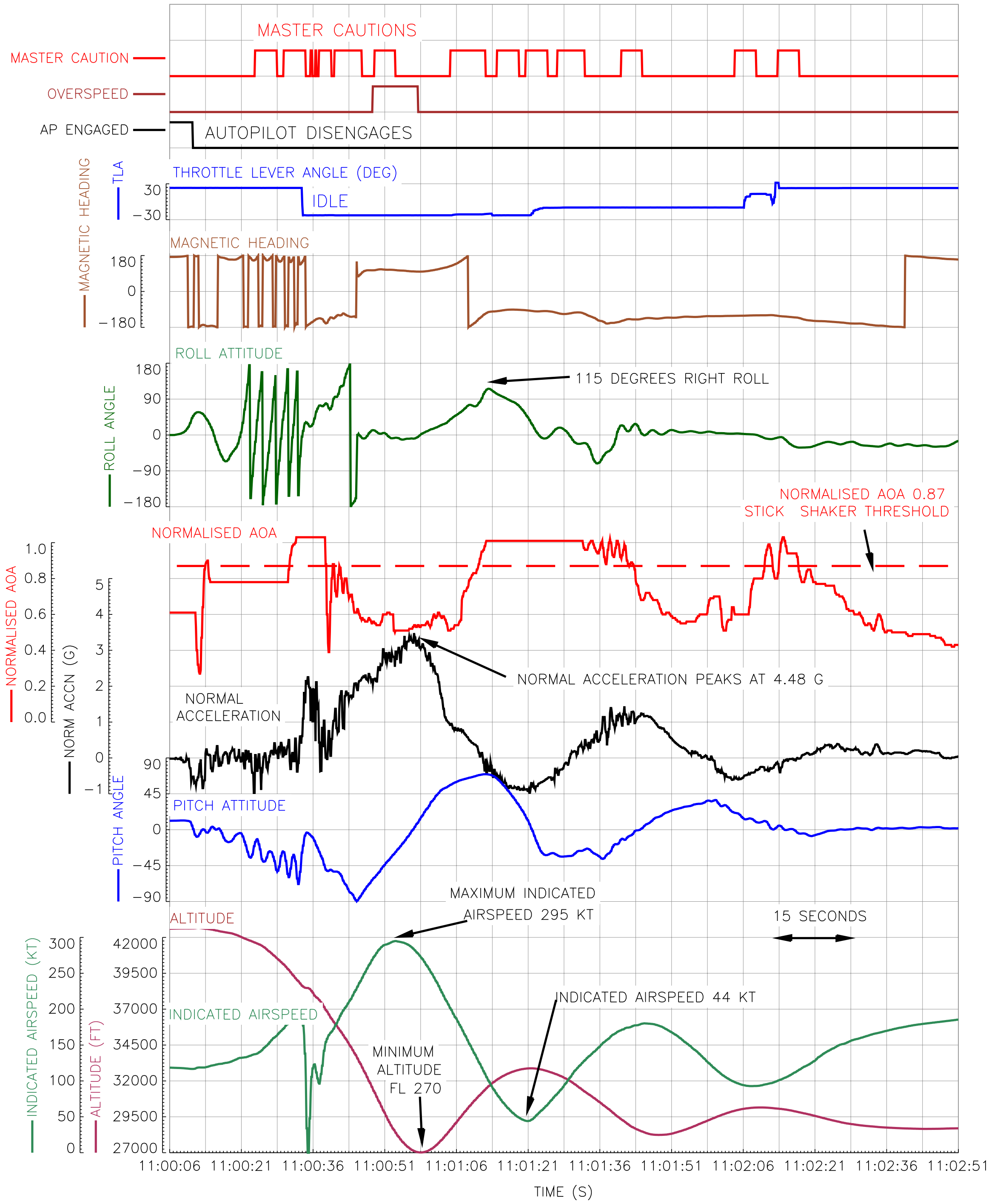

Figure 5

AReS data showing recovery

At the top of the second pitching manoeuvre, the normalised AOA again exceeded 0.87 for two separate periods of two seconds and four seconds, with a minimum recorded indicated airspeed of 93 kt.

At 1103:10 hrs, the pitch, roll and heading parameters stabilised, airspeed increased through 200 kt whilst the aircraft maintained FL300. Vertical speed for the next minute and a half varied between 2,400 ft/min to -2,300 ft/min but eventually stabilised. The autopilot was then re-engaged and the aircraft returned to Leeds Bradford Airport.

Aircraft description - general

The Citation CJ2+ is a low-wing monoplane business jet, with retractable tricycle landing gear and a T-tail. The cabin is pressurised and N380CR was equipped with seating for six passengers and two pilots. The aircraft is powered by two turbofan engines mounted on pylons attached to the rear fuselage.

The aircraft is certificated to FAR 23 in the Normal Category and the maximum indicated operating Mach number (M_{MO}), between 29,124 ft and the maximum operating altitude of 45,000ft, is 0.737. The maximum takeoff weight is 12,500 lbs and the maximum positive load factor, or 'limit load' with the flaps retracted, is +3.6g. The limit load is the load level that the aircraft's structure must be capable of sustaining without permanent deformation or damage occurring. The prescribed minimum factor of safety in FAR 23 for limit loads is 1.5[9], meaning that the 'ultimate' positive load factor on the aircraft is at least +5.4g. When the structure is subjected to load levels above the limit load but lower than the ultimate load, the structure must withstand the additional load but may permanently deform whilst doing so.

The Citation CJ2+, in common with many other twin turbofan business jets that are certified in the FAR 23 and EASA CS-23 categories, is equipped with a single AOA vane. Larger jet aircraft certified in the FAR 25 and EASA CS-25 '*Large Aeroplane*' categories are typically equipped with two or three AOA vanes, providing a degree of redundancy, and monitoring, in the AOA sensing system.

N380CR

Prior to the accident flight on 31 December 2013, N380CR had accumulated 312.2 flying hours since its manufacture in June 2010. The last scheduled maintenance inspection was completed on 17 September 2013 and no maintenance had been performed on the aircraft's AOA system since manufacture, in accordance with the aircraft's approved maintenance programme.

Aircraft attitude display

The aircraft was fitted with a Rockwell Collins Pro Line 21 Avionics System which features a fully integrated flight instrument, autopilot, communication, and navigation system. Part of this fit is the Attitude Heading Reference System (AHRS), including two separate Attitude Heading Computers (AHCs) which sense the aircraft attitude, heading, and three-axis rate of angular accelerations. This information is then displayed to the pilot on the Primary Flight Display (PFD).

Footnote

9 FAR 23.303 '*Factor of Safety*'.

The Pro Line 21 Manual describes the PFD attitude display as:

> *'The attitude ball is the traditional blue sky and brown earth depiction separated by a white horizon line. A V-shaped single cue aircraft symbol is in the center of the attitude ball.'*

The PFD attitude also includes a 'declutter' mode which is activated when an aircraft enters an unusual attitude:

> *'When pitch angle is greater than 30 degrees nose up or 20 degrees nose down, or roll angle exceeds 65 degrees, the warning chevrons show on the pitch tape. Non-essential information is removed from the PFD to emphasize the unusual attitude condition. The display returns to normal when pitch angle is ±25 degrees nose up or 15 degrees nose down, or roll angle is ±60 degrees.*
>
> *NOTE*
> *Non-essential information refers to any information on the PFD that is not airspeed, altitude, attitude, vertical speed, engine data, compass, YD[10] disengage, AP[11] engage/disengage, TRIM fail, and mistrim annunciations.'*

Figure 6 shows both a PFD nominal attitude display and the declutter mode encountered when at a roll attitude in excess of 60°.

Figure 6

Nominal PFD (left) and PFD declutter mode
after roll attitude greater than 60 degrees (right)
Picture courtesy of Rockwell Collins

Footnote

[10] Yaw damper.
[11] Autopilot.

Figure 7 shows the declutter mode at 65° pitch-up, which also features a large warning chevron pointing to the direction of the horizon:

Figure 7

PFD declutter mode at a pitch attitude of +65°

Picture courtesy of Rockwell Collins

Angle-of-attack (AOA) system

The aircraft's AOA system is shown diagrammatically in Figure 8. The system is electrically powered and consists of the following primary components:

- A single AOA airflow sensing vane mounted on the right side of the forward fuselage (Safe Flight Instrument Corporation model C-12717-1)
- Inputs from flap position and landing gear squat switches
- An analogue AOA gauge mounted in the upper left corner of the instrument panel
- An AOA 'indexer light' mounted above the glareshield, to the left of the windshield centre post
- A high-altitude ST035 barometric pressure switch
- An AOA normalisation module
- Outputs to the PFD and stick shaker unit

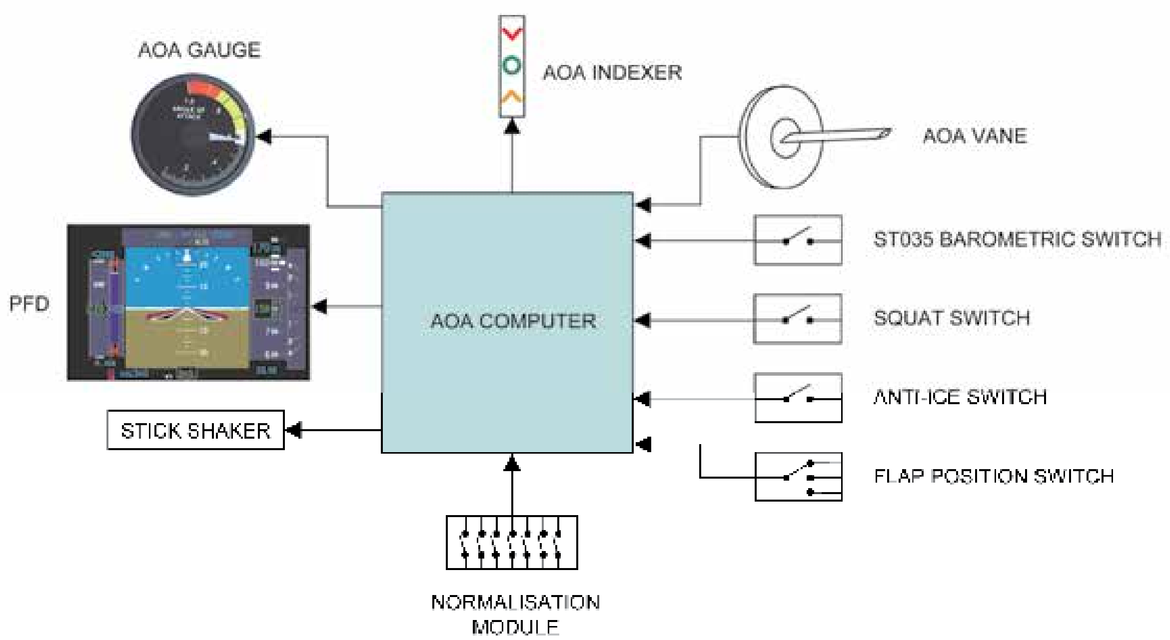

Figure 8

AOA system block diagram

The AOA vane's position is derived by a rotary transducer within the AOA vane case, and is sent to the AOA computer, which converts the AOA vane position into an analogue DC voltage, equivalent to a 'normalised[12]' value of AOA ranging between 0.0 and 1.0. A value of 0.6 AOA equates to V_{REF}, 1.3 times the stalling speed for any flap setting or weight. The stick shaker activates at a value of 0.87 or 0.88 AOA, depending on the pressure altitude[13], and a full stall occurs at 1.0 AOA.

