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ADDENDA and CORRECTIONS

None

(ALL TIMES IN THIS BULLETIN ARE UTC)

ACCIDENT

Aircraft Type and Registration:	Beech B200 Super King Air, G-BYCP
No & Type of Engines:	2 Pratt & Whitney PT6A-42 turboprop engines
Year of Manufacture:	1981
Date & Time (UTC):	24 March 2007 at 1635 hrs
Location:	Southend Airport, Essex
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 5
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nose fuselage, the nose landing gear and doors, and propeller tips
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	3,800 hours (of which 2,200 hrs were on type) Last 90 days - 137 hours Last 28 days - 30 hours
Information Source:	AAIB Field Investigation

Synopsis

After selecting the landing gear to UP after takeoff from Caen, the 'gear unsafe' light remained on. The flight crew established that the nose landing gear had neither retracted nor remained locked down and, despite recycling the gear and attempting to use of the emergency gear lowering system, the crew were unable to lock the leg down. On landing at Southend Airport, the nose leg collapsed, causing damage to the fuselage nose structure and the propeller blade tips. The investigation revealed that the nose gear actuator had been affected internally by corrosion, resulting from water ingress, which led to the failure of the threads within the actuation nut of the actuator. It had completed a total of 1,449 cycles of its 8,000 cycle life, but only 532 cycles since its last 1,000 cycle check.

One Safety Recommendation is made.

History of the flight

The aircraft departed from Caen Airport in France for a flight to Stapleford Aerodrome, Essex. On board were a flight crew of two and five passengers, three of whom were young children. When the landing gear was retracted after takeoff, the crew heard an unusual noise from the vicinity of the nose landing gear bay, and noticed that the red 'gear unsafe' light in the landing gear handle remained illuminated. The main gear was seen to be up, with all three green 'gear down and locked' lights extinguished, but the nose gear, which was visible by reflection in the engine cowlings, was not. Instead, it appeared to be extended, but at a slight angle from its normal down position.

The crew selected the landing gear down, and obtained two green lights for the main gear, but no such indication for the nose gear. They then selected it up again, but the nose gear remained in its previous position.

Initially, the flight proceeded towards Stapleford while the flight crew discussed the situation and briefed the passengers. They then decided to divert to Southend Airport, which was the site of the operator's maintenance organisation. They notified their company, contacted Southend ATC to alert them to the problem and initiated the diversion as planned.

At a range of 10 to 15 nm from Southend, the crew selected the landing gear down but, again, the main landing gears indicated down and locked but the 'gear unsafe' indication remained illuminated. They then attempted to lower the nose gear using the manual extension system, but without success. When it became clear that the aircraft would need to land with an unsafe gear, ATC instructed the crew to hold overhead Southend while the external emergency services were alerted; the airport emergency services had already been placed on standby. Whilst in the hold, the commander briefed the co-pilot on the landing and evacuation procedures. The passengers were also briefed.

The aircraft left the hold and was vectored for a Surveillance Radar Approach to Runway 06. There was a northerly surface wind of 10 kt and broken cloud at 600 ft, with a visibility of 5,000 m in haze; the crew became visual at about 600 ft and 2 nm from the airport. A normal main gear touchdown was made and, as they had previously discussed, the commander instructed the co-pilot to feather the propellers and to shut down both engines. The commander kept the nose raised for as long as possible before, at an estimated speed of 65 kt, it lowered and made contact with the runway.

After coming to a halt, the commander secured the aircraft whilst the co-pilot went back into the cabin and opened the main door. The aircraft had come to a stop on the runway in a nose down attitude, resting on the two main landing gear legs and the nose landing gear doors. Because of the aircraft's nose low attitude, there was a drop of two and a half to three feet below the integral stairs. The co-pilot descended to the ground and the adult passengers passed the children to him before they and the commander also evacuated the aircraft. The emergency services were on the scene soon after the aircraft came to rest.

Landing gear system description

The tricycle landing gear is electrically operated and controlled by the landing gear extension/retraction handle located on the right side of the instrument panel. A 28V motor/gearbox unit, located forward of the main spar, drives the main landing gear actuators via torque shafts. The nose landing gear actuator is driven via duplex chains from a sprocket attached to the motor gearbox. These chains rotate an input shaft into the actuator which, via a bevel gear, rotates a steel screw inside a lubricated aluminium bronze alloy nut. The movement of the screw through the nut extends and retracts the actuator, and in turn, the nose landing gear. Internal friction in the actuator holds the nose landing gear in the retracted position and the over-centre action of the drag brace on the nose landing gear assembly provides a positive mechanical downlock. An expanded view of the nose landing gear actuator is shown in Figure 1.

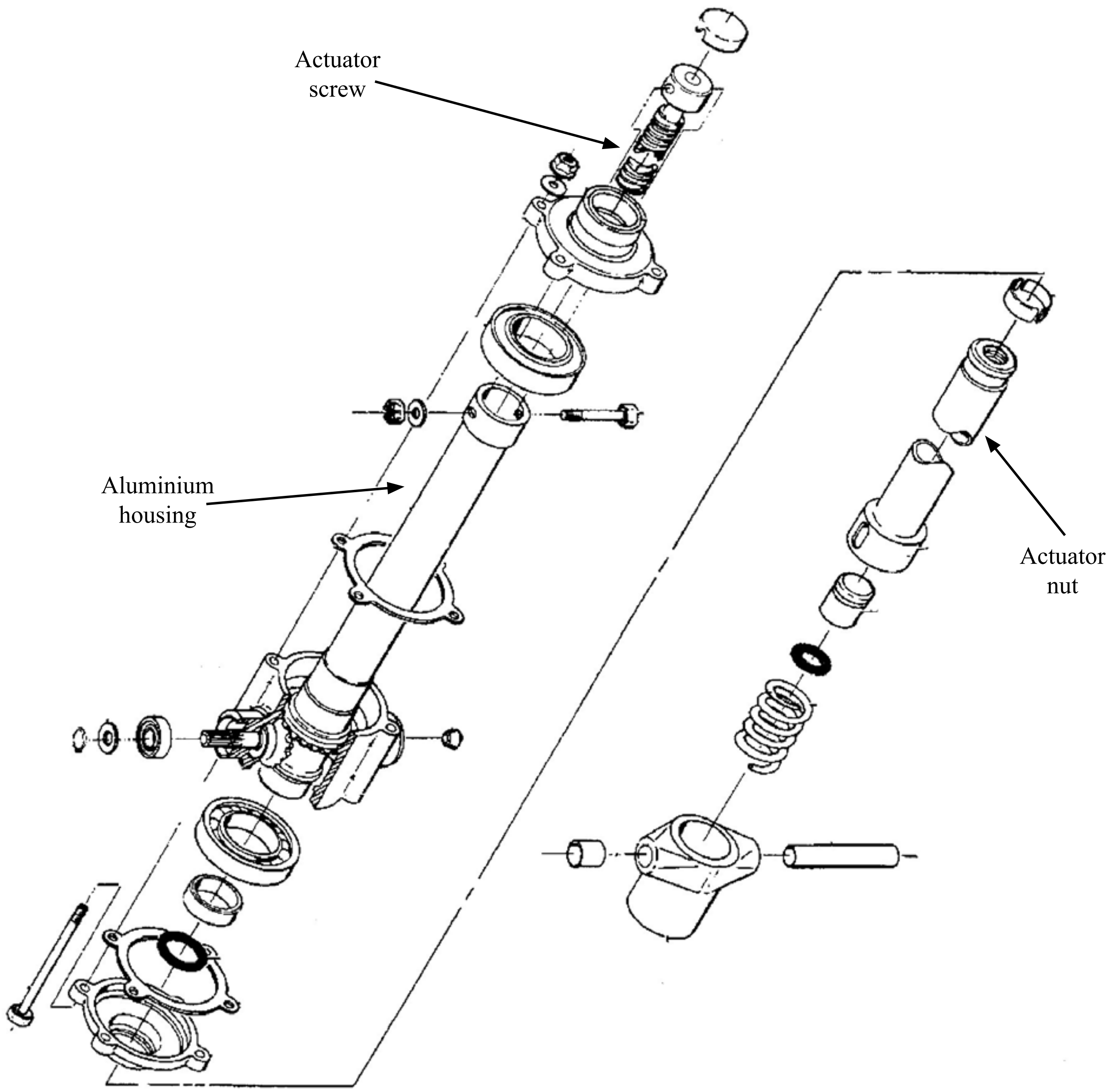


Figure 1

Nose Landing Gear Actuator Assembly

Landing gear position indication is provided by individual green GEAR DOWN annunciators. Two red indicator lights in the control handle illuminate whenever the gear is in transit or not locked; absence of handle illumination indicates that the gear is up and locked, or down and locked if combined with 'three greens'.

A separate, manually operated, chain-driven system provides emergency landing gear extension. Operation of the emergency handle disconnects the motor from the system and locks the emergency drive system of the gearbox. A ratchet handle, activated by hand pumping, drives the chain, and thus the actuators, to lower the main and nose landing gears. The system is designed to lower all three landing gears at the same time.

Aircraft examination

The aircraft had been moved into a hangar and was supported on jacks when viewed by the AAIB. Damage to the aircraft was limited to the fuselage skin around the area of the nose, the nose landing gear doors, and the propeller blade tips. The nose landing gear actuator, although still connected, was free to move and would not lock in any position. There was evidence of a contaminated liquid, with the appearance of a mix of grease and water, originating from within the actuator.

Actuator examination

The actuator was disassembled and the aluminium bronze nut assembly sectioned, to allow its interior to be examined. This revealed that the internal threads of the threaded nut (screw insert) assembly had been stripped, Figure 2.

There was evidence of compacted grease between the threads of the steel actuator screw thread along its length, and a considerable amount of aluminium bronze debris was found within this grease. Close examination of the screw showed that corrosion pitting damage was present, and that this was more extensive at the upper and lower ends of the screw, Figure 3. Corrosion was present on the apex, roots and flanks of the threads, and also observed on the internal surface of the gears within the aluminium housing.

Actuator maintenance

Prior to 2005, the manufacturer specified that the nose landing gear actuator had an overhaul life of 7,500 cycles, or a calendar life of six years, whichever occured soonest. In 2005, this was changed to introduce a calendar life 'backstop' of six years and a

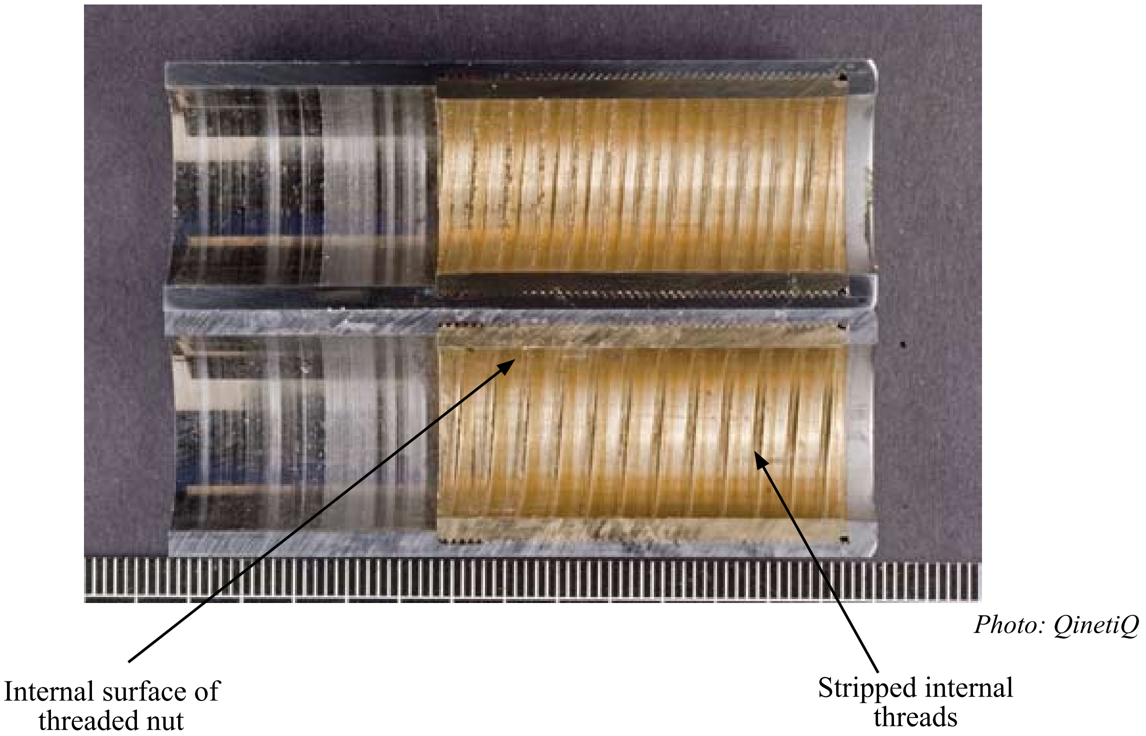


Figure 2

Internal surface of threaded nut (screw insert) assembly showing stripped internal threads


Photo: QinetiQ

Figure 3

Corrosion observed on upper end of screw.

limit of 8,000 cycles. It is subject to removal every 1,000 cycles, or 30 months, for a screw-nut end play check to be performed. The Component Maintenance Manual (CMM) details this check, which is designed to measure the amount of travel or 'play' between the lubricated bronze nut and the steel screw. It states:

> *'Assembly end play, measured from the nut to housing may be a maximum of 0.005 inch greater than screw-nut end play. However, the total assembly end play shall not exceed 0.01 inch.'*

There is no requirement for routine lubrication of the actuator during its life and, unless there is evidence of grease leaking past the seals, the end play check does not call for internal lubrication or repacking of the actuator.

Actuator history

The incident actuator, Pt No 50-820208-5, batch number P12630, Serial number ALG6591, was fitted to G-BYCP on 11 April 2005. It was overhauled in the USA and a new actuator nut was installed Pt No GMD90-820015-1B. This part number is an approved replacement part for the Original Equipment Manufacturer (OEM) item, whose part number for the nut assembly is 90-820015-1.

The Federal Aviation Administration (FAA) Parts Manufacturing Approval (PMA) No PQ1586CE, dated June 1 2004, gives approval for fitment of this nose gear actuator nut to several Raytheon (Beechcraft) Models. PMA manufacturing companies are subject to FAA regulations in the design, testing, approval and manufacture of such parts.

The Hawker Beechcraft Corporation (HBC) installation uses an aluminium bronze plug (nut) with a smooth exterior surface that is attached to the outer tube using an electron beam welding procedure, not the threaded installation as found in the actuator from G-BYCP. When HBC engineers examined the actuator nut, they reported that they could find "no instance where HBC used this threaded assembly."

At the time of the accident it had completed 1,449 cycles since overhaul. A satisfactory screw end play check was performed on 8 May 2006, 532 cycles before the accident.

Previous events

Another B200, G-FRYI, belonging to the same operator as G-BYCP, suffered landing gear problems in March 2007, when the landing gear failed to retract. The landing gear was locked down using the emergency system and the aircraft landed safely. The landing gear system was checked and the nose landing gear actuator replaced. A strip examination of this unit at the overhaul agency revealed the presence of corrosion. It had been fitted in 2001 and had accumulated 5,884 cycles since overhaul; the last end play check was on 27 February 2006, since when it had operated for 629 cycles.

A Canadian registered Beechcraft King Air A100 (Be-10), C-GISH, experienced a similar occurrence in Ontario in May 2002, when the nose landing gear collapsed. Further examination showed that the thread of the aluminium bronze nut assembly had failed but, in this event, the cause of this failure was determined to be lack of lubrication. The actuator had been installed on C-GISH in January 2000, and the last end play check was completed satisfactorily on 19 March 2002; however, 89 cycles later the actuator failed. It was concluded that differences in the King Air 100 and 200 maintenance manuals may possibly have resulted in inconsistent maintenance practices.

In 1994, severe corrosion was found in the nose landing gear actuator on a B200 during maintenance, following a landing gear retraction test that was slower than normal. In this case, the cause was identified to be a failed seal, which had allowed moisture ingress to cause bearing degradation. During routine maintenance, three other similarly corroded actuators were found.

Discussion

Examination of the nose landing gear actuator revealed that a complete failure of the internal threads in the aluminium bronze nut had occurred. The threads had stripped and, hence, the input from the landing gear motor/gearbox could not cause the nut assembly to traverse the screw. A considerable amount of aluminium bronze wear debris was present in the grease on the screw thread, which suggested that the nut had been wearing over a period of time prior to failure. Examination of the grease showed that it was contaminated with water, which is likely to have reduced its lubrication properties, leading to increased wear and corrosion damage of the screw. Also, the corrosion pits formed were likely to have increased the roughness of the screw and accelerated wear of the nut. This wear would have progressively reduced the load bearing capacity of the thread to a point when it could no longer support normal operating loads, leading to a failure of the remaining thread profiles. As the problem with the nose landing gear actuator was downstream of the emergency system input, it was not possible to lock the nose landing gear down.

Other incidents on B200 aircraft also showed corrosion and increased wear, due to lack of lubrication. Although the nose landing gear actuator in G-BYCP was a PMA part, the corrosion and lack of lubrication could equally have occurred to an OEM part since the only difference in design is the method of attaching the plug (nut) insert. The presence of excessive play at the 1,000 cycle end play check would indicate increased wear and, as such, an actuator would normally be returned for overhaul. However, the actuator from C-GISH 'failed' only 89 cycles after passing an endplay check, the actuator on G-BYCP at 532 cycles and the unit on G-FRYI at 629 cycles. Therefore, as the 1,000 cycle interval between checks would not appear to ensure detection of excessive wear before an actuator fails, the following Safety Recommendation is made:

Safety Recommendation 2007-126

It is recommended that the Federal Aviation Administration require Raytheon (Beechcraft) to review the maintenance requirements of the nose landing gear actuator fitted to the Beech B200 King Air series of aircraft, and any other model using a similar design of actuator, with regard to the requirement of periodic lubrication and the periodicity of inspections.

INCIDENT

Aircraft Type and Registration:	DHC-8-402, G-JECG	
No & Type of Engines:	2 PW150A turboprop engines	
Year of Manufacture:	2004	
Date & Time (UTC):	10 December 2006 at 1930 hrs	
Location:	Approximately 10 nm east of Prestwick Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 4	Passengers - 71
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	56 years	
Commander's Flying Experience:	9,950 hours (of which 650 were on type) Last 90 days - 173 hours Last 28 days - 50 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During flight in icing conditions, the flight crew experienced multiple flight instrument failures which were consistent with icing of the pitot/static probes. Recorded flight data indicated that the standby pitot/static probe heat switch had not been selected ON prior to flight, and the investigation concluded that, in all probability, the remaining two pitot/static probe heat switches had also not been selected ON. Non-standard checklist procedures and distractions may have created an environment in which the selection of the probe heat switches to ON was missed before takeoff, and not detected until after the icing encounter.

History of the flight

The aircraft was scheduled to fly two return flights between Edinburgh Airport and Belfast City Airport, to be operated by the same crew. The incident occurred on the third sector, whilst en-route to Belfast. The flight crew reported for duty at 1515 hrs and, as part of their normal pre-flight activities, checked the meteorological conditions. The weather was forecast to remain generally wet and windy, with extensive cloud and in-flight icing. However, temperatures at ground level were well above freezing.

The first two flights were unremarkable; when airframe icing had been detected, the aircraft's ice protection systems had been used and had functioned normally. The co-pilot had flown the sector inbound to Edinburgh, and was also to be the handling pilot for the flight to Belfast. During the 35 minute turn-round at Edinburgh, he carried out an external inspection of the aircraft, which included a check of the pitot/static probes and angle of attack sensors. No anomalies were noted. During the external inspection there was continual drizzle, with a temperature of 12ºC.

The aircraft subsequently taxied for a departure from Runway 24, with four crew and 71 passengers on board. The commander was handling the aircraft during taxi, as it could only be steered from his seat. During the taxi phase, the co-pilot noticed that an expected annunciation on the Engine Display (ED), regarding the engine bleed air system, was not present and brought this to the commander's attention. After a check of the takeoff configuration warning system, the propeller condition levers were found to be incorrectly set for takeoff. The situation was rectified and the correct indications were obtained on the ED.

The commander then called for the taxi checklist. The co-pilot read the checklist, which included a mixture of 'challenge and response' items as well as 'read and do' items. The crew received a takeoff clearance prior to arriving at the runway holding point, ahead of an aircraft which was on final approach. Takeoff commenced at 1913 hrs.

Precipitation was encountered about 1,000 ft after takeoff and propeller anti-ice was selected ON. The autopilot was also engaged. The crew were given a direct routing towards Belfast, and cleared to climb to FL160 (approximately 16,000 ft amsl). The aircraft encountered heavy precipitation during the climb, and a number of visual checks were made for ice. When airframe ice was seen, the crew switched the airframe icing protection system from MANUAL/OFF to FAST. The crew reported that, at FL100, they checked the altimeter indications, which were normal, and carried out a number of other routine check items. As the aircraft continued to climb, the crew received an ICE DETECTED message on the ED, generated by the automatic ice detection system. No action was necessary as airframe, engine and propeller de-ice systems were already on by this time, though it was noted that the ice build-up was exceptionally heavy on a dedicated and lighted spigot.

As the aircraft approached its cruising level, the crew received an "ALT MISMATCH" alert on their Primary Flying Displays (PFDs), warning of a discrepancy in the displayed altitude. A cross-check of the standby flight instrument display showed that the commander's (left-hand) PFD was showing an erroneous altitude of approximately 150 ft below the co-pilot's PFD altitude. As the autopilot was selected to receive its inputs from the right hand (co-pilot's) instrument sources, the crew were content for it to remain engaged.

The aircraft levelled at FL160, just above a cloud layer. Soon after reaching FL160, the crew began to experience further discrepancies between both indicated altitudes and airspeeds, and observed heavy icing on the aircraft structure. The autopilot then disconnected automatically. The commander's indications of altitude and airspeed decayed rapidly, and were replaced by red failure indications. By selecting the right hand instrument sources to feed his own PFD, the commander was able to restore speed and altitude indications to his display. The Air Traffic Controller handling the flight noticed that the aircraft's SSR Mode C altitude had disappeared from his radar display, and queried it with the crew. In response, the commander requested an immediate descent, stating that the crew were experiencing instrument problems and that he required a descent to clear the icing layer. The crew were cleared for a descent to FL80.

As the descent began, the co-pilot's altitude indication (now displayed on both pilots' PFD as a result of the commander's source selection) appeared to read correctly, but the airspeed indication began to show a deceleration at a rate which matched the decreasing altitude. The co-pilot kept the power levers at the cruise setting as the indicated airspeed reduced, concerned that the aircraft was approaching a stall (he recalled seeing an IAS of 134 kt). Recognising that this was an erroneous indication, the commander intervened and directed the co-pilot to reduce power and to select an appropriate pitch attitude for the descent. Both the altitude and airspeed indications subsequently reduced rapidly and were replaced by red failure indications. Both pilots reported that several amber caution lights illuminated on the Caution/Warning Panel (CWP), associated with the instrument failure indications.

The commander made a 'PAN-PAN' call to ATC, stating that the crew had lost all pressure instruments, and initiated the Emergency Checklist. The controller assisted by providing the crew with groundspeed readouts from his display, and Mode C altitude information, when it became available in the later stages of the descent. Both pilots reported that the standby IAS display also showed a red FAIL indication during the descent, though it was uncertain whether the standby altitude display remained valid.

As the aircraft approached FL80, the PFD altitude indication returned and the co-pilot used it to level the aircraft. Subsequently, the remaining airspeed and altitude indications from both left and right sources recovered to normal. The crew considered a diversion, but it was decided that continued flight to Belfast at the lower level was the best option, given the relatively short distance to Belfast and the reported weather. During discussion between the flight crew immediately after the icing encounter, the co-pilot queried the position of the pitot/static probe heat switches with the commander, and said that he thought they may be OFF. Later, neither pilot could be completely certain whether or not the switches were physically moved at this point, but information from the Flight Data Recorder (FDR) was consistent with the standby pitot/static probe heat switch[1] being moved from OFF to ON, about three minutes after levelling at FL80, having been at OFF since the start of the recording (switches for the left and right pitot systems were not monitored by the FDR). The aircraft landed at Belfast at about 1950 hrs, without further incident.

Meteorological information

A broad warm sector was covering the Edinburgh area at 1800 hrs on the evening concerned, giving extensive layer cloud. A tight isobaric gradient gave rise to reasonably strong winds. Upper air soundings showed the freezing level to be at about 8,500 ft, and the -5ºC level at about 12,500 ft. There was likely to have been large amounts of layered cloud to 12,000 ft, and possibly higher in places. Since the surface temperature at Edinburgh was 12ºC, the aircraft was not considered to be in icing conditions for takeoff.