The computed value of AOA is displayed on the analogue AOA gauge on the instrument panel and on the glareshield indexer light, which displays a green circle or 'donut' when the AOA value is 0.6. The indexer lights are only active when the landing gear is down and locked. If the airspeed is below V_{REF} the indexer light displays a downward pointing red chevron and if it is above V_{REF}, an upward pointing yellow chevron is displayed.

The AOA computer also provides a signal to the PFD such that a small green circle ('donut'), corresponding to V_{REF}, is displayed on the airspeed tape. This circle is displayed regardless of the landing gear position.

The AOA vane is electrically heated for operation in icing conditions, although no separate AOA vane case heater is fitted. AOA vane heating is turned on when the pitot-static heating switch on the anti-ice/de-ice switch panel is selected ON. If the vane heater has been detected as failed, the annunciator panel AOA HTR FAIL warning is illuminated.

Footnote

[12] Normalised AOA is the ratio of actual angle-of-attack to stalling angle-of-attack.
[13] A reduced stick shaker onset point of 0.87 AOA is used above a pressure altitude of 30,000 ft, as sensed by the ST035 high-altitude barometric pressure switch.

A configurable AOA 'normalisation' module is connected to the AOA computer. This unit consists of seven 'dip' switches, each of which may be set to ON or OFF, to allow calibration of the AOA system during production flight testing. Inspection of the aircraft's production flight test report showed that the normalisation unit's dip switch settings at the time of the accident were the same as those set following the production flight tests.

Output to Pro Line 21 system

The AOA computer provides two signals to the Pro Line 21 system; an analogue DC voltage representing normalised AOA and an 'AOA validity' discrete[14]. These signals are acquired by the Data Concentrator Units (DCUs) which convert them into a digital signal. This digital signal is then transmitted to other avionics components fitted to the aircraft on an ARINC 429 databus.

The 'AOA valid' discrete and the analogue signal are monitored for validity by the DCU. If the AOA signal is detected as invalid, a warning flag will appear on the PFD and the data on the databus will be fixed at the last valid value. The ARINC 429 Sign/Status Matrix (SSM)[15] will be set to a condition other than Normal Operation so it is possible to ascertain whether data which appears static on the databus is due to a declared failure or from a static AOA position.

Low-speed alerting and stall warning system

The manufacturer's operating manual describes the stall warning system as:

> *'Stall Warning*
>
> *Stall warning includes one stall strip on the inboard leading edge of each wing and a stick shaker that the angle-of-attack system operates. Stall strips (Figure 15-2) create turbulent airflow at high angles of attack, which causes a buffet to warn of approaching stall conditions.'*

The aircraft therefore has a combination of aerodynamic and electro-mechanical warnings.

The Pro Line 21 Operator's Guide describes the PFD in more detail. Low-speed alerting is provided by various elements on the PFD speed tape. A red Impending Stall Speed (ISS) bar (Figure 9) is positioned at the speed equivalent to 1.1 V_s[16]. This is calculated by the avionics system using airspeed, AOA and normal acceleration.

If the aircraft speed trend is slower than ISS by 2 or more knots for more than 5 seconds, or the indicated airspeed is slower than ISS by 2 or more knots, then a visual warning occurs with the line changing to a wider blue and red checkerboard pattern. The airspeed readout flashes red for 5 seconds, then shows steady red when the current airspeed is less than or equal to the ISS.

Footnote

[14] A discrete signal is one which conveys one of two states such as on or off, open or closed.
[15] ARINC 429 uses the SSM to indicate one of four health states of the data; Failure Warning, No Computed Data, Functional Test or Normal Operation.
[16] V_s is the stall speed for the aircraft configuration.

Figure 9

PFD showing ISS with an aircraft speed of 120 kt, normalised AOA of 0.9

Should the system detect an invalid AOA then the 'low speed range marker' replaces the ISS. This consists of a yellow bar covering the 72 to 97 kt speed range.

Autopilot vertical modes

The following vertical modes are available for selection by the pilot:

- Pitch
- Flight Level Change (FLC)
- Vertical Navigation (VNAV)
- Altitude (ALT)
- Vertical Speed (VS)

VS mode

The Pro Line 21 Operator's Guide states:

> *'Vertical Speed mode generates commands to capture and track the Vertical Speed reference shown on the PFD.'*

There is no reference in any supplied manual to the risks of operating in VS mode with insufficient energy to achieve the selected vertical speed.

Flight Level Change mode

The Pro Line 21 operator's guide states:

> *'Pressing the flight level change (FLC) button selects and deselects a speed command for climbs or descents.'*

The Collins Pro Line 21 Manual describes the PFD AOA display as follows:

> *'The Reference Approach Speed (RAS) cue is a small green circle that shows at the bottom right of the airspeed tape to indicate the calculated RAS.*
>
> • *RAS is variable and is automatically calculated using 1.3 VS. Airspeed, AOA, and normal acceleration are also used to calculate RAS'*

Based on the calculations supplied by the Pro Line 21 manufacturer and recorded AReS data, just prior to the loss of control, with the normalised AOA static at 0.61, at 117 kt, the calculated ISS would have been 100 kt, with the 'green donut' at 122 kt. For a normalised AOA of 0.87, the onset of the stall warning, the ISS would have been 122 kt and the green donut at 141 kt.

Tests and research

Pitot-static system

The aircraft's pitot-static system was tested for leaks and calibration in accordance with the AMM and, apart from a minor 30 ft discrepancy in the standby altimeter at one test point, all measurements were within the required tolerances. The actuation values for the aircraft's stick shaker system were tested by rotating the AOA vane with a calibrated test fixture and measuring the AOA values when the stick shaker operated, in accordance with the test procedure listed in the AMM. The stick shaker operated as required at a value of 0.88 AOA at a test pressure altitude of 5,000 ft and also operated correctly at 0.87 AOA when the test pressure altitude was increased to 30,000 ft. This showed that the ST035 pressure switch was operating correctly.

AOA system

The AOA vane's heater was functionally tested by following the ground test procedure provided in the AMM and was determined to function correctly. The AOA vane unit was

CT-scanned[17] prior to disassembly to record its internal condition. The CT scans showed that an internal PTFE (polytetrafluoroethylene – a synthetic fluoropolymer) seal was laterally displaced and was not concentric with the vane spindle assembly or the AOA vane case, Figures 10 and 11. When viewed from the side, a gap was visible between the PTFE seal flange and the vane spindle assembly, which is not intended by the design, as the PTFE seal is required to prevent moisture and foreign objects from entering the AOA vane case from outside the unit.

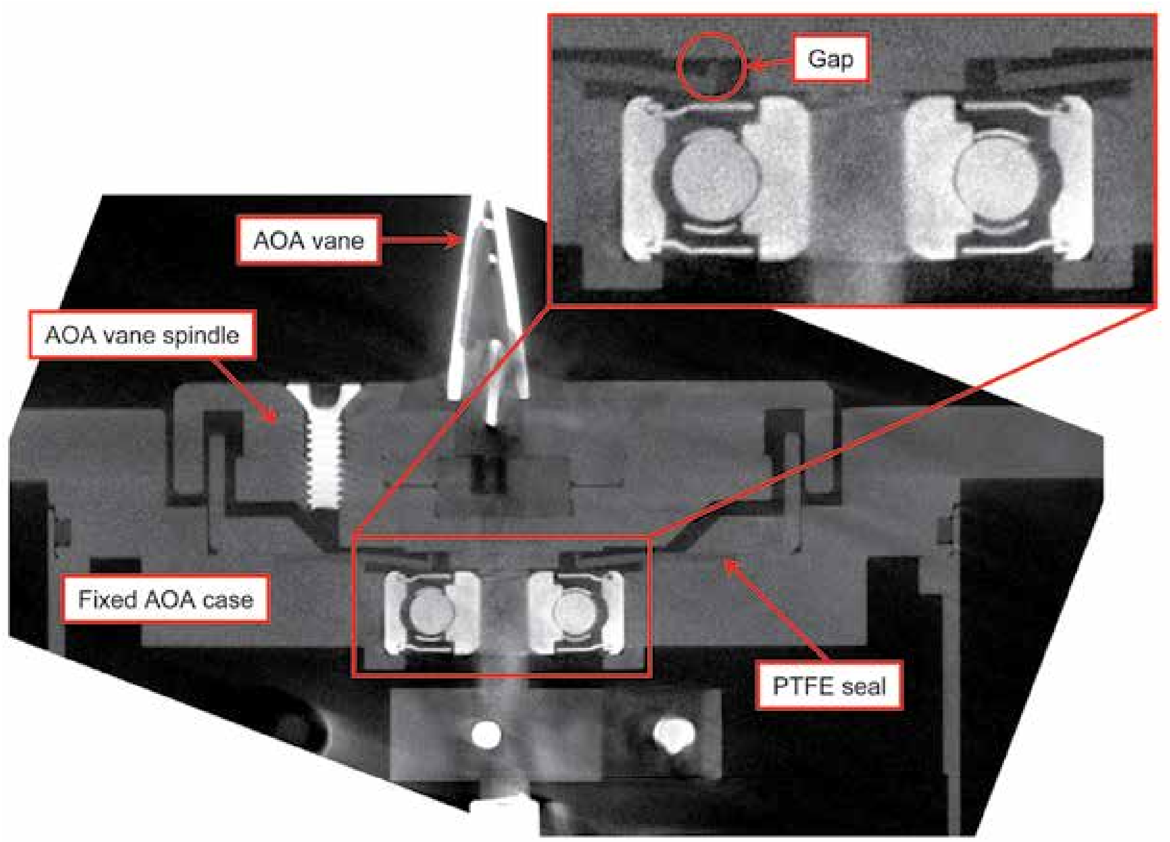

Figure 10

Gap between AOA seal and vane spindle

AOA vane unit and AOA computer were taken to the manufacturer for detailed testing and inspection. When subjected to the factory acceptance test procedure, the AOA computer passed all the tests with no failures and was deemed to be serviceable. The AOA vane unit was initially leak checked to assess the sealing capability of the PTFE seal. This procedure is followed for new production and repaired units, but is not conducted when units are received for overhaul. The AOA vane unit was attached to a sealed box, using the mounting flange screws and sealing gasket as it would be installed in the aircraft. The box was then pressurised to 10.1 psi and the leak rate through the unit was measured using a calibrated mass flow instrument. The measured leak rate was 1,338 cm^3/min, which is approximately

Footnote

17 Computed Tomography is an X-ray scanning technique in which X-ray images are computer-processed to produce individual 'slice' images through an object.

2.6 times the factory acceptance limit value of 500 cm^3/min. Application of a soap bubble solution showed that the leaking air was escaping past the internal PTFE seal and through the annulus formed between the AOA vane spindle and the AOA case.

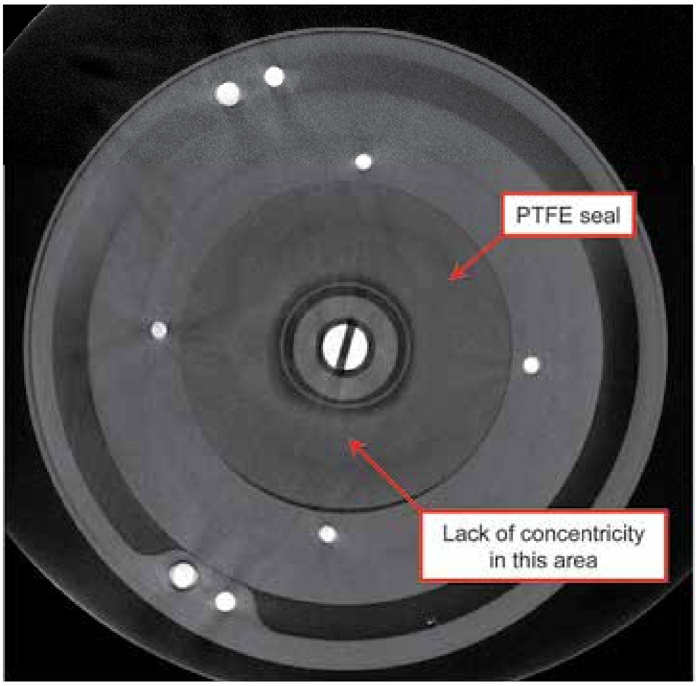

Figure 11
Lack of concentricity of AOA seal

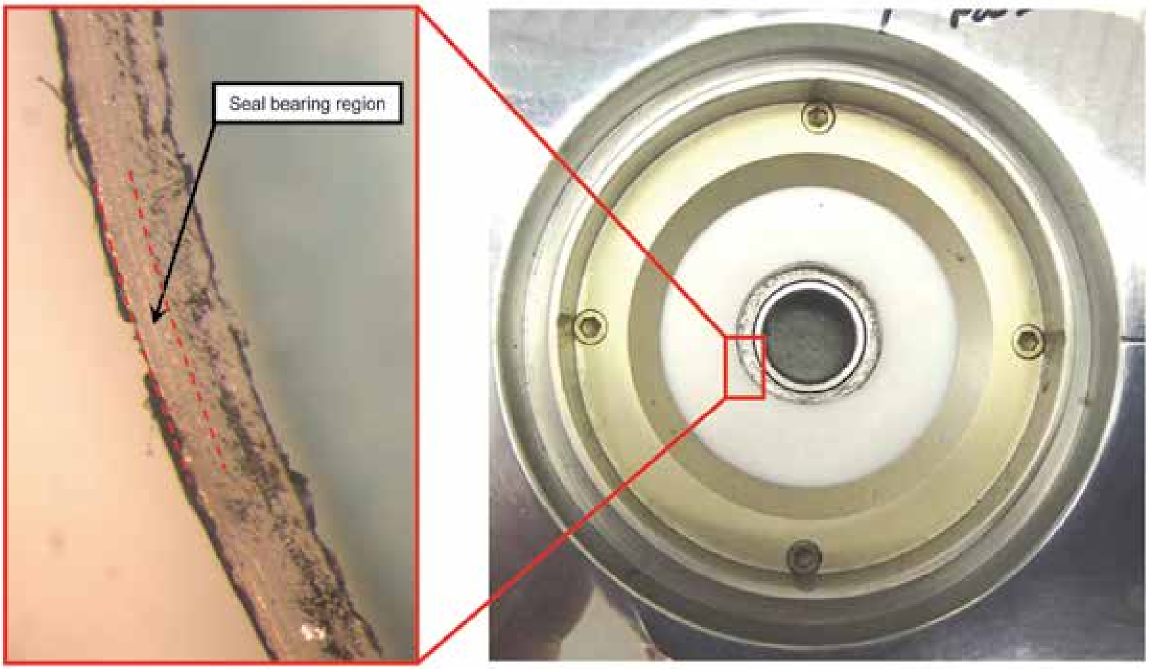

Figure 12
AOA seal condition showing circumferential wear marks on the bearing region

The AOA vane unit was functionally tested using the procedures set out in the factory acceptance test procedure. The unit passed all the tests and the accuracy and linearity of the angular position of the vane spindle was well within allowable tolerances. The AOA vane unit was then carefully disassembled and each component inspected; apart from the lack of concentricity of the PTFE seal, as previously seen in the CT scans, there were no discrepancies. The PTFE seal had been firmly clamped within the vane case by a clamping plate and four cap screws, indicating that this lack of concentricity had occurred when the unit was assembled.

The sealing flange of the PTFE seal exhibited surface wear marks around the complete circumference of the flange, indicating that at some point following manufacture, the entirety of the seal's flange had been in sliding contact with the AOA vane spindle. It was therefore determined that the PFTE seal flange had moved to its deflected position at some point during the unit's service life on N380CR.

Aircraft operation

Suggested climb profile

The manufacturer's Operating Manual page 18-5 describes the climb as:

> *'Climb*
>
> *Ensure gear and flaps are up, set power as needed and select autopilot (if desired). Monitor pressurization and fuel. Climb at approximately 200 kt until nearing 30,000 feet, then use a slower speed. Complete appropriate checks (refer to the AFM).'*

Chapter 20, on page four of the Manual provides a table to allow calculation of cruise climb performance. To climb from sea level to 43,000 ft at a takeoff weight of 12,250 lb and an average of ISA-5°C requires:

Time (Minutes)	20.25
Distance (Nm)	100.5
Fuel (lbs)	449.3
Vetical speed (ft/min)	638.5

Table 2
Cruise climb table

The manual also provides a cruise climb speed table that recommends maintaining an indicated airspeed of 230 kt to 20,000 ft, then reducing gradually to 181 kt at 35,000 ft, 160 kt at 40,000 ft and 142 kt at 45,000 ft.

Stalling speed table

The manufacturer's Airplane Flight Manual (AFM) includes a table of stalling speeds. The manufacturer informed the AAIB that this table is only applicable within the certified takeoff and landing altitudes of the aircraft, plus a margin of 1,500 ft, which for this aircraft is a maximum altitude of 15,500 ft. It is therefore not applicable for use at high altitudes.

Low-speed buffet

The cruise-climb performance section of the aircraft Operating Manual directs the pilot to check the buffet onset table in the AFM to ensure sufficient manoeuvre margin exists for the planned flight.

The AFM provides a method for calculating the available buffet margin for various weights and altitudes. Applying the aircraft's estimated weight of 11,758 lb and an altitude of 42,500 ft shows that, using a 1.3g margin, the low-speed buffet would be encountered at M 0.52 and an indicated airspeed of 140 kt. The accident aircraft was effectively in wings-level flight with 1g recorded just before the loss of control and in this condition the buffet speed is reported as M 0.45 (120 kt) – very close to the actual recorded speed of the accident aircraft just before it departed from controlled flight.

Certification requirements - stalling

FAR 23.201(e) states that the stall characteristics should be such that:

> *'… during the entry into and the recovery from stalls performed at or above 25,000 feet, it must be possible to prevent more than 25 degrees of roll or yaw by the normal use of controls'*

Regarding stall warning FAR23.207(c)[18] requires that:

> *' … the stall warning must begin at a speed exceeding the stalling speed by a margin of not less than 5 knots and must continue until the stall occurs'*

The manufacturer provided data from certification flight tests, including one conducted at 43,267 ft, and at a similar weight to the accident aircraft, to show that the aircraft met these requirements. In this high altitude test, the stick shaker activated at an indicated airspeed of approximately 116 kt and the minimum airspeed was 109 kt. Buffet was encountered at approximately 115 kt followed by left roll with the maximum roll attitude encountered during the recovery of approximately 10º which was quickly corrected by control inputs.

Footnote

[18] http://www.ecfr.gov/cgi-bin/text-idx?SID=04108958b44cc3c6236ce36f096951c3&node=14:1.0.1.3.10&rgn=div5#14:1.0.1.3.10.2.65.41

Pilot training

The pilot held a FAA Private Pilot Licence issued on the basis of his UK PPL. He completed initial type rating training for the Citation CJ series at a major training provider in Witchita, in 2006 and had returned to this provider for annual recurrent simulator and ground school training.

In addition he had completed a 'jet upset' course on an L-39 aircraft in Albuquerque, New Mexico in 2006. This comprised ground school and two flight sorties of 0.6 hours each.

The Training organisation's textbook states that the PFD attitude display features include:

> *'Large red chevrons point towards the horizon line when pitch attitudes approach 30° up or down…*
>
> *The PFD declutters (removes unnecessary information) automatically if pitch exceeds 30° nose up, 20° nose down, or 65° of bank. Only attitude, heading, airspeed and altitude are displayed in declutter mode. As pitch and/or bank is reduced all normal displays return.'*

Climb technique

The pilot later stated that he had started to use Vertical Speed mode during the climb after he found that N380CR "hunted in pitch" when climbing in Flight Level Change mode.

Analysis

Operational aspects and aircraft examination

The investigation determined that the pilot was trained and licensed in accordance with the relevant regulations. He was experienced and in current flying practice. When the aircraft departed from controlled flight, it was subjected to normal accelerations beyond its design limit, which was reflected in the damage sustained by the airframe. The aircraft had been maintained in accordance with the approved maintenance schedule and the only technical anomaly identified was in the AOA sensing system.

Use of the autopilot

The pilot had previously noticed his aircraft "hunting" in pitch in FLC mode and had therefore decided to operate in VS mode during the climb. Whilst the use of VS mode in the climb is not prohibited by the AFM, it exposed the aircraft to the risk of entering a low-energy state during the climb. Without greater systems knowledge the pilot was unaware of the additional risks involved in the use of VS mode. Therefore he was unable to make an informed decision regarding this autoflight mode.

The autopilot will, in this mode, prioritise maintaining vertical speed over airspeed and pilot vigilance and intervention is required to avoid a low-speed condition. As the aircraft was operating at the edge of its climb performance envelope there was insufficient thrust to follow the selected climb profile. Over a period of 50 seconds up to the departure from controlled flight, the airspeed steadily decayed, by 10 kt.