Although icing is most commonly associated with large convective clouds, layers of stratiform clouds can also contain large quantities of supercooled droplets because such clouds include continuous, if limited, convective activity. Temperature ranges in which airframe icing can be expected are from a slightly positive temperature down to -40ºC, though severe icing rarely occurs below about -12ºC.

Footnote

[1] For ease of reading, the term *"pitot/static probe heat switch"* is reduced to *"pitot heat switch"* for the remainder of this report, unless required in full.

Recorded information

Flight data

The aircraft was fitted with a 128 word per second Solid State FDR and Solid State Cockpit Voice Recorder (CVR). The FDR recorded just over 26 hours of operation and was downloaded at the AAIB. By the time the order was made for the preservation of the CVR, data for the incident flight had been over-written.

Engine start was at 1902 hrs. Prior to taxi, the engine condition levers were advanced from the 'START/ FEATHER' position to the '900' position (this commanded a constant propeller speed of 900 rpm). Two and a half minutes later, the Condition Levers were then advanced to 95 degrees (corresponding to the '1020' or 'MAX' position). Analysis of the previous three flights showed that the condition levers were advanced directly from the 'START / FEATHER' position to the 'MAX' position after engine start without an intermediate stop at the '900' position.

Recorded information showed that, just prior to takeoff, the pneumatic de-icing system switch was either in the SLOW, FAST or MANUAL position (individual positions were not recorded). The standby pitot heat switch was OFF, as it had been from commencement of the flight recording[2]. The pitot heater has an associated pitot heat caution light which is illuminated on the CWP based on actual heater current measurement. When there is little or no heater current, the caution light will be on, independent from the switch selection. The previous 21 flights on the recording were checked and in each case the standby pitot switch was recorded ON just after engine start. No further parameters from the ice protection system were recorded so that pitot heat caution lights for the No 1, No 2 and standby systems, the position of the No 1 and No 2 pitot heat switches and propeller de-icing were not recorded.

At 1913 hrs takeoff power was applied. As the aircraft was passing 12,200 ft, the ice detection system detected ice, at which point, the Static Air Temperature (SAT) sensor recorded a temperature of -3ºC. Around 20 seconds later, the barometric altitude from the left and right Air Data Computers (ADCs) began to diverge, reaching a difference of 218 ft. According to the aircraft manufacturer, the trigger threshold for the ALT MISMATCH alert is a function of the altitude recorded by the left and right ADCs. At the time of maximum altitude mismatch, the threshold for this alert was 123 ft.

The aircraft levelled at 16,000 ft (FL160), at which time the difference between the two recorded altitudes had reduced to around 50 ft, which was below the ALT MISMATCH threshold. The aircraft was established in cruise flight with the autopilot ALTITUDE HOLD mode engaged. About 50 seconds later, the recorded altitude dropped around 200 ft within 1 second, to 15,800 ft. This then slowly recovered to 16,000 ft.

Just under four minutes after levelling off, the ice detection system again detected the presence of ice. Around 30 seconds later, both left and right ADC altitudes began to fluctuate again. As this occurred, the left ADC calibrated airspeed (CAS) dropped to zero and the autopilot disengaged. About 20 seconds after this, the recorded altitude data from the left ADC dropped to zero ft (Figure 1). The remaining altitude information from the right ADC indicated that the fluctuations then ceased and the altitude recovered to 16,000 ft.

Footnote

[2] The FDR records switch position as an open circuit or grounded electrical signal. This signal is also wired to both the Ice and Rain Protection System Timer and Monitoring Unit and the relay which supplies power to the standby pitot heater.

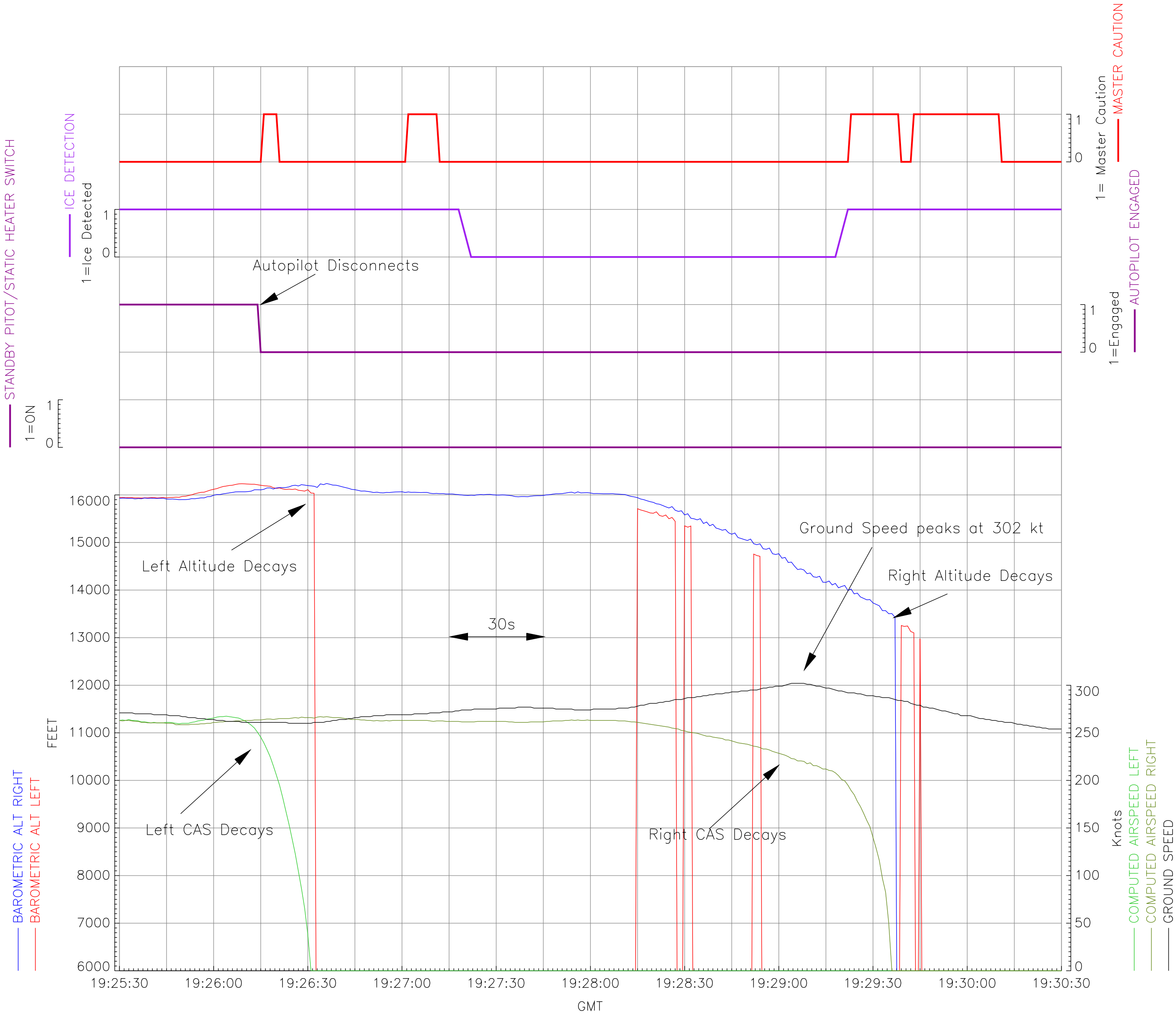


Figure 1

Loss of flight data and aircraft descent

At 1928 hrs, about 6 minutes after levelling at FL160, a descent commenced with a CAS of 263 kt and ground speed of 270 kt. During the descent, the airspeed from the right ADC decreased but the groundspeed increased. Maximum ground speed achieved was 302 kt whilst the airspeed indicated 220 kt. During this descent, altitude data from the left ADC appeared to recover, but for no more than 6 seconds. About a minute after the descent had begun, the CAS from the right ADC decreased further, over a period of 16 seconds, to read zero kt. Two seconds after this, altitude data from the right ADC recovered briefly to read 13,428 ft, but dropped to zero immediately afterwards. Two further recoveries of the left ADC altitude were noted, but again were only temporary.

Altitude data from the left and right ADC was absent from the recording for the next two minutes. The left

ADC altitude data returned at 8,914 ft and, 17 seconds later, the right ADC altitude also returned at the same value as the left ADC (Figure 2). CAS did not recover until nearly three minutes after being lost, as the aircraft was levelling at FL80, with an SAT of 2.75ºC. Both CAS values recovered to within 3 kt of each other and within 30 kt of the ground speed. No further anomalous behaviour was observed with altitude or airspeed for the remainder of the flight.

At 1935 hrs, about 2 minutes after levelling at FL 80, the standby pitot heat switch was selected ON (Figure 2). No parameters from the standby instrumentation were recorded. Stall system outputs remained valid, with no stick shaker or stick push events recorded during the flight. Output from both Angle of Attack (AOA) vanes continued to vary within expected values for the flight conditions.

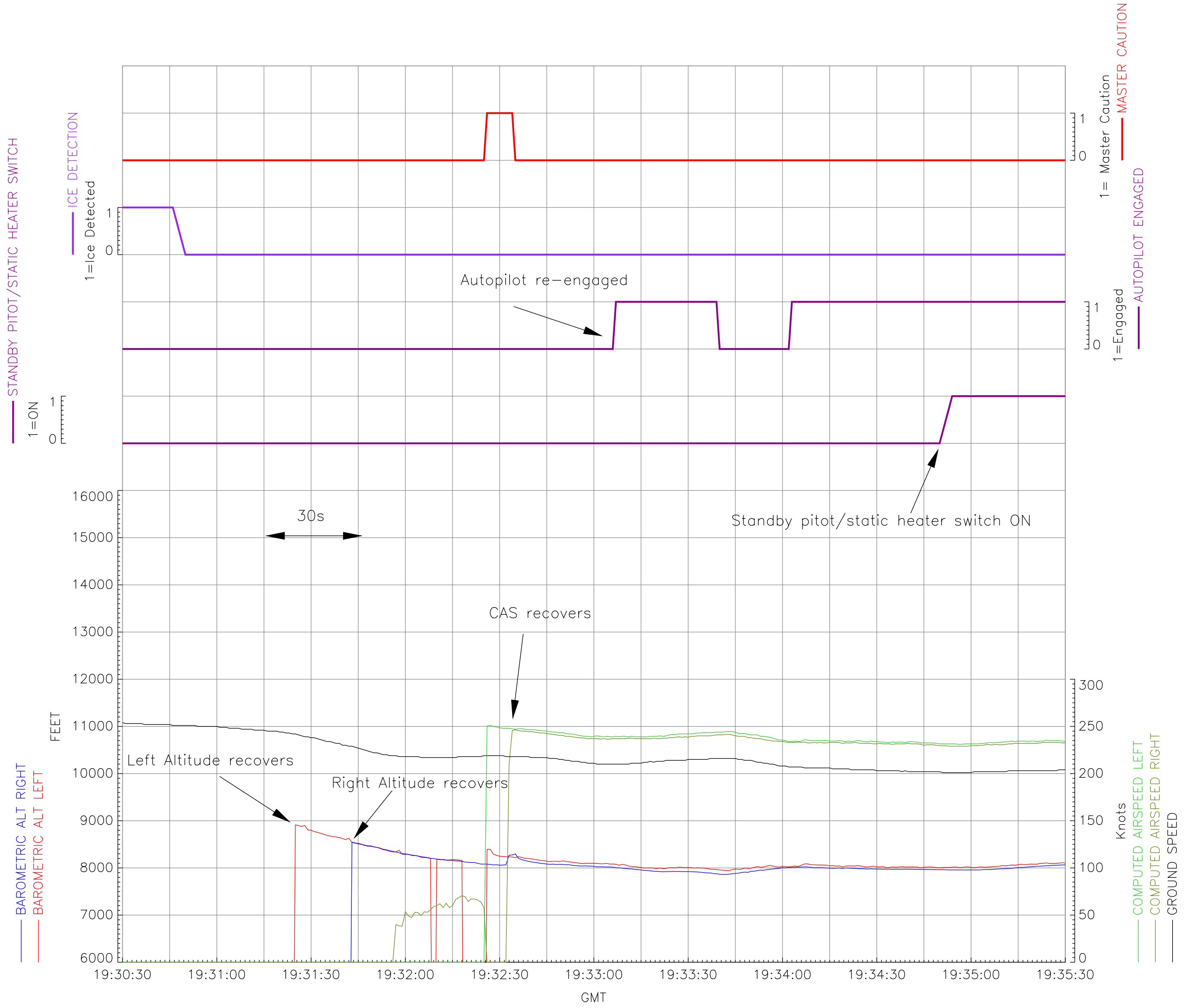


Figure 2

Aircraft level-off, flight data recovery and standby pitot heat switch position

Radiotelephony data

Recorded radio transmissions showed that the crew of G-JECG contacted the Edinburgh Tower controller whilst taxiing as instructed, and were asked to report passing holding point Delta 3 (a short distance before the runway). Forty seconds later the crew reported that they were approaching Delta 3 and were given clearance to line up and take off. There was one aircraft on final approach at this time, which had made an "EIGHT MILE" call before G-JECG was on frequency. Immediately after the co-pilot's acknowledgment of the takeoff clearance, the controller instructed the aircraft on final approach to "CONTINUE THE APPROACH ONE TO DEPART". From the timing of the approaching aircraft's radio call, and assuming it had reduced to minimum approach speed when G-JECG was issued takeoff clearance, it would have been less than 4 nm from the runway as G-JECG lined up for takeoff.