As the pilot approached FL430 he was distracted by looking at a portable electronic device. The upper winds information provided on the device was pertinent to the flight but was not as important at this point as the flightpath and energy information available on the PFD. Therefore he did not recognise the alerting features of low energy flight, specifically an unusually nose-high attitude, and unusually low, and decreasing, airspeed. The pilot's ability to recognise the low airspeed was also partially compromised by the static normalised AOA. The relationship between the red ISS and green V_{REF} 'donut' marker is complex. However, the green 'donut' would have been almost co-incidental with the aircraft's speed and the red ISS bar 19 kt below the speed indication on the tape. If the pilot had looked at this area of the display, the relationship between the red ISS, green 'donut' and indicated airspeed would have looked relatively normal and therefore unlikely to attract his attention, although the indicated airspeed would have been unusually low. At this point the pilot was not observing the PFD, the roll forces overcame the autopilot's control authority and the aircraft rolled to beyond 45°, disengaging the autopilot.

Stall warning system performance

The AReS recorded data shows that the AOA vane was sticking on the accident flight and also on a previous flight on 7 December 2013, in which the sticking AOA occurred at or close to the top of the climb to cruising altitude, where the ambient air temperature was very low. On the accident flight, this appeared to occur at a higher static air temperature and lower altitude but, in both cases, any moisture within the AOA vane case would readily form into ice, restricting the rotation of the AOA vane.

CT-scanning images of the AOA vane showed that an internal PTFE seal was displaced and was not sealing correctly against the vane spindle, and leak testing of the unit confirmed the lack of sealing capability of the PTFE seal. Witness marks on the PTFE seal's flange showed that, at some point since the AOA vane unit was manufactured, the seal had been in full circumferential sliding contact with the vane spindle. It must, therefore, have moved position at some point during its service life in N380CR.

The presence of a gap between the PTFE seal and the internal volume of the AOA vane case provided a path for moisture to enter the vane case, when the aircraft is parked and unpressurised. There was, however, no visible evidence of water staining or corrosion on the internal components of the AOA case when those parts were examined but it is likely that only a small amount of moisture would be required to create an intermittent AOA 'sticking' mechanism. The sticking of the AOA position represented a subtle, dormant failure that was not readily apparent to the pilot as it did not generate a warning annunciation.

The stall warning system was reliant on a single AOA vane to provide data to both the indicating system on the PFD and the stick shaker, which should have activated at least 5 kt before the stall. The sticking of the AOA vane, probably by freezing, removed the safety feature that was designed specifically to be a barrier to this type of event.

This aircraft type relies on a single AOA vane to provide stall warning, and failure of the internal PTFE seal may render the AOA vane unserviceable. As shown in this report, the AOA data recorded on the AReS system installed in the Citation CJ2+ is capable of detecting a 'sticking' (static) AOA vane during flight operations. Therefore, in the absence of any maintenance instruction that would result in this abnormal condition being detected in service, the following Safety Recommendations are made:

Safety Recommendation 2014-041

It is recommended that the Federal Aviation Administration requires the Cessna Aircraft Company, as the Type Certificate holder for the Citation CJ2+ aircraft, to conduct a survey of recorded flight data from Safe Flight Instrument Corporation model C-12717-1 angle-of-attack vane units, to determine the frequency of 'sticking' (static) angle-of-attack data.

Safety Recommendation 2014-042

It is recommended that the Federal Aviation Administration requires the Cessna Aircraft Company, as the Type Certificate holder for the Citation CJ2+ aircraft, to use the results of their survey (Safety Recommendation 2014-041) of recorded flight data from Safe Flight Instrument Corporation model C-12717-1 angle-of-attack vane units to amend the safety assessment of the aircraft's stall warning system.

Loss of control

From the analysis, the loss of control in this accident was caused by four factors:

- The pilot chose to operate in an autopilot flight mode that allowed the aircraft to decelerate to the stall.
- The pilot was distracted by a PED at a critical phase of flight and did not recognise the low airspeed, excessive pitch attitude or unusual roll angle.
- Whilst approaching a stall, the aircraft began to roll to the right. This was not corrected and the roll continued to 57° to the right in four seconds, causing the autopilot to disconnect.
- The safety feature provided by the stall warning system failed without alerting the pilot, due to the angle of attack probe freezing at 0.61 AOA.

Without recorded data showing control inputs, or the ability to model or simulate post-stall aircraft behaviour, it cannot be determined why the aircraft initially rolled right before departing from controlled flight.

After the initial roll to the right, the pilot was not presented with the correct ISS indication on his PFD, valid normalised AOA on the AOA gauge or the operation of the stick shaker. Other classic indications of an impending stall would have been present, including buffet and a display of low airspeed. The confusion encountered after autopilot disconnection, uncommanded roll and distraction from his PED is likely to have compromised any immediate recovery by reducing angle of attack.

As the aircraft departed from controlled flight into the sequence of right rolls, the display system reverted to the 'declutter' mode, with which the pilot was not familiar. A number of EGPWS 'BANK ANGLE' audio warnings were triggered and the AOA vane only moved during the fourth complete roll, which should have led to a stick-shaker activation for six seconds. The high roll rate, its effect on the attitude display and the prevailing IMC conditions resulted in a prolonged upset that was only recovered once the pilot had a visual external horizon. This recovery may, in part, have been due to the additional upset training the pilot received in 2006.

Conclusion

The pilot operated the aircraft in an autopilot mode which left it vulnerable to a stall and did not monitor the reducing airspeed as the aircraft reached its cruising altitude. The 'sticking' of the stall warning system removed the safety feature specifically designed to protect against this.

ACCIDENT

Aircraft Type and Registration:	Piper PA-31-350, N66886
No & Type of Engines:	2 Lycoming 540-J2B2 piston engines
Year of Manufacture:	1974 (Serial no: 31-7405188)
Date & Time (UTC):	9 April 2014 at 1447 hrs
Location:	Field near Stonehaven, Aberdeenshire
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:	Airline Transport Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	3,188 hours (of which 19 were on type) Last 90 days - 16 hours Last 28 days - 1 hour
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was on a ferry flight from Seattle in the USA to Thailand via Canada, Greenland, Iceland, Scotland and across Europe. However the flight crew abandoned the aircraft in Greenland late in December 2013 after experiencing low oil pressure indications on both engines. This may have been due to the use of an incorrect grade of oil for cold weather operations. The aircraft remained in Greenland until 28 February 2014, when a replacement ferry pilot was engaged. Although the engine oil was not changed prior to departing Greenland, the flight continued uneventfully to Wick, in Scotland. Following some maintenance activity on the right engine, the aircraft departed for Le Touquet in France. However, approximately 25 minutes after takeoff, the engines successively lost power and the pilot carried out a forced landing in a ploughed field. Examination of the engines revealed that one piston in each engine had suffered severe heat damage, consistent with combustion gases being forced past the piston and into the crankcase.

History of the flight

This accident occurred to a private aircraft and did not result in any injuries, so the AAIB initially dealt with it in the form of a correspondence investigation. However, in attempting to discover the facts surrounding the double engine failure, it was realised that this could not be achieved without conducting an examination of the engines. It then became apparent that the flights preceding the accident flight were relevant to the investigation. These flights were conducted outside the United Kingdom and involved foreign nationals, so no formal statements from the flight crew or maintenance personnel were available.

Some of the following information on the recent history of the aircraft is therefore based on anecdotal evidence.

The aircraft, a Piper PA-31-350 Chieftain, registration N66886, was purchased in Seattle, USA, in August 2013 and was in the process of being delivered to a customer in Thailand. The intended routing for the aircraft was that it would fly east across the continental USA and then across the North Atlantic from Canada to Greenland, Greenland to Iceland, Iceland to Scotland, Scotland to France and onward to Thailand.

The information indicated that the aircraft was flown from Seattle as far as Sondrstrom in Greenland by two pilots normally employed by an Asian airline. The ferry flight was abandoned at Sondrstrom late in December 2013, with the aircraft being parked and the pilots leaving it there due to reports of low oil pressure on both engines. It was considered that the low engine oil pressure may have been caused by the aircraft being operated in extremely low temperatures in December with the incorrect grade of engine oil for cold-weather operations. Arrangements were subsequently made, in conjunction with an aircraft handling company based at Wick in Scotland, to send an appropriate quantity of multigrade oil suitable for low-temperature operation, together with two replacement oil filters, to Sondrstrom for installation on the aircraft in order to permit further flight. The aircraft was, however, left at Sondrstrom until the 28 February 2014 when a replacement ferry pilot was engaged to continue the ferry flight to Thailand by the originally intended route. It is apparent from the engine log books that no engine oil change or any other maintenance activity was conducted at Sondrstrom; the pilot commented that this was due to a combination of a lack of maintenance facilities and normal indications, including oil pressure, when he started the engines. In fact the most recent log book entry prior to the aircraft's arrival in the UK was dated 12 August 2013, when the engines were each subjected to an Annual Inspection and serviced with Aeroshell W100 oil.

Having departed Sondrstrom, the flight continued uneventfully, with no engine oil pressure problems, through Narsarsuaq in Greenland then via Iceland to Wick Airport in the north of Scotland, arriving there on the 3 March 2014 where the right-hand engine was noted to be running roughly. After investigation by a local qualified aircraft engineer, it was discovered that the No 4 cylinder had low compression and consequently a replacement cylinder set, complete with associated seals, gaskets and other required parts, was fitted to the aircraft. The work was completed and certified in the engine logbook on the 27 March 2014.

The ferry pilot subsequently arrived at Wick to resume the aircraft ferry flight on the 9 April 2014 and, following an inspection of the aircraft, he departed at 14:50 hours local with the intention of completing the first leg of his flight to Le Touquet Airport in France. However, approximately 25 minutes after departure, and at Flight Level 090 routing from Aberdeen direct to the VOR located at St Abbs Head, the pilot noted falling manifold pressure and fuel flow on the right-hand engine. He selected the mixture to rich, switched on the standby fuel pump and changed the fuel supply from the outboard to the inboard tank. He then engaged the starter and conducted the re-start procedure, without success. The pilot increased the power on the left engine and informed Aberdeen of his problem, requesting a diversion there. Having altered course towards Aberdeen, the pilot then found he was unable to maintain height due to a loss of power on the left engine. Although he had received clearance to land, it quickly became apparent that he would be unable to reach Aberdeen; he therefore opted to put the aircraft down in a ploughed field. Shortly before touching down, both engines failed completely and the pilot reduced his airspeed before landing heavily and coming to a halt after a short ground-slide. There was no fire and the pilot was uninjured.

Aircraft recovery

The aircraft was recovered to the premises of a breakdown and accident recovery company near Aberdeen, where it was stored in the open. The engines were subsequently removed to an aircraft engineering company at Perth, where they were disassembled under the supervision of an AAIB Inspector.

Examination of the engines

Left engine

Photographs taken at the accident site indicated that the left engine nacelle and horizontal stabiliser were both heavily smeared with oil. In addition the oil filler flap on the cowling was open and the dipstick was missing. The photographs also indicated that the propeller had not been feathered.

Before commencing disassembly it was observed that the engine could be turned, albeit stiffly, and that the turbo spool could be easily rotated under finger pressure. Very little oil remained in the sump - approximately a quarter of a litre.However, it was reported that the engine had been placed upside down on the ground at some stage which, in the absence of the dipstick could have allowed oil to escape. The dipsticks in both engines were of the 'push-in' as opposed to 'screw-in', type.

On removing the cylinders it was found that the No 6 piston (rear left) had sustained severe damage, in the form of burning and melting, around a portion of its circumference and this extended to the piston skirt and rings; see Figure 1. There were two compression rings and one oil scraper ring and it was apparent that the gaps in the rings were aligned, whereas normal practice is to install the rings such that the gaps are positioned well apart from each other around the piston circumference.

Figure 1
Left engine No 6 piston, showing damage to crown, skirt and rings

It was apparent that the ends of the rings had been eroded to the extent that the gaps had widened to between 0.5 and 1.0 in.

The damage was indicative of 'blow by', where the combustion gases find a way past the piston and into the crankcase. After removing the piston it was found that the connecting rod, together with that of No 5 cylinder opposite, had been severely heat-affected. Removal of the No 5 cylinder revealed that the big end bearing shell material had become extruded onto the flanks of the connecting rod, where it had solidified into flakes; see Figure 2. Similar debris was also found in the oil filler shaft.

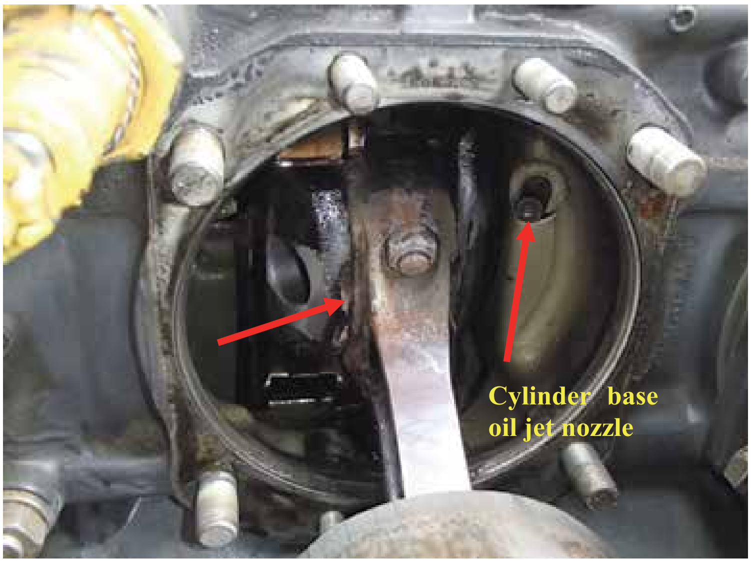

Figure 2

No 5 piston connecting rod showing flakes of extruded bearing shell material and oil jet nozzle

The connecting rod was stiff to rotate, indicating a partially seized big end bearing. The No 6 connecting rod rotated easily, but some radial play was noted, suggesting that much of the bearing shell material had disappeared from its associated bearing.

Elsewhere in the engine, the No 1 cylinder proved difficult to remove. This was found to be the result of the cylinder base jet oil nozzle (an intact example is seen in Figure 2) having become loose and, at some point, become jammed against the cylinder skirt, possibly by the big end bearing cap, which was damaged, causing distortion. The flattened remains of the nozzle were found within the crankcase.

No significant features were observed in the remaining cylinders. In particular, the combustion deposits were light and normal in appearance. Finally, it was observed that cylinder Nos 1 and 6 were not manufactured by the engine manufacturer, Lycoming, but were 'PMA' (Parts Manufacturer Approval) components, approved by the Federal Aviation Administration (FAA).

Right engine

Prior to disassembly, it was noted that the propeller, like that on the left engine, was not in the feathered position. The engine was difficult to turn, suggesting partial seizure or crankshaft distortion as a result of the ground impact, although the turbo spool could be rotated under finger pressure. The oil level did not reach the bottom of the dipstick, with 3.5 litres eventually being drained from the sump.

On removing the cylinders it was found that the No 3 piston had sustained almost identical damage to the No 6 cylinder from the left engine (see Figure 3).

The piston crown was perhaps less severely damaged in comparison with the left engine's No 6 piston, although the skirt appeared in worse condition, and the observed damage was again indicative of 'blow by' of the combustion gases. It was noted that, although the gaps in two of the rings had become aligned, this was away from the area of burn damage. It was also noted that the rings had broken into a number of segments, a likely consequence of the piston damage.

Figure 3

Damaged No 3 piston on right-hand engine

Removal of the remaining cylinders revealed no additional defects. In particular, the No 4 cylinder, which had been replaced at Wick, appeared in good condition, although the associated connecting rod was stiff on its bearing. The No 3 cylinder was observed to be a PMA component, the remainder being manufactured by Lycoming.

As with the left engine, the combustion deposits in the unaffected cylinders were normal in appearance.

Oil analysis

Samples of oil taken from both engines were subjected to detailed analysis by a specialist company.

The sample from the left engine contained a significant quantity, some 2 to 4%, of water. The bulk of this is likely to have been rainwater introduced as a result of the engine having been stored outdoors, with the dipstick missing. The water content in the sample from the right hand engine was much lower, but was still considered high for used engine oil. Whilst high water content can affect the viscosity of oil, both samples were found to be broadly consistent with Aeroshell W100.

Both samples contained considerable quantities of sludge and particulates, including metal debris. The sample from the right engine had a burnt odour and it was concluded, as a result of acidity analysis, that the oil from both samples was significantly oxidised, which was indicative of being well used and exposed to elevated temperatures.

The particulate material was found to include elevated levels of silicon, which may be due to general dirt, grease and sealants. Metal particles were consistent with originating from bearings and pistons.

Additional analysis revealed that both samples contained trace metals at elevated levels; these were typical wear metals and included iron, copper, aluminium, magnesium and chromium. Lead was also present, which can come from white metal bearings but in this case was considered likely to have originated from the fuel, AVGAS. None of the analyses found any evidence of kerosene type fuels (Jet A-1).

There was no opportunity to conduct an analysis of the fuel carried in the aircraft as no samples were available in either engine, and the fuel removed from the aircraft after the accident had been transported in containers contaminated with other liquids.

Engine manufacturer's comments

The engine manufacturer confirmed that the W100 grade of oil was incorrect for cold-weather operation and commented that using this oil during cold-weather starting, without pre-heating the engine, could result in damage consistent with lack of lubrication.

The condition of the No 6 piston on the left engine and the No 3 piston on the right engine appeared consistent with detonation (pre-ignition) damage. Lycoming's experience has shown that such damage can arise from a number of factors, including lean mixture setting, incorrect ignition timing, induction leaks, excessive oil consumption and incorrect or contaminated fuel. In their opinion, the extreme heat, leading to the extrusion of bearing material in the No 5 connecting rod bearing in the left engine, may have been caused by operating the engine with less than the minimum safe quantity of oil in the sump.

The manufacturer made no comment on the use of PMA components on their engines.

Discussion

The aircraft began experiencing engine problems, leading to the forced landing, approximately 25 minutes after departing Wick, in Scotland. However, it is possible that these problems may have originated prior to the aircraft arriving in the UK. The low oil pressures in both engines, reported by the crew on the flight leg to Greenland, may have been due to the wrong grade of oil, W100, being used in what would have been very low temperatures experienced in December in Canada and Greenland. Despite supplies of multigrade oil being sent to Greenland, the engine oil was not changed. This was due to the fact that the pilot noted normal engine indications combined with the lack of maintenance facilities. Thus the aircraft continued its journey with the same oil in the engines with which it left Seattle; this was confirmed by the subsequent analysis of the oil. No further oil pressure problems were observed, although it is likely the aircraft would have been operating in warmer temperatures at the end of February in comparison with those in December.

The engine manufacturer suggested that engine damage could have occurred as a result of operating the engines at low temperatures with the wrong grade of oil. Whilst this may have been the case, it is surprising that any damage did not progress to the point where it became readily apparent during the subsequent flights, via Iceland, to Wick. In fact the pilot did report rough running of the right-hand engine, but the investigation revealed a problem only with the No 4 cylinder compression, which led to replacement of this cylinder. Since the compressions in all the cylinders were presumably assessed during the diagnosis, it must be concluded that any damage in the No 3 cylinder of the right engine was not, at that stage, significant.

Ultimately, it was not possible to establish why pistons in both engines had suffered virtually identical types of damage, although it is likely to have been a ‘common mode’ failure, which could include wrong fuel, incorrect mixture settings (running too lean) and existing damage arising from the use of incorrect oil in cold temperatures. The oil analysis excluded the possibility of the aircraft having been mis-fuelled with Jet A-1 at Wick. No conclusion can be drawn regarding the possibility of one of the pilots having leaned the mixtures to an excessive degree, although this would require that either high cylinder head temperature indications were ignored, or that the temperature gauges (or sensors) on both engines were defective.

The engines would have begun to fail when the combustion gases started to ‘blow by’ the pistons, causing progressive damage to the piston crowns, skirts and rings. This would have also caused pressurisation of the crankcases, which in turn would have tended to blow oil out of the crankcase breathers. In the case of the left engine, the pressurisation was such that the dipstick was blown out of its tube, resulting in more oil being lost overboard. This may have accounted for the more severe damage to the left engine, having lost more oil than the right. The detached No 1 cylinder base jet oil nozzle in the left engine may have contributed to a slight reduction in the oil pressure, but is otherwise considered to have played no part in the engine failure.

AAIB correspondence reports

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

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

The accuracy of the information provided cannot be assured.

ACCIDENT

Aircraft Type and Registration:	Beech F33A, N999F
No & Type of Engines:	1 Continetal Motors Corp IO 520-BB
Year of Manufacture:	1988 (Serial no: CE-1282)
Date & Time (UTC):	21 June 2014 at 1515 hrs
Location:	Jersey Airport
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to left wing and landing gear
Commander's Licence:	Private Pilot's Licence
Commander's Age:	65 years
Commander's Flying Experience:	1,177 hours (of which 501 were on type) Last 90 days - 10 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The left gear leg failed to lock down prior to landing and slowly collapsed during the landing roll, causing the aircraft to veer off the runway. The gear extension rod for the left gear leg was subsequently found to have failed in compression, but the reason for the failure was not evident.

History of the flight

The aircraft was inbound to Jersey Airport. The pilot was unable to obtain a green light for the left landing gear, despite several checks and attempts to recycle the gear. He made an approach knowing that the left gear leg might not be locked down. After the aircraft touched down, the left gear leg slowly collapsed and the aircraft veered off the runway onto the grass.

Additional information

The landing gear actuation system on the F33A Bonanza consists of a central gearbox that drives three gear extension rods, one for each of the three gear legs. The gear extension rod for the left gear leg was found to have failed in compression.

This aircraft had suffered a gear leg collapse on landing in 2006. In November 2012, the extension rod for the left gear leg was found to be bent during the annual inspection and was replaced. It was this replacement extension rod that failed in compression at Jersey.

The cause of the failure to the extension rod was not determined, but the central gearbox is being replaced as a precaution.