Crew interviews

Initial interviews

The commander and co-pilot were interviewed individually by the AAIB, two days after the incident. Information from the FDR, which indicated that the standby pitot heat switch had been selected to OFF for the majority of the flight, was not available until after the initial crew interviews. However, the co-pilot had already considered the possibility that the pitot heat switches may inadvertently been left off for takeoff, and he raised this at interview.

The co-pilot said that he had developed a routine of completing two checklist items from memory before the taxi checklist was called for by the commander. These were: selection of pitot heat switches to ON and selection of reduced torque for takeoff. The pitot heat switches were an item which the co-pilot was required to action in response to the checklist, and did not require a response from the commander.

The co-pilot said that the issue of the ED indications associated with the incorrectly set condition levers may have presented a distraction, which could have led to the pitot heat switches being left off. Immediately after the engine condition levers had been corrected, the commander called for the taxi checklist, by which time the co-pilot would normally have turned the pitot heat switches ON. There was therefore the possibility that the switches were at OFF on this occasion when the co-pilot read the taxi checklist.

Furthermore, the line-up checklist was carried out as the aircraft was entering the runway, as was usual practice. With another aircraft on approach to land, the co-pilot sensed a degree of urgency to commence the takeoff without undue delay possibly pressurising him to complete the pre-takeoff checklist as soon as possible.

The co-pilot reported that he made the standard call "ALTIMETERS" as the aircraft passed FL100. On this cue, the commander, as "Pilot Not Flying" (PNF), should have carried out certain actions (see '*Checklists and procedures*' section). These would have included turning off the landing lights. However, the co-pilot reported that he turned the landing lights off himself a short while later, and was not certain whether or not the rest of the checks were done, although the commander stated that they were.

Concerning the discussion on the flight deck immediately after the descent to FL80, the co-pilot said that he expressed some doubt as to whether the pitot heat switches were physically selected ON. However, he did not think the associated CWP cautions were illuminated then, or at takeoff.

The commander recalled the issue of the engine condition lever settings, although he thought it had occurred on a previous sector. At initial interview he did not mention the post-descent discussion regarding the pitot heat switches, but did state that he was sure the pitot heat cautions lights were not illuminated at takeoff.

Both pilots reported seeing a number of CWP cautions during the incident, though neither reported seeing the pitot heat system cautions. The co-pilot described "several" cautions, and the captain described between six and ten. They both identified ELEV FEEL plus one or two others on the left side of the CWP, with the bulk of the captions being on the centre/right of the panel. Both mentioned that the majority of the captions were in the general area of the three stall warning system captions, towards the right of the panel; the co-pilot mentioned that stall warning captions may have been among those he saw. However, the crew's Air Safety Report on the incident stated that cautions seen included 'STALL SYSTEM' and 'PUSHER' cautions.

Subsequent interviews

When the FDR data was analysed and the history of the standby pitot heat switch became known, both pilots were asked for further clarification about the discussion immediately after the icing encounter.

The co-pilot felt that the distractions during taxiing could have accounted for missed switch selections. After the incident, he voiced his concern to the commander about the pitot heat switch positions, as they were small and not easy to see at night under reduced flight deck lighting. The commander agreed that there had been some discussion, and that the co-pilot thought the switches might have been off, but the commander thought the switches appeared to be on. Both recalled that the co-pilot had put his hand up to the vicinity of the switches, but the co-pilot was not sure if he had actually moved the switches, and the commander thought that the co-pilot had not done so. Neither pilot thought that any of the associated three pitot heat caution lights had been illuminated on the CWP, though the co-pilot observed that the cautions were on the far left of the panel, furthest from him.

During discussion after landing, the co-pilot had offered the possibility that the pitot heat switches may have been turned off inadvertently by the commander at FL100, instead of the landing lights (which had been left on). The commander rejected this, pointing out that the master caution light would have alerted the pilots if the switches had been turned off in flight.

Engineering investigation

The commander placed the aircraft unserviceable on arrival in Belfast, by making an entry in the aircraft Technical Log. The operator's engineering personnel conducted a water drains inspection, checks of the pitot head heaters, an operational test of the Air Data Computers, a sense and leak test of the pitot/static system and also a complete check of the Central Warning System but no fault was found.

The aircraft was subsequently returned to service and has not suffered any similar or related occurrences, and no other related Air Safety Reports (ASR) or CAA Mandatory Occurrence Reports (MOR) have been raised for this aircraft, either before or since.

There have, however, been a number of occurrences on other DHC-8s within the operator's fleet, involving suspected icing of the pitot/static system. Between 22 October 2006 and 29 December 2006, six ASRs were raised, including one for this incident. Four of these ASRs were raised for incidents on the same day, 29 December 2006, all involving company DHC-8s in the same general area and at the same time. Between 18 August 2006 and 8 December 2007, 13 MORs were raised by the operator, concerning related events.

Bombardier has introduced a set of modifications to improve the drainage of the pitot/static system and reduce the risk of icing of the pitot heads. At the time of the incident G-JECG was fitted with the redesigned pitot/static lines but did not have the modified pitot heads.

Aircraft information

General

The Dash 8-Q400 is a high-wing, twin-turboprop aeroplane manufactured by Bombardier Inc. It is a two-pilot transport category aircraft approved for instrument flight and for flight into known icing conditions. G-JECG carried the manufacturer's Production Serial Number 4098.

Ice protection

Aircraft ice and rain protection includes ice detection, de-icing, anti-icing, and rain removal systems. The de-icing system uses engine bleed air to operate conventional inflatable boot sections installed on the leading edges of the wings, horizontal and vertical stabilizers, and to protect the engine nacelle inlet lips. The anti-icing systems use electrical heating elements to prevent ice formation. The system heats the leading edges of the propeller blades, the three pitot/static probes, two Angle of Attack (AOA) vanes, engine intake flanges, windshields and both the pilot's side windows.

An Ice Detection System (IDS) uses two ice detector probes to actively detect icing conditions. If one or both probes detect more than 0.5 mm of clear ice, an ICE DETECTED message appears on the ED, which remains displayed until icing is no longer detected. There is no flight deck control for the Ice Detection System (IDS), which operates automatically as soon as electrical power is available.

The No 1, No 2 and standby pitot/static probes incorporate integral, electrically powered heaters which are switched on by the flight crew before flight to prevent ice build up. All three pitot/static probes and the AOA vanes are controlled and monitored by separate modules of a Timer and Monitor Unit (TMU). Pitot/static probe heat is controlled by the pitot/static probe heat switches on the ice protection panel on the flight deck overhead panel (Figure 3). The PITOT HEAT STBY, 1, and 2 caution lights on the CWP are illuminated based on the heater current measurement. Normally the switch selection and the heater current will agree. In the case of a heater or wire failure causing an open circuit, the caution light will accurately indicate the status of the heater, ie not being powered, even though the switch may be selected.

The AOA vanes are electrically heated automatically during flight; they do not require pilot selection. There are no CWP caution lights for AOA heater failures. However, if the Stall Protection Module (SPM) senses an AOA heater failure, it causes the PUSHER SYS FAIL caution light to come on, and the applicable STALL SYST FAIL caution light.

Flight deck displays

An Electronic Instrument System (EIS) displays primary flight data, navigation, engine and system parameters on five display units on the flight deck, including both pilots' PFDs and the ED. Critical air data is supplied to the flight instruments by the Air Data System (ADS). In normal operation each pilot receives air data from his own data source: ADC 1 for the commander and ADC 2 for the co-pilot. An ADC source reversion selector

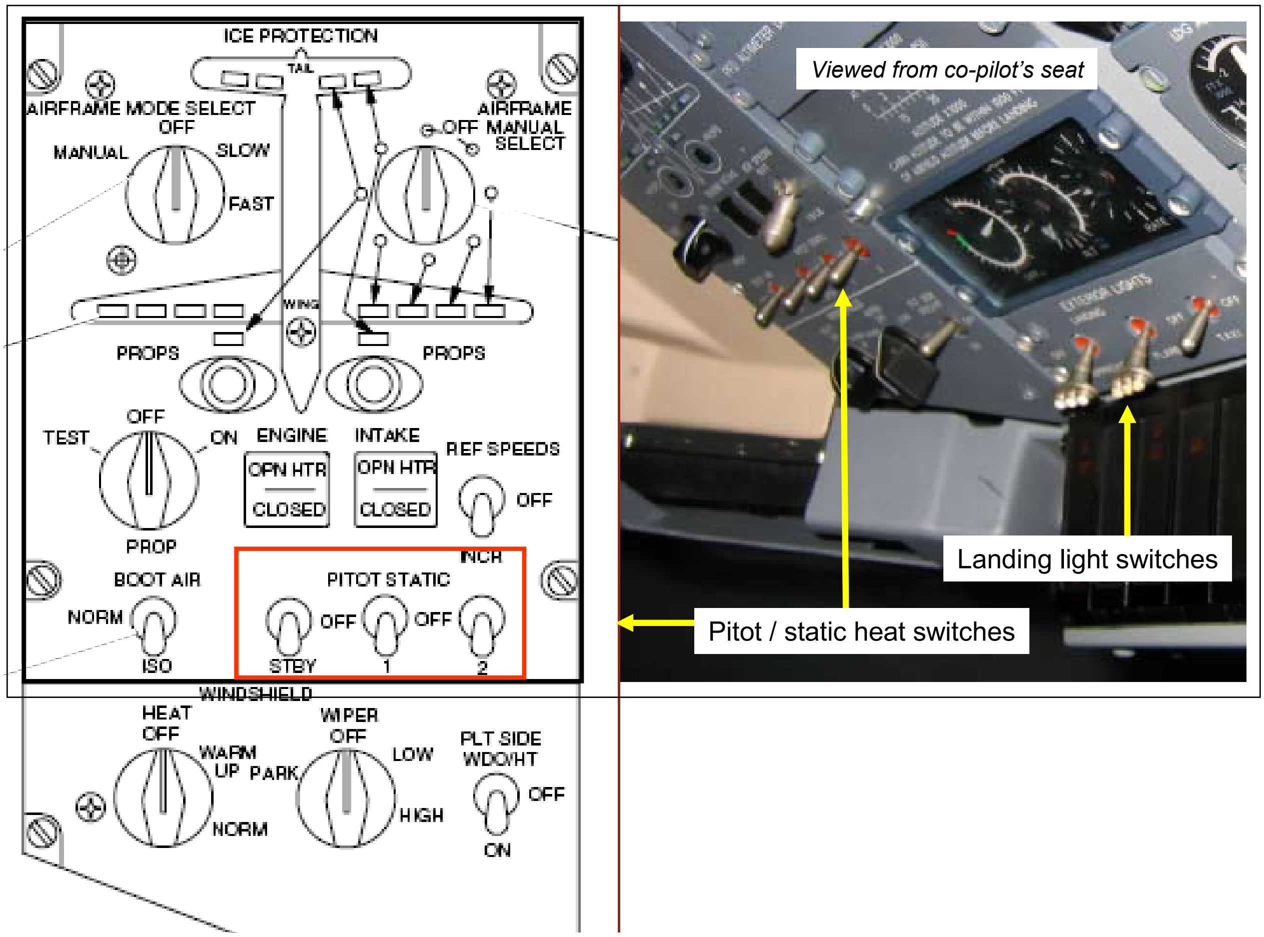


Figure 3

Pitot/Static probe heat switches – panel layout and cockpit view

allows either pilot to select the opposite side air data source to feed his PFD.