ACCIDENT

Aircraft Type and Registration:	Grob G115E Tutor, G-BYWK
No & Type of Engines:	1 Lycoming AEIO-360-B1F piston engine
Year of Manufacture:	2000 (Serial no: 82146/E)
Date & Time (UTC):	11 October 2014 at 1130 hrs
Location:	Colerne Airfield, Somerset
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damaged propeller and tail skid
Commander's Licence:	Student pilot
Commander's Age:	20 years
Commander's Flying Experience:	15 hours (of which 5 were on type) Last 90 days - 3 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Earlier on the day of the accident, the student pilot had flown a circuit consolidation exercise, during which she conducted eight landings. Her instructor reported that the circuits were generally well flown. Following three consecutive good landings, the instructor made the decision that his student was ready to undertake her first solo flight.

The weather was fine, with a surface wind from 220° at 9 kt. The student was briefed to fly a single circuit on Runway 20, a 900 m hard runway. The circuit was observed by the student's instructor, watching from the ATC control tower. He reported that it appeared satisfactory until the point of landing, when the aircraft bounced a number of times. The student decided to abandon the landing attempt and successfully flew a go-around manoeuvre.

On the second landing attempt the aircraft again bounced a number of times and appeared to enter a Pilot Induced Oscillation (PIO) for a time, before the student pilot was able to bring the aircraft under control on the runway. She was instructed to taxi clear of the runway and await assistance. It was subsequently established that the aircraft's propeller and tail skid had struck the runway surface.

ACCIDENT

Aircraft Type and Registration:	Pioneer 300, G-DEWY
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2005 (Serial no: PFA 330-14292)
Date & Time (UTC):	16 August 2014 at 1810 hrs
Location:	Churt, Surrey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - N/A
Nature of Damage:	Severe airframe damage
Commander's Licence:	Light Aircraft Pilot Licence
Commander's Age:	81 years
Commander's Flying Experience:	2,200 hours (of which 66 were on type) Last 90 days - 13 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft suffered an engine failure whilst it was positioning to land, flying over a wooded area. The aircraft hit the trees and the pilot sustained serious injuries. The reason for the engine failure was not positively determined.

History of the flight

After an uneventful flight from Old Sarum, the pilot carried out his joining checks for Frensham Airfield, during which he selected the fuel tank that was indicating it had the most fuel, to feed the engine. The weather conditions were good with moderate winds.

The local procedures at Frensham require joining aircraft to overfly the airfield at 600 ft agl before landing, to check for horses, and to give riders time to vacate the strip. The pilot complied with this procedure and, having determined there were no horses, he flew a second circuit intending to land. During the base leg, at 400 ft, the aircraft experienced some turbulence whilst flying over a wooded area, and the engine stopped. The pilot recalls turning directly for the airfield, checking his fuel pump was on and selecting the other fuel tank, whilst adjusting to the best glide speed of 55 kt. The next recollection the pilot has was that the aircraft stopped abruptly in the tree tops and fell to the ground inverted.

The pilot was discovered some time later but, because of the location of the accident, it was several hours before paramedics were able to cut him free from the aircraft. His injuries were categorised as severe.

The pilot checked the gascolator after the accident and found it to be clear of debris. He considered the engine failure was probably caused by an unreliable fuel sender, or fuel gauge, leading the engine to be starved of fuel. His calculations showed that 24 litres should have been available in his other fuel tank, which would be enough for more than an hour of flight.

Comment

The emergency procedures section of the aircraft flight manual contains the following warning:

> *'The engine installed in the Pioneer 300 is not certified and can fail at any time. Never fly over areas on to which a safe landing cannot be made in the event of an engine failure. On cross country flights, continually update safe landing fields as the journey progresses.'*

ACCIDENT

Aircraft Type and Registration:	Piper PA-24-250 Comanche, G-ARLB
No & Type of Engines:	1 Lycoming O-540-A1D5 piston engine
Year of Manufacture:	1960 (Serial no: 24-2352)
Date & Time (UTC):	1 October 2014 at 1153 hrs
Location:	Turweston Aerodrome, Northamptonshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Engine shock-loaded, damage to propeller and fuselage underside
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	76 years
Commander's Flying Experience:	2,492 hours (of which 892 were on type) Last 90 days - 8 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot took off from Blackbushe to position the aircraft to Turweston for maintenance. During the climb-out, whilst retracting the landing gear, the aircraft lost electrical power. The pilot was unable to restore power and elected to return to Blackbushe. He then found that the landing gear could not be lowered manually and so he decided, as originally planned, to fly to Turweston where the aircraft's maintenance organisation was based. The aircraft made a gear-up landing at Turweston and the pilot, who was uninjured, exited the aircraft normally.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-161 Cadet, G-BXJJ
No & Type of Engines:	1 Lycoming O-320-D3G piston engine
Year of Manufacture:	1989 (Serial no: 2841200)
Date & Time (UTC):	17 October 2014 at 0820 hrs
Location:	Near White Waltham Aerodrome, Berkshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 2 (Minor) Passengers - N/A
Nature of Damage:	Substantial, both wings detached
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	2,890 hours (of which 1,200 were on type) Last 90 days - 180 hours Last 28 days - 56 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and information from the operator

Synopsis

Whilst the aircraft was engaged in a circuit training flight, the engine suffered a loss of power on base leg. The instructor took control and carried out a forced landing. As the aircraft descended, power cables were spotted on the approach path and in avoiding them the aircraft landed short of the intended field and collided with a hedge. The aircraft was severely damaged in the collision. In the absence of any mechanical defects, carburettor icing is considered to be the most likely cause of the power loss, given the number of risk factors present on the day.

History of the flight

The purpose of the flight was for the student pilot to practise flying circuits. The daily inspection was completed normally and no defects were noted. The fuel onboard was 34 US Gal and the check of the fuel drains did not identify any water or other contamination. The start-up, taxi and pre-takeoff checks were normal. Application of carburettor heat for approximately 10 seconds produced a 50 rpm drop and the rpm returned to its original value when the control was returned to the OFF position.

The takeoff, climb out and downwind leg were normal, except that the carburettor heat was left in the ON position after the downwind checks. The instructor noticed this, but decided to not to say anything as it would be needed again for the imminent descent. The student pilot then reduced the engine power, possibly slightly more than normal, to slow the aircraft in order to extend two stages of flap and commence the approach. The aircraft became lower than planned and when the throttle was advanced to add power, the engine did not respond. The instructor took control, declared a MAYDAY on the aerodrome frequency and then conducted emergency drills, which included changing the fuel selector to the other tank. The aircraft descended faster than anticipated and as the height reduced power cables became visible on the approach path. In order to avoid a potential stall by attempting to fly over the cables, the instructor decided to descend and fly under the cables. The aircraft landed short of the intended field (Figure 1) and it collided with a hedge and was severely damaged. The student selected the electrical master and other switches OFF.

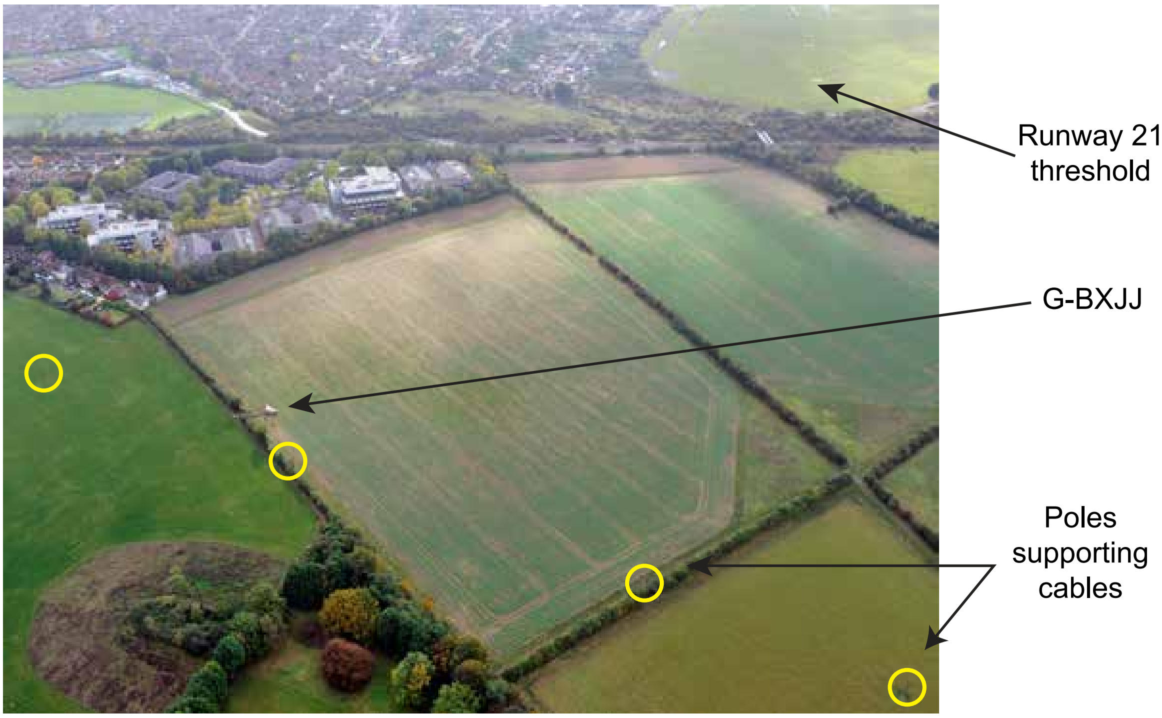

Figure 1

Aerial view of the accident site
(courtesy National Police Air Service)

Evacuation

The fuselage came to rest on its right side and the occupants were therefore unable to open the cabin door. They could smell fuel and saw it leaking from the detached wings. They were unable to dislodge the windscreens, but were able to make their escape through the left side window. They used the fire extinguisher to break the window using the direct vision window cut-out as a weak point. There was no fire.

The aerodrome called the emergency services and dispatched their own rescue and fire fighting services to the off-aerodrome location. After vacating the aircraft the instructor was able to use his mobile telephone to call the aerodrome operations to pass them his location. Assistance arrived a few minutes later.

Engineering examination

The aircraft was recovered to the operator's maintenance facility where it was examined by their engineers. The throttle and mixture controls were found connected and they operated normally through their whole range. The carburettor heat control was connected but unable to move over its full range due to distortion to the air box caused by the accident. The primer was found in and locked. The fuel system was checked and no defects were identified; the gascolator filter was clean. The engine was removed from the airframe and taken to a test facility, where it ran normally.

Weather conditions

At the time of the accident the METAR for London Heathrow Airport, 10 nm to the east, reported the wind from 190° at 6 kt, scattered cloud at 1,200 ft with temporary broken cloud at 1,200 ft, temperature 15°C and the dew point 14°C.