Airspeed is indicated on a vertical scale and digital readout on the PFD. A yellow IAS MISMATCH message on the PFD indicates that the two ADC sources are providing IAS values that differ by 10 kt or more. If the airspeed parameter malfunctions, the scale and digital readout are removed and replaced by a red IAS FAIL message.

Altitude is similarly indicated on the PFD by a scale and digital readout. A yellow ALT MISMATCH message appears on the PFD when ADC sources are providing different barometric altitude values. The message appears at a variable threshold, ranging from a difference of 60 ft at sea level to 180 ft at 27,000 ft. In the case of an altitude parameter failure, the indications are removed and replaced by a red ALT FAIL message.

An integrated electronic standby instrument presents airspeed and altitude information in a similar, though simplified, format to that of the PFDs. The instrument operates independently and does not interface with other systems. The standby airspeed and altitude functions are independent of the primary ADS, and receive data from pressure sensors which utilize pressure from the standby pitot/static probe. If a failure in either function is detected by internal monitors, the relevant information is removed from display and replaced by a red failure message.

Central Warning System

The Central Warning System (CWS) monitors aeroplane equipment malfunctions and unsafe operating conditions. Caution and warning lights provide a visual indication to the flight crew of a non-normal condition, and are housed in a Caution/Warning Panel (CWP) forward of the overhead panel. If one on these illuminates, it is accompanied by a MASTER WARNING or MASTER CAUTION light, located at eye-level on the center glareshield, alerting the crew to the non-normal situation. The MASTER CAUTION light is accompanied by a single chime, and the MASTER WARNING light by three chimes. When either the MASTER CAUTION or MASTER WARNING light is pressed, it extinguishes and is reset; if a subsequent fault occurs, the MASTER CAUTION or MASTER WARNING light flashes with the new caution or warning, until either is pressed again. A caution/warning light on the CWP remains on for as long as the non-normal condition exists.

In the case of an IAS mismatch, when the discrepancy reaches 17 kt, the following amber cautions should illuminate:

a)	RUD CNTRL	(rudder control)
b)	ELEVATOR FEEL	
c)	SPLR OUTBD	(spoiler outboard)
d)	PITCH TRIM	

Each of the three pitot heat switches has an associated caution light on the CWP which illuminates if the systems fails or is switched off (Figure 4).

Documentation supplied by the aircraft manufacturer described failure indications for the aircraft's stall warning system. In general terms, the three cautions associated with the system, NO 1 STALL SYST FAIL, NO 2 STALL SYST FAIL and PUSHER SYST FAIL, illuminated in flight only for failures which inhibited the Stall Protection System (SPS) from computing stick-shaker and stick-pusher commands, such as failures

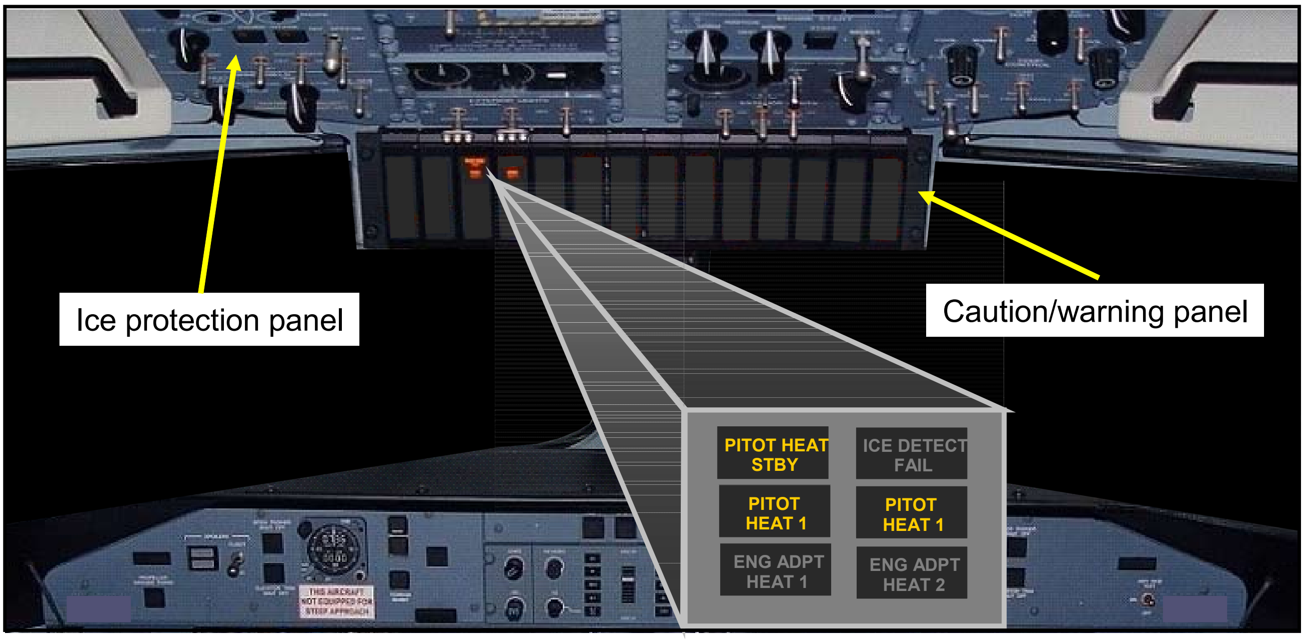


Figure 4

CWP arrangement and pitot/static caution lights

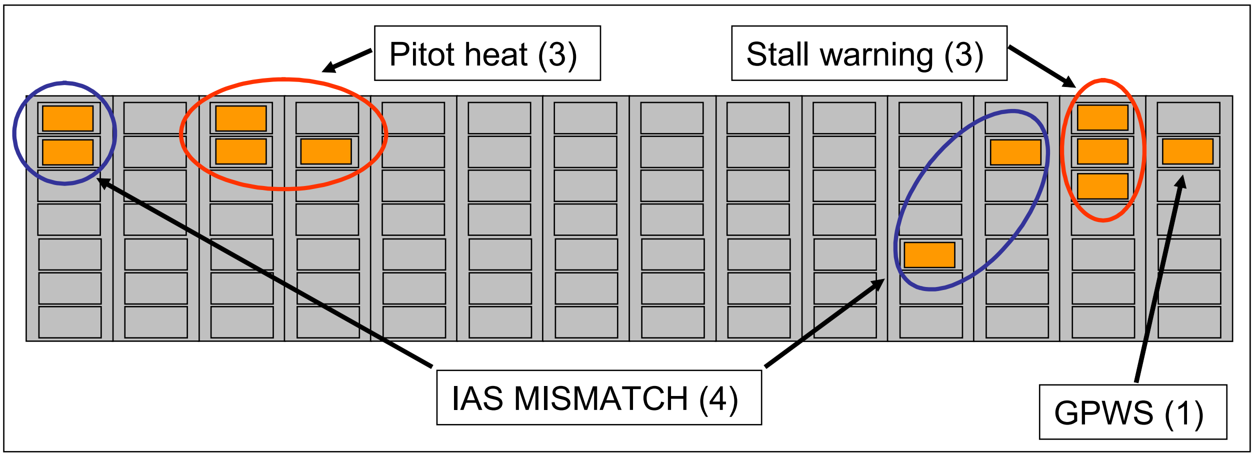


Figure 5
Distribution of CWP caution lights

of the stall protection modules or the AOA vanes. For other, non-critical failures, such as inputs from the ADCs, the SPS would not be prevented from generating a stall warning indication, so the CWP caution lights for such failures would be inhibited until 30 seconds after landing. The failure of both Mach number inputs to the SPS would generate all three cautions only after landing. The distribution of relevant CWP caution lights is shown at Figure 5.

Checklists and procedures

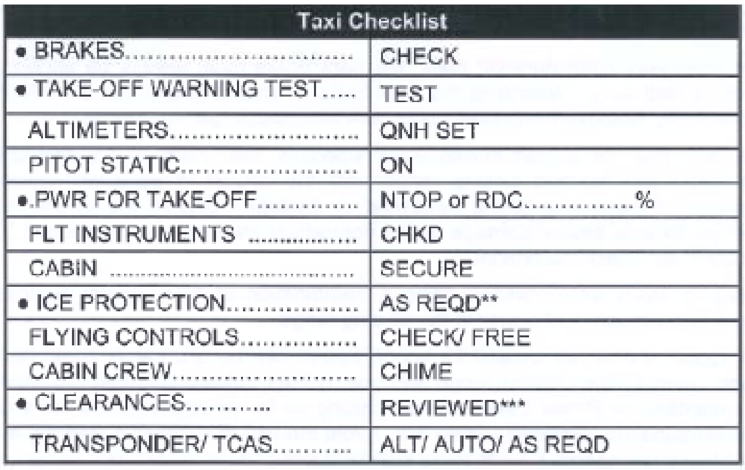
The operator's Operations Manual (OM) included detailed instructions about how various checklist should be completed. In general, checklists were of a 'challenge and response' type, with some exceptions (see below). The 'After Start' checklist included the item:

> *'Condition Levers………………MAX'*

During taxi, the commander would request the 'taxi' and the 'line-up' checklists, and these were always read aloud by the co-pilot (Figure 6). According to the OM, the co-pilot was required to *'SAY and DO'* the checklist items, with a response only required from the commander for items marked with a '●'. The *'PITOT STATIC'* (taxi checklist) and *'CAUTION WARNING LIGHTS'* (line-up checklist) were among those items not requiring a response from the commander.

Despite the specific instructions that the co-pilot should *'SAY and DO'* the taxi checklist items, the OM also stated that '*set-ups or flows*' preceded certain checklists, including the taxi checklist, and that such flows were performed automatically when the associated trigger was reached. It went on to say that the checklist would then be called for, and that the checklist itself may be the trigger. The trigger for the taxi checklist was not stated, nor was any 'set-up or flow' listed.

The manufacturer's Airplane Flight Manual called for the selection of pitot heat switches in its *'pre-taxi'* checklist only when conditions of slush or wet snow-covered taxiways exist. The switches are normally selected ON as part of the *'pre-take-off'* checklist, a sequence intended to reduce thermal damage of the pitot heads. The manufacturer stated



Taxi Checklist	
• BRAKES..............................	CHECK
• TAKE-OFF WARNING TEST.....	TEST
ALTIMETERS.........................	QNH SET
PITOT STATIC.......................	ON
•.PWR FOR TAKE-OFF.............	NTOP or RDC..............%
FLT INSTRUMENTS	CHKD
CABIN	SECURE
• ICE PROTECTION.................	AS REQD**
FLYING CONTROLS................	CHECK/ FREE
CABIN CREW........................	CHIME
• CLEARANCES...........	REVIEWED***
TRANSPONDER/ TCAS..........	ALT/ AUTO/ AS REQD

Figure 6

Taxi and line-up checklists (operator's Operations Manual)

that, at the operator's discretion, in order to standardise procedures, the pitot heat switches may be selected ON in the after-start check for all weather conditions. The operator's OM contained expanded checklists, which contained additional information or guidance regarding checklists. For the taxi checklist item '*Pitot Static Switches*', the expanded checklist included the note:

> *'Under conditions of slush or wet snow covered runways, put on before commencing taxiing'.*

The crew actions required passing FL100 were listed in the OM thus (see Figure 7):

Simulator trial

A full-flight DHC-8-400 simulator was used to study the flight deck environment, and indications experienced by the crew. Areas of particular interest were:

i. Operation and conspicuity of pitot heat switches

ii. Conspicuity of pitot heat caution lights at various stages of flight

iii. Lighting conditions

EVENT	PF	PNF
FL 100	***"Altimeters"***	***"Passing FL … climbing FL …"*** Land / Taxi Lights …. OFF Fasten Belts ……… As reqd by Captain Checks: Pressurisation, Anti-icing, Cabin Temp

Figure 7

Operations Manual crew action required passing Flight Level 100

iv. Flight instrumentation in normal and degraded/failure modes

v. Behaviour of sub-systems after ADC failure/icing events

vi. Ergonomic and human factors considerations

The pitot heat switches were grouped together on the icing panel immediately above the commander's head. The switches were not large, and their throw was not great, such that it was difficult to be certain, when viewing the switches in isolation from either seat, whether they were all ON or all OFF. This was particularly true from the co-pilot's seat, looking up and across the panel (Figure 3), and even more so in low lighting conditions. However, this was only true when all the switches were in the same position: if one switch was in a different position from the other two, the fact was more obvious.

The three pitot heat caution lights were grouped together on the left side of the CWP. As expected, the cautions appeared obvious when illuminated together on an otherwise dark panel. However, it was noted that the CWP itself was not naturally in the line of sight of either pilot when seated correctly at the controls looking directly ahead or down at the flight instruments. While taxiing the three pitot heat cautions could be illuminated but not obvious to either pilot. Once airborne, it was felt that the three cautions, if illuminated, would be noticed by the crew as they looked up to action items on the overhead panel, such as turning off the landing lights. The visual impact made by the cautions themselves when the CWP was set to its night DIM setting was, to a limited extent, dependent upon the level of flight deck lighting selected by the crew. Overall, the pitot/static caution lights were generally less noticeable from the co-pilot's (right-hand) seat position.

The level of light returned from the landing lights when flying in cloud was felt to be accurately simulated, and this tended to lessen the impact of CWP cautions at the DIM setting. Switches for the landing lights were just above the left part of the CWP. Although looking at these switches would have brought CWP pitot/static cautions into line of sight, a qualified instructor on type (who was assisting during the detail and who also conducted training for the operator's flight crews), noted that it was common for the light switches to be selected by feel only, being the only switches of that type in that part of the overhead panel. The pressurisation system panel was immediately above the landing lights, and it was noted that, unless the overhead panel lighting was set unusually dim, considerable light escaped from the dials within the indicator panel. When the pitot/static lights were illuminated, their conspicuity was reduced slightly by this effect when viewed from the commander's seat.

A number of instrument and ADS failure/icing scenarios were examined. It was noted that the IAS MISMATCH message appeared at about 10 kt IAS discrepancy, accompanied by autopilot disengagement. When outputs from ADC 1 were failed, the amber cautions RUD CNTRL, ELEVATOR FEEL, SPLR OUTBD and PITCH TRIM illuminated, with the MASTER CAUTION light and chime, as expected. It was not possible to simulate a failure of both ADCs, but a simultaneous ADC 1 failure and simulated icing of the right pitot/static head did not produce additional CWP cautions. The caution lights were spread evenly on the CWP with two on the left and two on the right. If pitot/static cautions were also illuminated, the majority of captions were on the left of the CWP.

No stall system cautions illuminated during the simulator 'flight' until after landing, at which point NO 1 STALL SYST FAIL, NO 2 STALL SYST FAIL and PUSHER

SYST FAIL cautions illuminated (on the right side of the CWP). This was consistent with information from the manufacturer regarding failure of ADC inputs to the stall warning systems.

With the engine condition levers advanced to the "900" detent, the engine rating mode annunciation on the ED showed "MCL" (maximum climb rating) for each engine. The levers were considerably further aft (more vertical) than the fully forward, 'MAX' position. At the 'MAX' position, the ED displayed "NTOP" (normal takeoff power) and "BLEED" annunciations (with engine bleed selected on).

The type rating instructor who assisted with the simulator trial reported that he had encountered instances of crew's omitting anti-icing system selections in error on the ground (particularly the pitot heat switches), and becoming airborne with the system(s) selected off. This was not common, but was usually associated with an abnormal level of pressure or distraction as can be generated in a flight simulator. He commented that he had not seen this happen when crews exercised the correct level of checklist discipline. On the subject of conspicuity of CWP cautions and fields of view, the same instructor reported cases in the simulator of crews taxiing the aircraft with a red engine oil pressure light on the CWP which had failed to extinguish after start, because the warning light was not in their natural field of view during the taxi phase (the MASTER WARNING and MASTER CAUTION 'attention-getting' lights on the glareshield would not illuminate in this case, as the CWP lights had remained on since engine start).

Operator's safety action

The operator conducted an internal investigation into the incident. Whilst it was noted that standard operating procedures had not been followed at all times, the report made a number of internal recommendations, which were under consideration at the time of writing. These included moving the pitot/static probe heat switch selections to the *'After start'* checklist, and requiring that fault diagnosis in the event of a failed takeoff configuration test should be carried out with the aircraft stationary. The second item was intended to eliminate possible distractions and pressures which may have played a part in this incident. The report also recommended making the CWP check before takeoff a 'challenge and response' item.

Analysis

A number of superficially similar events had been recorded in both the company's ASR system and also by the CAA MOR system. These other events probably involved icing of the pitot/static system although the possibility of the pitot/static anti-ice system not being selected ON is not raised in any of them. None of these other events is associated with G-JECG. Although the co-pilot had himself raised the possibility that the pitot heat switches were left OFF for take-off, both pilots thought that they would certainly have noticed if the CWP caution lights had been illuminated before the incident. They must have believed that the cautions were not on, since otherwise they would not have commenced takeoff. However, FDR data showed that the standby pitot heat switch remained OFF until a point in the flight when a discussion about the switch positions occurred, about which point it was selected ON. Although neither pilot reported being certain that the switch was moved, the FDR data showed that it was.

The possibility of an erroneous FDR signal for the standby pitot heat switch was considered, and it is acknowledged that the FDR signal records only either an open or ground circuit based on the switch position. However, FDR data from the 21 previous flights showed the switch being operated at the correct phase of flight, and it continued to show operation in the correct sense after this incident. Additionally, the recorded in-flight switch movement occurred at a point in the flight when the co-pilot raised doubts about the position of the pitot heat switches and, by his own report, may possibly have moved them. Given the generally high level of confidence in FDR data together with the continued correct functioning of the standby pitot heat system on earlier and subsequent flights, it was concluded that the FDR signal relating to the standby pitot heat switch was valid.

The pitot heat switches were normally selected either all ON or all OFF; it would be an unusual event to move a single switch in isolation, either in flight or on the ground. This, combined with the fact that a single switch out of position is more likely to have been noticed, strongly suggests that all three pitot heat switches were OFF for the majority of the flight, and therefore turned ON at the same time, a scenario that is supported by the recorded air data, though not by the crew's accounts. The view of the investigation team was that all three pitot heat switches were in the OFF position from before takeoff until after the descent to FL80.

The fact that neither pilot could be absolutely certain about whether the pitot heat switches had actually been moved after the incident may be due to the stress of the situation. Although the crew did not recall seeing any pitot heat cautions on the CWP, the probability of them all not illuminating with the switches at OFF is extremely low. It would have required independent systems to each have simultaneous undetected faults which did not affect other CWS cautions. Furthermore, the faults would have to be temporary, and affect only the very flight on which at least one of the pitot heat switches was known to have been left OFF for takeoff. Therefore, it was considered that the three pitot heat caution lights were illuminated on the CWP from before take-off until after the descent to FL80.

During the post-incident discussion between the pilots, reference was made to the position of the pitot heat switches, and, from the FDR, at least one was actually moved from OFF to ON. It is unlikely that reference was not made to the CWP cautions at the same time, if there was any doubt about the switch positions. As at least one pilot reported the *possibility* that a switch was moved, and both pilots reported that the associated pitot heat caution lights were not illuminated, it may be expected that a measure of doubt existed at that time about the integrity of the CWP (although neither pilot expressed such a doubt). However, there was no reported attempt to 'troubleshoot' this by, for example, simply cycling a pitot heat switch, nor was any report made by the crew, after landing or since, about the reliability of the CWS.

The co-pilot's routine of selecting the probe heat switches before the checklist called for this action probably contributed to the incident, though it was by no means the only factor. Although he recognised that this was not the correct checklist discipline, it should be noted that the operator's own OM did contain somewhat conflicting guidance in this respect, in that it referred to a *'set-up or flow'* which preceded the taxi checklist, though none was listed. On this occasion the co-pilot was distracted by the incorrect ED indications, such that when the commander called for the taxi checklist, the co-pilot had not completed his own memory items. This created the potential for an act of omission: the co-pilot had become used to responding to the checklist item *'PITOT STATIC'* with the knowledge that he had already moved the switches, and therefore probably did so on this occasion without positively checking the switches or CWP caution lights.

The taxi route to the runway was quite short, and the crew received a line-up and takeoff clearance before reaching the normal runway holding point. With another aircraft on final approach, there was an element of time pressure (at least from the co-pilot's perspective) to become airborne expeditiously. As the commander was taxiing the aircraft, there had to be a hand-over of control on the runway, probably soon after the co-pilot read the last of the line-up checklist items, which was '*CAUTION WARNING LIGHTS.....CHECK*'. This CWP check either did not occur or was ineffective, and this was not noticed by the commander. The handover of control may have interfered in some way with the co-pilot's normal method of checking the CWP, and was probably also influenced by the aircraft on final approach, awaiting a landing clearance.

Simulator trial

The simulator trial showed that it was possible to taxi the aircraft with CWP cautions illuminated but with neither pilot aware of the fact, unless either a deliberate scan was made of the CWP or the pilot's attention was directed to the forward overhead panel area. The position of the probe heat switches in the checklist sequence meant that it was normal on *every* flight (unless taxiways were contaminated) to taxi with the probe heat cautions illuminated (ie probe heat switches OFF). It is difficult to say whether this fact may have had a bearing on this incident, but it is important to stress that a correct and disciplined use of the checklist should alert the flight crew to the fact before takeoff. However, the operator was considering moving the probe heat switches to the after-start checklist as a direct result of this incident.

Central Warning System

Both crew members described a number of CWP cautions illuminating; the commander put the figure at between six and ten, and the co-pilot "several". Out of 84 amber caution lights on the CWP, four are directly associated with an IAS mismatch and three are associated with the stall warning system. Additionally, a GPWS light indicates an invalid or defective ground proximity warning computer; this system receives inputs from ADCs 1 and 2 and generates ground proximity warnings when the aircraft is between 50 ft and 2,450 ft radio altitude. This is the only caution, other than the seven previously mentioned, that monitors a system which receives an IAS or barometric altitude input. However, the GPWS caution does not illuminate for IAS mismatches.

Both pilots indicated that the majority of CWP cautions were toward the right of the panel, but such a spread of cautions appears to be dependent upon illumination of the stall warning cautions. However, the stall warning cautions would not illuminate in the air for an IAS mismatch or loss of ADC inputs, such as associated with this incident. Instead, this would require failures that would render the stall warning systems incapable of generating their respective warnings. In an icing scenario, this would most likely be a loss of information from, or loss of heating of, the AOA probes, although these were heated automatically as long as electrical power was available.

The FDR confirmed that AOA information remained valid throughout the flight and that the stall warning system outputs remained valid. It was therefore the view of the investigation team that the stall warning cautions, if they illuminated at all, did so only after landing at Belfast. There was therefore the possibility that the crew may have noted the cautions on landing and later incorrectly recalled them as having illuminated in flight. It was concluded that only four CWP cautions probably illuminated during the incident, as a direct result of the IAS mismatch (the autopilot disconnect warning light was separate from the CWP). These were spread equally between left and right sides of the CWP panel. If the probe heat cautions are added, this makes a total of seven which matches each pilot's estimate, though the bulk of them would clearly be on the left side, not the centre/right as the crew recalled. It was not possible to reconcile the differences between the crew's reports and the other information available to the investigation, including the recorded data, information from the manufacturer and observations during the simulator trial.

Flight crew effectiveness

The incident would have been disorientating and confusing and the crew were faced with a serious loss of flight instrumentation. However, there are a number of aspects which suggest that the flight crew were, at times, not working together as effectively as possible, although the reasons for this are not obvious. It is quite likely that the crew's workload was one factor in their performance. There were undoubtedly distractions and pressures during the taxi and early takeoff phase, as well as the matter of monitoring the icing and general poor weather situation during the climb.

It is known that the after-start actions were not fully completed at first and that the challenge and response item in the after-start checklist was completed without an effective check by either pilot of the condition levers or the ED indications. Despite the crew's recollections, the probability is that the checklist was completed incorrectly resulting in the probe heat switches being left at OFF. Then, before takeoff, a critical check of the CWP was ineffective and the aircraft subsequently became airborne with flight critical systems not operating.

The check items at FL100 were not fully completed by the commander. As these included a check of the pressurisation and anti-icing systems, and inspection of these panels should also have brought the relevant part of the CWP into view, it may be concluded that the FL 100 items were not carried out by either pilot. One effect of this was that the aircraft continued to climb for a short while further with the landing light glare reflected from the cloud, continuing to reduce the conspicuity of the probe heat lights which were selected to the night 'DIM' setting.