Carburettor icing

The CAA Safety Sense Leaflet No14, '*Piston Engine Icing*' (http://www.caa.co.uk/docs/33/20130121SSL14.pdf) gives advice and guidance on how to recognise and avoid carburettor icing. It notes:

> *'The most common, earliest to show, and the most serious, is carburettor (carb) icing caused by a combination of the sudden temperature drop due to fuel vaporisation and pressure reduction as the mixture passes through the carburettor venturi and past the throttle valve.*
>
> *If the temperature drop brings the air below its dew point, condensation results, and if the drop brings the mixture temperature below freezing, the condensed water will form ice on the surfaces of the carburettor. This ice gradually blocks the venturi, which upsets the fuel/air ratio causing a progressive, smooth loss of power and slowly 'strangles' the engine.'*

The leaflet also includes a chart, Figure 2, to show the atmospheric conditions most likely to cause carburettor icing. Plotting the temperature and dew point reported on the day of the accident onto this chart indicates that serious carburettor icing was likely to be present at any power setting.

A number of risk factors are also indentified in the leaflet, including:

> *'when:*
> - *just below cloud base*
> - *the ground is wet (even with dew) and the wind is light'*

The summary section of the leaflet includes the advice:

> *'Icing may occur in warm humid conditions and is a possibility at any time of the year in the UK.*

> *Low power settings, such as in a descent or in the circuit, are more likely to produce carburettor icing.*
>
> *Warming up the engine before take-off improves the effectiveness of any carburettor body heat.'*

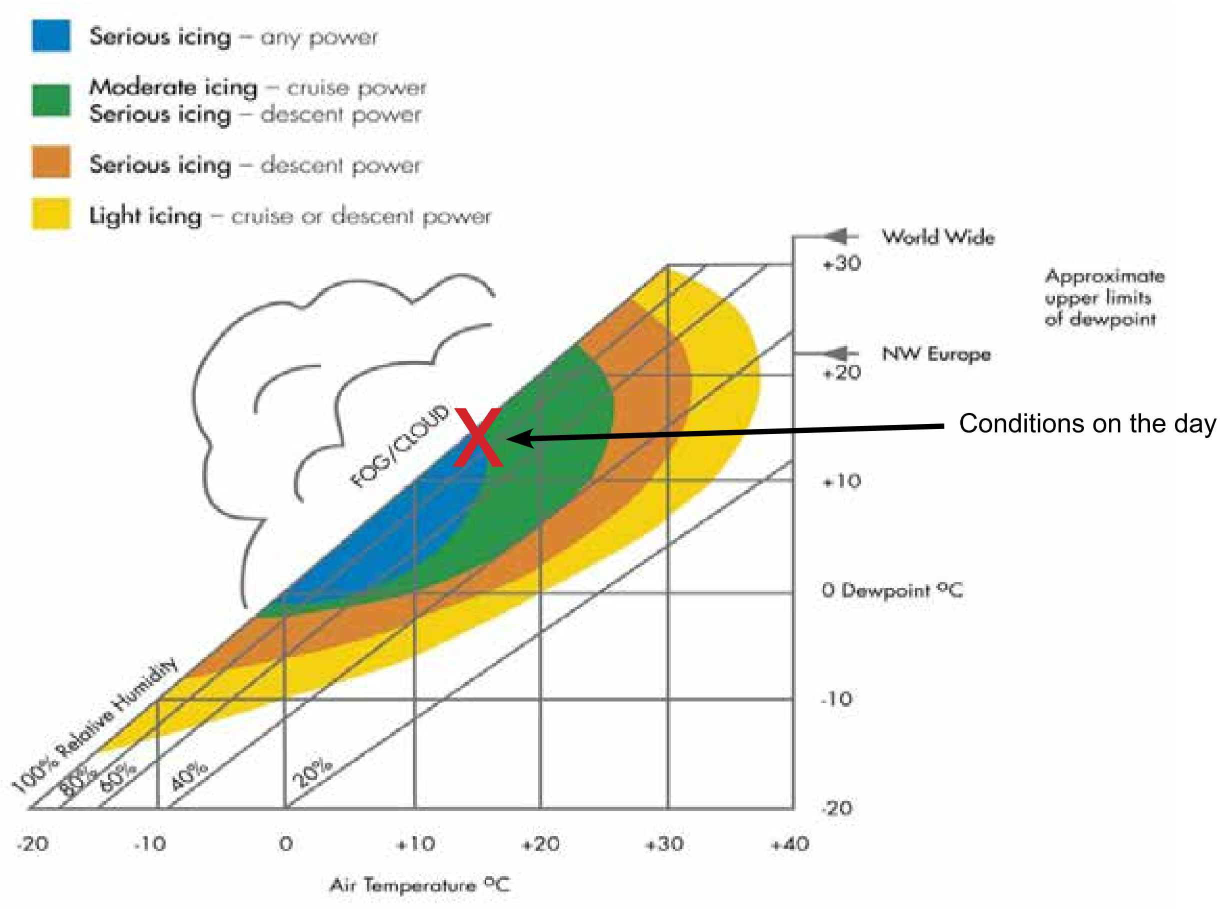

Figure 2

Carburettor icing chart from CAA Safety Sense Leaflet 14, *Piston Engine Icing*

The operator's Operations Manual V2.0 also notes:

> *'Carburettor icing is not restricted to cold weather and can occur on warm humid days, especially at low throttle settings (for example when descending or on approach to land).'*

Discussion

In the absence of any mechanical defects, it seems that carburettor icing is a likely cause of the power loss, given the number of risk factors present on the day. These included: high humidity, a low power setting and the engine was probably not up to full operating temperature. The CAA Safety Sense Leaflet No14, '*Piston Engine Icing*' discusses carburettor icing and its avoidance in more detail.

The student pilot commented that he had not been shown how to remove the fire extinguisher from its stowage and he feels if he had been, he would have been quicker to exit the aircraft. He also noted that it would have been useful to know the left side window offered an alternative means of escape and the DV window cut-out provided a useful weak point to assist in breaking the window.

Safety action

The operator has highlighted the CAA Safety Sense Leaflet 14, '*Piston Engine Icing*' to its members. It has also placed a laminated copy of the leaflet in their flight planning room for easy reference and included a link to the leaflet in the Pilot Information section of their website.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-181 Cherokee Archer II, G-BSIM
No & Type of Engines:	1 Lycoming O-360-A4M piston engine
Year of Manufacture:	1986 (Serial no: 28-8690017)
Date & Time (UTC):	28 October 2014 at 1545 hrs
Location:	Near RAF Henlow, Bedfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to left landing gear, left wing and fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	188 hours (of which 71 were on type) Last 90 days - 4 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and recorded weather information

Synopsis

The aircraft experienced a loss of engine power whilst in the visual circuit. Unable to restore power, the pilot carried out a forced landing in a nearby field, during which the aircraft struck an obstacle and was damaged. The pilot, who was uninjured, reported that the loss of power had been due to induction system icing; conditions at the time were conducive to such icing.

History of the flight

The pilot was conducting a local general handling flight from the airfield at RAF Henlow. The weather was fine and clear, with a temperature of about 15°C. A weather front was approaching the area from the north-west and cloud associated with it was visible to the pilot at the time, albeit some distance away. Pre-flight preparations and engine checks were normal, and the aircraft took off at 1515 hrs from the grass Runway 20.

The pilot flew three takeoffs and landings, during which time engine performance appeared normal. On the fourth circuit, as the aircraft turned onto the base leg and the pilot applied carburettor heat prior to reducing power, there was an immediate drop in engine rpm and an increase in engine noise.

The pilot throttled back but the engine continued to run abnormally. It did not stop but power delivery was erratic. The pilot declared an emergency and carried out cockpit actions in an attempt to recover engine power. This was not effective and, with insufficient power available to reach the runway, the pilot identified a field for a forced landing.

Touchdown was made on the mainwheels and the landing roll was normal at first. However, the aircraft encountered a small land drain, that deformed the left main landing gear which led, in turn, to some damage to the left wing. The aircraft continued to decelerate for about 30 or 40 m while yawing to the left. It came to rest having deviated 90° from the direction of landing.

The pilot, who was uninjured, reported that the loss of engine power was due to carburettor icing. The meteorological report for Luton Airport (8.5 nm south) at 1520 hrs gave a temperature of 16°C and a dew point of 11°C. Over the next two hours, these values changed to 14°C and 13° C respectively. Figure 1 shows a graph widely used to predict the likelihood of induction system icing. Using the conditions reported at Luton Airport, the aircraft can be seen to have been at risk of moderate icing at cruise power and serious icing at descent power. A more refined version of the graph (not shown here) identifies a risk of serious icing at both cruise and descent power settings for carburettor equipped engines, such as that fitted to G-BSIM.

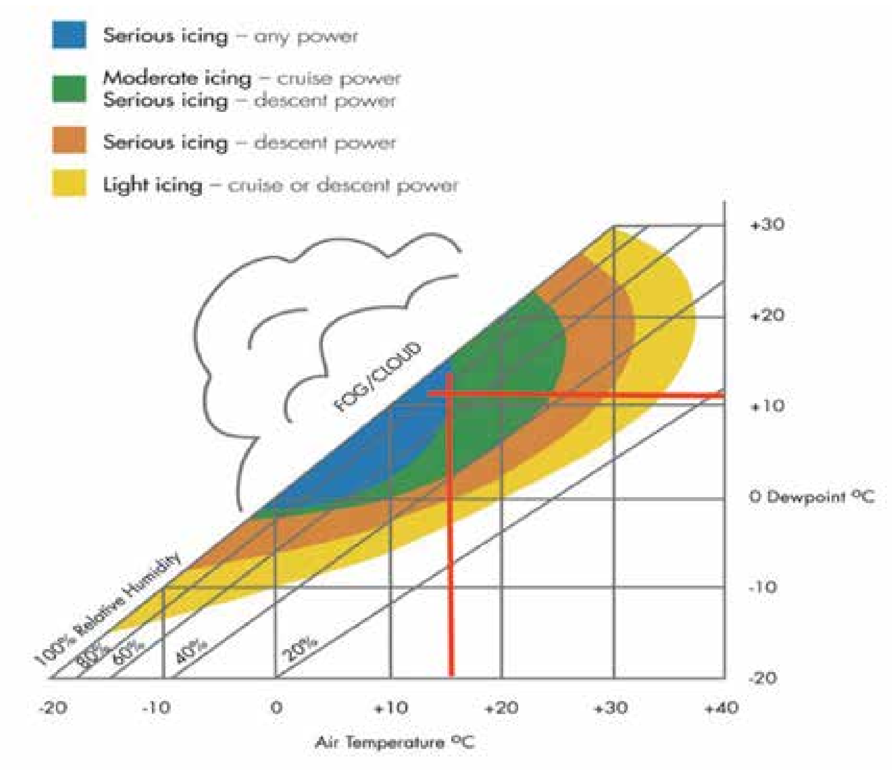

Figure 1

Graph predicting risk of induction system icing; actual values of temperature and dewpoint shown by red lines

ACCIDENT

Aircraft Type and Registration:	Reims Cessna F172P Skyhawk, G-SBAE
No & Type of Engines:	1 Lycoming O-320-D2J piston engine
Year of Manufacture:	1983 (Serial no: 2200)
Date & Time (UTC):	6 August 2014 at 1614 hrs
Location:	Blackpool Airport, Lancashire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Engine shock-loaded; damage to nose gear and propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	113 hours (of which 53 were on type) Last 90 days - 2 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was practising circuits. His approach for a planned touch-and-go appeared normal, but on touchdown the aircraft bounced twice before the nosewheel touched firmly and the propeller struck the runway. The pilot considered that he should have initiated a go-around after the first bounce.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-MOGY
No & Type of Engines:	1 Lycoming O-320-B2C piston engine
Year of Manufacture:	1988 (Serial no: 899)
Date & Time (UTC):	30 October 2014 at 1258 hrs
Location:	0.5 nm SE of West Chevington, Northumberland
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Helicopter destroyed
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	2,019 hours (of which 1,133 were on type) Last 90 days - 189 hours Last 28 days - 48 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst an instructor and student were practising circuits over a muddy stretch of open ground, the right skid dug into the surface and the helicopter rolled over, coming to rest on its left side. The instructor, who was in control at the time, believes several factors led to him misjudging the helicopter's height above ground when transitioning from the hover to forward flight.