Manufacturer's procedures

It is desirable to minimise a flight crew's workload during the taxi phase, and some other aircraft manufacturers elect to switch on the pitot heat switches prior to taxi. In this case, the manufacturer had a specific reason for delaying the pitot heat switch selections (unless required for environmental considerations), namely the avoidance of thermal damage to the pitot/static probe heads. This procedure was reflected in the operator's OM, and the flight crew had been correctly trained in such procedures. These established procedures provided two formalised opportunities for the pitot heat switches to be checked prior to takeoff.

Contributory factors

A combination of non-standard use of the checklist, distraction on the flight deck and external pressure contributed to the aircraft taking off with the pitot/static probe heat switches incorrectly selected OFF. A high workload during the climb in poor weather and heavy icing conditions probably contributed to further missed checklist actions, such that the aircraft climbed to its cruising level without the omission being noticed. The resulting instrument failure indications and subsequent recovery of information were consistent with the probe heat switches being OFF until after the incident had occurred. The position of the CWP meant that, under specific circumstances, it may not have been readily obvious to the crew that pitot heat caution lights were illuminated.

Flight crew response

Although the crew were consulted during the investigation and the report production process, they expressed concerns about the views contained in the analysis of the facts in this report. In particular they were concerned about reliability of the FDR data in determining the physical position of the standby pitot heat switch. Furthermore, they felt that insufficient weight had been given to their recollection of events. The conclusions in this report however, recognise that anomalies and discrepancies existed in the crew's accounts, which were difficult to reconcile with recorded and other information.

INCIDENT

Aircraft Type and Registration:	Embraer EMB-145EP, G-RJXA
No & Type of Engines:	2 Rolls-Royce AE 3007A turbofan engines
Year of Manufacture:	1999
Date & Time (UTC):	10 May 2007 at 1215 hrs
Location:	In the climb, 20 nm south-west of Aberdeen Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 16
Injuries:	Crew - None Passengers - None
Nature of Damage:	No 1 IC-600 computer unserviceable
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	5,000 hours (of which 3,000 were on type) Last 90 days - 112 hours Last 28 days - 39 hours
Information Source:	AAIB Field Investigation

Synopsis

Approximately four and a half minutes after takeoff from Aberdeen (Dyce) Airport, while in the climb passing FL116, the Engine Indicating and Crew Alerting System (EICAS) caution and the 'AUTOPILOT DISCONNECT' warnings sounded. At the same time the commander's Primary Flight Display, Multi Function Display and EICAS went blank and smoke appeared from the left side of his seat. After the crew declared an emergency and completed limited cockpit drills, G-RJXA returned to Aberdeen, where it landed within 15 minutes without further incident. The aircraft's No 1 Integrated Avionics Computer (IC-600) had failed.

History of the flight

G-RJXA was on a scheduled flight from Aberdeen (Dyce) Airport to Manchester Airport. This was the operating crew's fourth and final sector of the day. The co-pilot was PF for this sector.

The start up, takeoff and initial climb proceeded without event. Approximately four and a half minutes after takeoff, while in the climb passing FL116, the Engine Indicating and Crew Alerting System (EICAS) caution and the 'Autopilot (AP) disconnect' warnings sounded. At the same time the commander's Primary Flight Display (PFD), Multi Function Display (MFD) and EICAS went blank and smoke appeared from the left side of his seat. The flight deck crew described this as a "smoky haze" and they smelt an "acrid burning smell". After the PFD, MFD and EICAS went blank a red 'X' was displayed on the screens. The Radio Management Unit (RMU) had also changed to an Engine display. The commander declared an in-flight emergency to ATC, and a return to Aberdeen was initiated. At the time the aircraft was in IMC and the co-pilot flew the aircraft manually.

Soon after the descent was initiated, the commander said to the co-pilot that he was selecting the AUTO/MAN switch, on the pressurisation control panel at the rear of the centre pedestal, to MAN (MANUAL) he then rotated the manual controller to the 1 o'clock position. He did this without referring to the Quick Reference Handbook (QRH).

Three minutes after the start of the incident the commander gave the senior member of the cabin crew a NITS[1] brief, using the interphone, and enquired whether there was any smoke in the cabin. She replied that there was a strong smell at the front of the passenger cabin. The commander then said that they expected to land in approximately 10 minutes and asked her to try and find the source, if she had time. The commander then said to the co-pilot "FORGET ALL THE CHECKS THERE'S NO TIME". He added there was only a little smell of smoke and "I'M HAPPY TO CONTINUE WITHOUT MASKS ARE YOU?". The co-pilot agreed. Approximately 30 seconds later the commander said "IT STINKS IN HERE" adding they had to land as soon as possible.

Two minutes later the cabin crew contacted the commander and said that there was only a smell of smoke and a "smoky haze" at the front of the passenger cabin. The commander informed them that he had turned the No 1 air conditioning pack OFF. During this exchange the commander had to interrupt the cabin crew in order to acknowledge and action instructions from ATC.

Radar vectors from ATC put the aircraft on a closing heading for a position 5 nm out on the runway centreline and it broke cloud at approximately 1,500 ft amsl. Once below cloud the commander quickly became visual with Runway 34, but as the co-pilot could not see it; the commander took control. After the Landing checklist was completed, the commander asked the co-pilot to try to contact the cabin crew, at approximately 300 ft aal, in order to see how the smoke was in the cabin; they did not respond.

The aircraft landed on Runway 34, 15 minutes after the incident started, with the red 'X' still on the commander's PFD, MFD and EICAS. The aircraft vacated Runway 34 onto Runway 32, where it was brought to a stop and an evacuation initiated with the AFRS in attendance. All passengers and crew vacated the aircraft without incident.

At no time during the incident did the crew put on their oxygen masks, instruct the cabin crew to put on their oxygen masks, deploy the passenger oxygen masks or refer to the QRH. Throughout the approach, to Aberdeen, the commander handled all the communication with ATC and the cabin crew.

Quick Reference Handbook (QRH)

Smoke checklists

There are three checklists associated with smoke, in the QRH, for this operator's EMB 145 aircraft. They are 'Air Conditioning Smoke', 'Electrical System Fire Or Smoke' and 'Cabin Fire Or Smoke'.

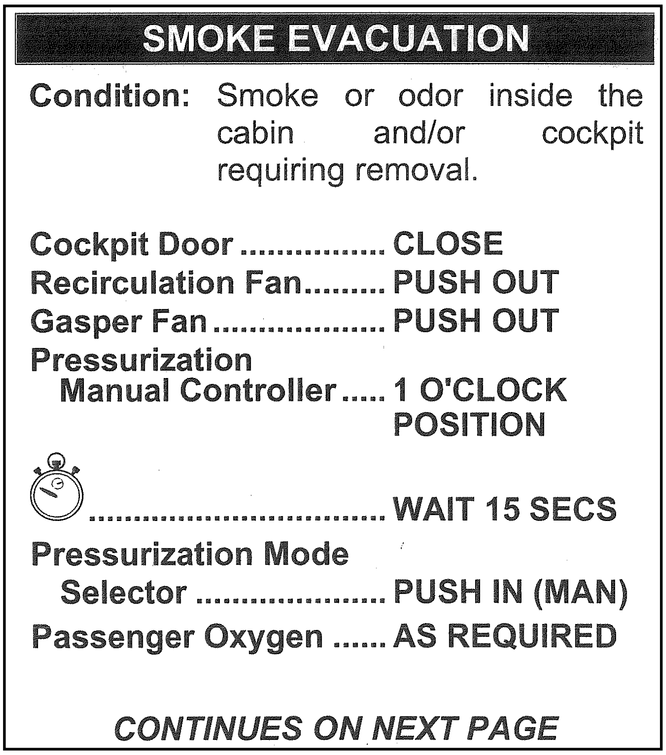
Footnote

[1] A 'NITS' brief is given to the senior member of the cabin crew, by the operating crew, in the event of an incident or emergency. NITS stands for Nature [of emergency], Intentions, Time [available before landing] and Special instructions e.g. whether there will be a need to evacuate upon landing.

After the description of the condition, for the use of the checklist, the following four actions are common to all three drills. They are boxed to indicate that they are Immediate Actions (IA), that is, items to be done from memory:

Crew Oxygen Masks........DON, 100%
Smoke Goggles................DON
Crew Communication......ESTABLISH
Recirculation Fan............PUSH OUT

The following checklist is to be done to remove smoke once the source has been isolated (Figures 1a and 1b):



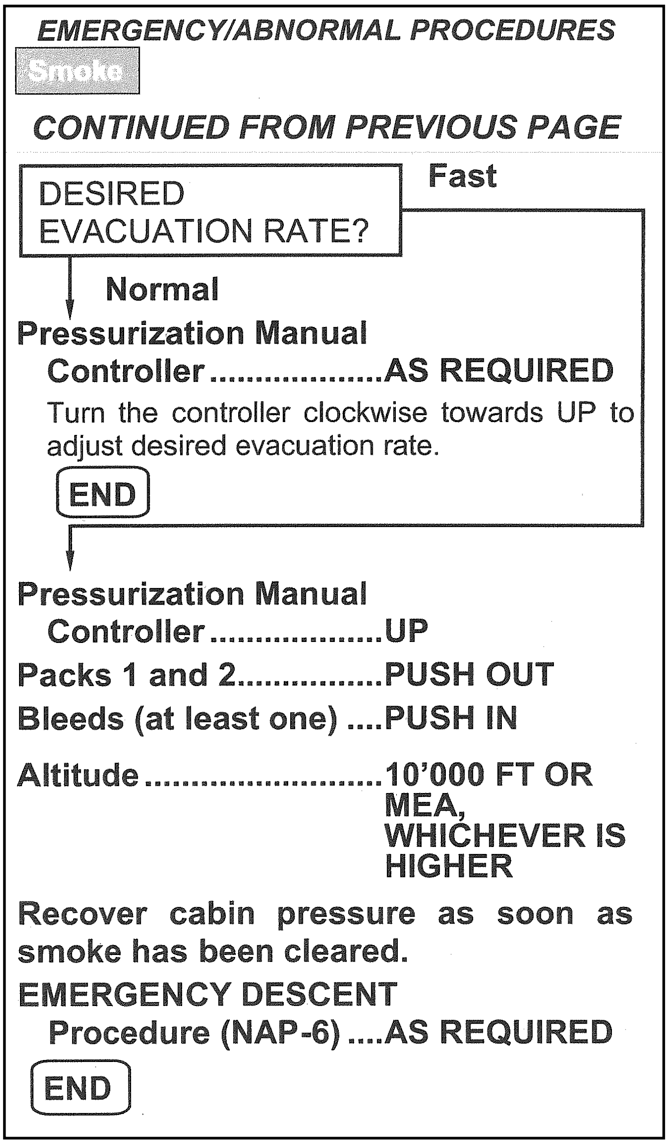
SMOKE EVACUATION

Condition: Smoke or odor inside the cabin and/or cockpit requiring removal.

Cockpit Door .... CLOSE
Recirculation Fan......... PUSH OUT
Gasper Fan .... PUSH OUT
Pressurization
Manual Controller..... 1 O'CLOCK POSITION
.... WAIT 15 SECS
Pressurization Mode
Selector .... PUSH IN (MAN)
Passenger Oxygen ...... AS REQUIRED

CONTINUES ON NEXT PAGE

Figure 1a



EMERGENCY/ABNORMAL PROCEDURES

Smoke

CONTINUED FROM PREVIOUS PAGE

DESIRED EVACUATION RATE?

Fast

Normal

Pressurization Manual
Controller ....AS REQUIRED

Turn the controller clockwise towards UP to adjust desired evacuation rate.

END

Pressurization Manual
Controller ....UP
Packs 1 and 2................PUSH OUT
Bleeds (at least one) ....PUSH IN

Altitude ....10'000 FT OR MEA, WHICHEVER IS HIGHER

Recover cabin pressure as soon as smoke has been cleared.