History of the flight

The instructor and student were engaged on a training assignment identical to one they had practised the previous day. They departed Newcastle Airport to the north and commenced a series of autorotations from altitude with power recovery at a piece of open ground about 26 km from the airport. They then began circuit practice, which was performed into wind and in a right-hand direction.

At the time of the accident, the instructor was demonstrating a circuit to the student. During the transition to forward flight from the hover, having gained Effective Translational Lift (ETL), the instructor applied more forward cyclic control in order to gain speed. Simultaneously, he lowered the collective control to remain at the same height, as he felt that the extra lift was causing them to climb. However, it appears that these control inputs caused the helicopter to descend until the front of the right skid struck the ground and dug into the muddy, level surface. The instructor also recalled that the helicopter was yawing to the left as it struck the ground, which he believes indicates that the collective had been lowered excessively. The helicopter pivoted forward and rotated to the right about the skid, before coming to rest on its left side. The instructor shut down the engine and both occupants evacuated through the shattered windscreens.

Pilot's comments

The instructor cited a number of possible causal factors in the accident. Firstly, he states that the first part of his helicopter flying career was carried out in hot climates, which dictated that hover heights were generally lower due to power limitations and he was therefore comfortable with such heights. Secondly, the muddy nature of the field was conducive to inadvertent contact leading to dynamic rollover. Finally, the level, featureless surface may have created difficulties with depth perception at the time of the accident – an opinion he states was expressed by the crew of a police helicopter that attended the scene.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-OKEY
No & Type of Engines:	1 Lycoming O-320-B2C piston engine
Year of Manufacture:	1991 (Serial no: 2004)
Date & Time (UTC):	21 September 2014 at 1600 hrs
Location:	Elstree Aerodrome, Hertfordshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Substantial damage to fuselage, windscreen, main rotor and skids
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	4,560 hours (of which 2,000 were on type) Last 90 days - 154 hours Last 28 days - 60 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The instructor was conducting an introductory flying lesson. He lifted off and flew into the circuit to the north of the airfield and, after turning onto the downwind leg, he handed control of the cyclic stick to the student. The student flew the rest of the circuit with very little intervention from the instructor down to about 300 ft agl, where the instructor again took control.

The instructor then flew the helicopter to the hovering area where he again gave control of the cyclic to the student. After about a minute of hovering, the instructor applied a gentle forward pressure on the cyclic to correct a somewhat nose-high attitude, whereupon the student suddenly applied a large, aggressive rearwards input to the stick and then 'froze'. Before the instructor could take corrective action, the helicopter impacted the ground in a nose-high, right-skid-low attitude and the main rotor struck the ground, spinning the aircraft round through 180º. The helicopter came to rest in an upright attitude, but with the right skid collapsed. No explanation was forthcoming as to why the student had reacted in this manner.

INCIDENT

Aircraft Type and Registration:	Vans RV-8, G-NRFK
No & Type of Engines:	1 Lycoming YIO-360-M1B piston engine
Year of Manufacture:	2013 (Serial no: PFA 303-14135)
Date & Time (UTC):	2 October 2014 at 1304 hrs
Location:	Norwich Airport
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Main wheel fairings damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	466 hours (of which 7 were on type) Last 90 days - 7 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot, who had previous experience on tailwheel aircraft, was undergoing dual conversion training on the Vans RV-8. The weather conditions were fine, with a wind of 3 to 5 kt, variable in direction. He reported that he flew a stable approach and achieved a gentle touchdown, which the pilot's instructor reported as being normal for the type. As the aircraft decelerated after landing, it deviated to the right and the pilot attempted to correct the deviation with increasing left rudder pedal. The aircraft then yawed to the left and ground looped (at a speed the instructor estimated as 30 kt) before being brought to a stop on the runway. The main wheel fairings were broken but the aircraft was otherwise undamaged.

BULLETIN CORRECTION

The occurrence was incorrectly classified as an accident. The occurrence is reclassified as an incident.

The online version of the report was corrected on 17 March 2015.

ACCIDENT

Aircraft Type and Registration:	Kolb Twinstar MKIII (Modified), G-MYPC
No & Type of Engines:	1 Rotax 582 piston engine
Year of Manufacture:	1994 (Serial no: PFA 205-12437)
Date & Time (UTC):	21 August 2014 at 1850 hrs
Location:	Field near Shifnal Airfield, Shropshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to fuselage pod and boom, wings, landing gear and propeller
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	32 years
Commander's Flying Experience:	64 hours (of which 5 were on type) Last 90 days - 4 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst flying at circuit height, the pilot experienced severe vibration, probably from the engine/propeller. He performed a forced landing in a field but overran into a hedge, causing extensive damage. It is possible that damage to the propeller may have been responsible for the vibration.

History of the flight

The pilot, who had not flown for about nine weeks, was practising circuits. The engine had recently been fitted with a new crankshaft and he had run it in as per the manufacturer's instructions. He performed two approaches to Runway 18 before landing and backtracking to take off again. He climbed to circuit height (500 ft), retracting the flaps at 200 ft but, as he reduced power to cruise rpm, he heard a "rough noise" coming from area of the engine. This was accompanied by a violent vibration throughout the airframe and the pilot looked for his options to carry out a forced landing, being somewhat limited by the presence of several sets of power cables. Eventually, he chose a field and touched down in it. Unfortunately, his groundspeed was too high and he realised that he would collide with a wooden fence at the end and so he tried to climb over it. There was insufficient energy to clear the fence, which was struck by the main landing gear wheels, and the aircraft came to a halt in a hedge further on.

In addition to the extensive damage to the airframe, the pilot later observed that two of the three propeller blades had been damaged – one was missing a few millimetres of its tip and the other blade had started to delaminate at the tip. He believes that if either damage had pre-existed the landing, then that might explain the vibration. In addition, he noticed that the starter motor mounting flange had a piece missing (Figure 1). Again, he was uncertain whether this piece may have been liberated in flight and struck the propeller, or occurred as a result of the accident.

Figure 1

Starter motor mounting flange showing missing section

ACCIDENT

Aircraft Type and Registration:	Skyranger Swift 912S(1), G-CDMV
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2005 (Serial no: BMAA/HB/455)
Date & Time (UTC):	31 October 2014 at 1245 hrs
Location:	London Colney Airstrip, Hertfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose landing gear, propeller and windscreen
Commander's Licence:	Private Pilot's Licence
Commander's Age:	62 years
Commander's Flying Experience:	377 hours (of which 296 were on type) Last 90 days - 7 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft made an approach to Runway 23 at London Colney airstrip with the wind direction and strength reported to be southerly at 8 kt by Elstree Airfield. On touchdown the aircraft bounced twice before the nosewheel collapsed and it flipped inverted.

The pilot has stated that another pilot at the airfield reported that the wind had been very variable but, whilst he believes this may have contributed to the bounce, he recognises that he should have initiated a go-around after the first bounce.

ACCIDENT

Aircraft Type and Registration:	Skyranger Swift 912S(1), G-CFIA
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2008 (Serial no: BMAA/HB/561)
Date & Time (UTC):	14 September 2014 at 1100 hrs
Location:	Brookfield Farm Airfield, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left wing, left landing gear, nosewheel, engine cowls, propeller and engine
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	571 hours (of which 390 were on type) Last 90 days - 42 hours Last 28 days 12 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft had slowed to a speed of around 20 kt when, after a bump in the grass runway, it veered sharply to the right, exiting the runway and entering a cultivated field. The aircraft pitched forward and to the left, causing the propeller and left wing to impact the ground. The pilot, who was unhurt, made the aircraft safe and he and his passenger exited it normally.

The pilot considered the accident was caused by the left wheel entering a rut or rabbit hole in the runway. This caused the left landing gear spat to break loose and rotate forward over the wheel, rendering the left brake inoperative. When the pilot applied the brakes only the right brake was effective, with the result that the aircraft then veered to the right before departing the runway.

Miscellaneous

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

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

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

4/2010 Boeing 777-236, G-VIIR
at Robert L Bradshaw Int Airport
St Kitts, West Indies
on 26 September 2009.

Published September 2010.

5/2010 Grob G115E (Tutor), G-BYXR
and Standard Cirrus Glider, G-CKHT
Drayton, Oxfordshire
on 14 June 2009.

Published September 2010.

6/2010 Grob G115E Tutor, G-BYUT
and Grob G115E Tutor, G-BYVN
near Porthcawl, South Wales
on 11 February 2009.

Published November 2010.

7/2010 Aerospatiale (Eurocopter) AS 332L
Super Puma, G-PUMI
at Aberdeen Airport, Scotland
on 13 October 2006.

Published November 2010.

8/2010 Cessna 402C, G-EYES and
Rand KR-2, G-BOLZ
near Coventry Airport
on 17 August 2008.

Published December 2010.

1/2011 Eurocopter EC225 LP Super
Puma, G-REDU
near the Eastern Trough Area
Project Central Production Facility
Platform in the North Sea
on 18 February 2009.

Published September 2011.

2/2011 Aerospatiale (Eurocopter) AS332 L2
Super Puma, G-REDL
11 nm NE of Peterhead, Scotland
on 1 April 2009.

Published November 2011.

1/2014 Airbus A330-343, G-VSXY
at London Gatwick Airport
on 16 April 2012.

Published February 2014.

2/2014 Eurocopter EC225 LP Super Puma
G-REDW, 34 nm east of Aberdeen,
Scotland on 10 May 2012
and
G-CHCN, 32 nm southwest of
Sumburgh, Shetland Islands
on 22 October 2012

Published June 2014.

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

Published September 2014.

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 System
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EGPWS	Enhanced GPWS
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FAA	Federal Aviation Administration (USA)
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth's gravity
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
mb	millibar(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
PNF	Pilot Not Flying
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
TGT	Turbine Gas Temperature
TODA	Takeoff Distance Available
UHF	Ultra High Frequency
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

Air Accidents Investigation Branch