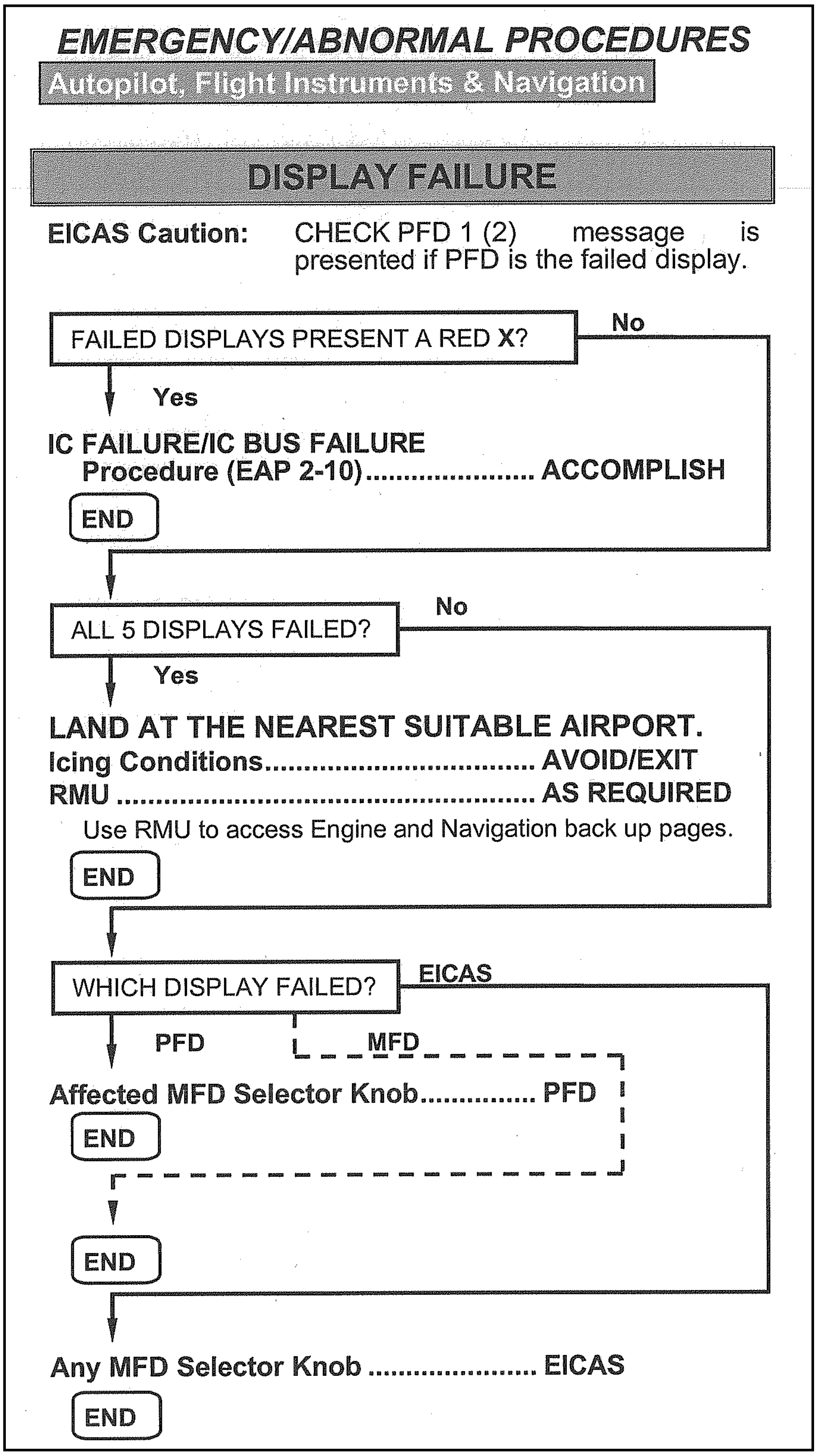
EMERGENCY DESCENT
Procedure (NAP-6) ....AS REQUIRED

END

Figure 1b

Display and IC failures

The following is the Display Failure checklist, for the symptoms the commander experienced (Figure 2):



EMERGENCY/ABNORMAL PROCEDURES

Autopilot, Flight Instruments & Navigation

DISPLAY FAILURE

EICAS Caution: CHECK PFD 1 (2) message is presented if PFD is the failed display.

FAILED DISPLAYS PRESENT A RED **X**?

IC FAILURE/IC BUS FAILURE Procedure (EAP 2-10)...................... ACCOMPLISH

END

ALL 5 DISPLAYS FAILED?

LAND AT THE NEAREST SUITABLE AIRPORT.

Icing Conditions................................. AVOID/EXIT

RMU .... AS REQUIRED

Use RMU to access Engine and Navigation back up pages.

END

WHICH DISPLAY FAILED?

Affected MFD Selector Knob............... PFD

END

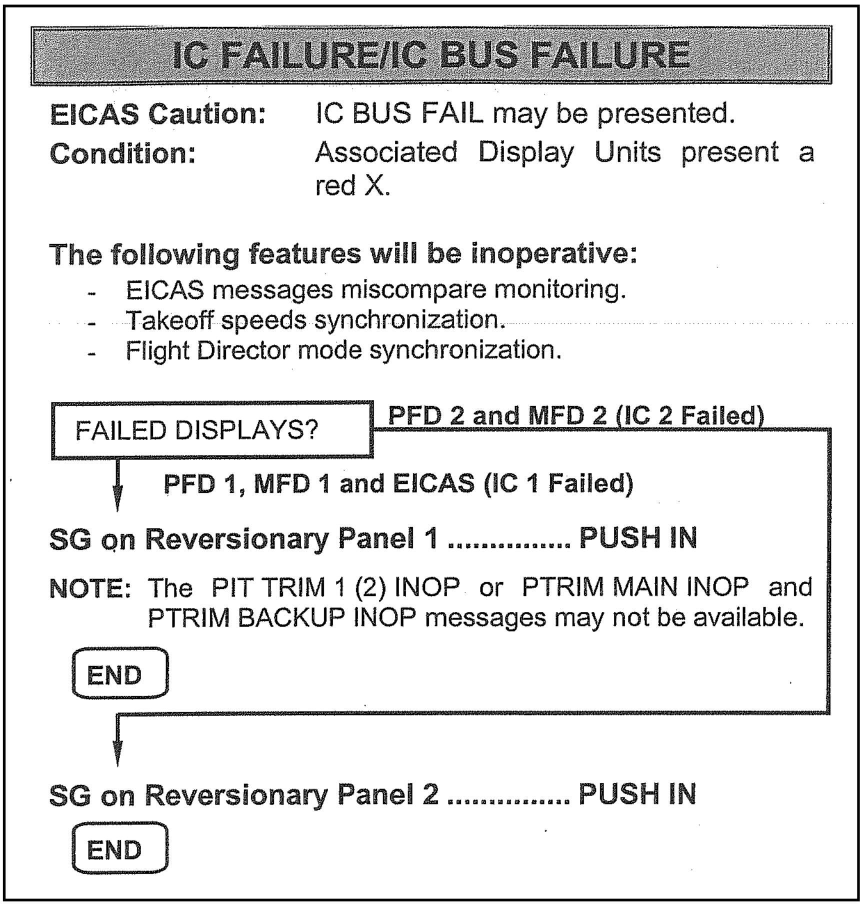
END

Any MFD Selector Knob .... EICAS

END

Figure 2

The following is the 'IC Failure' drill to which the 'Display Failure' checklist directs the crew (Figure 3):



IC FAILURE/IC BUS FAILURE

EICAS Caution: IC BUS FAIL may be presented.
Condition: Associated Display Units present a red X.

The following features will be inoperative:

- EICAS messages miscompare monitoring.
- Takeoff speeds synchronization.
- Flight Director mode synchronization.

FAILED DISPLAYS?

PFD 2 and MFD 2 (IC 2 Failed)

PFD 1, MFD 1 and EICAS (IC 1 Failed)

SG on Reversionary Panel 1 .... PUSH IN

NOTE: The PIT TRIM 1 (2) INOP or PTRIM MAIN INOP and PTRIM BACKUP INOP messages may not be available.

END

SG on Reversionary Panel 2 .... PUSH IN

END

Figure 3

Weather information

The METAR for Aberdeen Airport, issued at 1220 hrs, reported that the wind was from 020° at 9 kt, there were FEW clouds at 900 ft aal and BROKEN clouds at 1,000 ft aal, the air temperature was 8°C, the dew point was 7°C and the QNH was 995 mb.

Crew's comments

Commander's comments

The commander had been with the operator since September 2000. He had a total of 5,000 hrs, 3,000 of which were on type, with 1,500 hrs in command.

The commander commented that he did not put his oxygen mask on as there was only a small amount of smoke. After the smoke had cleared, and having discussed it with the co-pilot, he did not want to put his oxygen mask on as he was concentrating on monitoring the co-pilot, thought it might "hamper things" and did not want to cause undue concern to the passengers in the event of doing an announcement with the mask on. He added that if the smoke returned, or if he felt "giddy", he would have put on his oxygen mask.

The commander said that a training captain had demonstrated the smoke removal Immediate Actions to him during a simulator check and had told him that this was the best way to deal with smoke events in the cockpit.

Co-pilot's comments

The co-pilot had been with the operator since January 2006. He had a total of 2,200 hrs with 700 hrs on type.

The co-pilot commented that he did not call for the appropriate QRH checklist as he was concentrating on manually flying the aircraft. Additionally, he was worried his screens might go blank too.

He added he had done some screen failure training in the simulator but had not done any 'IC failure' training.

CAP 768 - Guidance Material for Operators

Chapter 15, Emergency Procedures and Oxygen Requirements, of CAP 768 contains the following:

> ***'2 Use of Oxygen***
>
> ***2.1 Smoke and Fumes in the Flight Deck***
>
> *2.1.1 The first action in the event of smoke or fumes in the flight deck should be for the flight crew to don oxygen masks and establish communications. If during flight it appears that both pilots are suffering from some form of incapacitation or that one pilot appears to be in any way incapacitated for no obvious reason, then the flight crew should don oxygen masks without delay.*
>
> ***2.1.2 Operations manual procedures should contain detailed instructions to crews on the necessity to use oxygen masks at 100% whenever contamination is present or suspected and the need to establish communications by the appropriate switch selections. In addition, cabin crew should monitor the flight deck, but this should not be to the detriment of other emergency procedures such as dealing with cabin smoke or fires, especially where only one cabin crew member is carried.*** *Incapacitation procedures should be practised regularly during recurrent training and case based studies are discussed at joint flight deck/cabin crews' safety training. The potential for a smoke/fumes event to adversely affect the subsequent operating effectiveness of the flight or cabin crew must be considered.* ***Flight crews should be aware that the first action in the event of smoke or fumes in the flight deck should be to don oxygen masks and establish communications.'*** *(AAIB Bold type)*

This guidance is contained in Part B, Section 3.3 of the operator's Operation Manual.

The operator commented that all crews should complete the IA stated in the QRH at the first signs of smoke and should refer to the QRH before completing any complex checklist such as smoke evacuation.

Crew training

During their initial conversion and recurrent training in the simulator, crews regularly practise operating the aircraft with oxygen masks on during an appropriate emergency. Additionally, they practise monitoring the PF, while the aircraft is being flown manually, at the same time as completing checklists and wearing oxygen masks during high workload scenarios.

Flight Recorders

General

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR), capable of recording a minimum duration of 25 hours of data and

120 minutes of audio respectively. The architecture of the FDR system was such that the majority of recorded parameters were acquired from the No 1 IC-600. In the event of the IC-600 failing, the FDR would continue to operate, but all associated parameters would stop being recorded, with no provision for alternate data sources. Unaffected FDR parameters were: tri-axial accelerations, control column and control wheel positions, rudder pedal positions, brake pressures and the clock.

Incident data

Both the FDR and CVR were removed from the aircraft and successfully replayed at the AAIB. The CVR provided audio for the entire flight; from pre-flight checks to final shutdown. All the recorded parameters were available from the FDR, until the failure of the No 1 IC-600. This occurred at 1154 hrs as the aircraft was climbing through FL116 and the aircraft had been airborne for about four and a half minutes. The aircraft landed at about 1209 hrs, with the FDR and CVR stopping about one minute later as the aircraft was shut down.

Engineering

System description

The aircraft is fitted with two IC-600 computers which are the primary components of the integrated avionics system. They exchange information with all other components, perform a cross-check with each other and manage all the information for the flight displays. Each IC-600 unit has a symbol generator and flight director. The No 1 IC-600 has an additional autopilot function.

There are two PFDs, two MFDs and one EICAS display. In normal operation the left PFD, MFD and the EICAS display are driven from the No 1 IC-600 computer, and the right PFD and MFD driven by No 2 IC-600 computer. In the event of an IC-600 computer failure, the corresponding PFD, MFD and EICAS displays will go blank and the No 1 Radio Management Unit (RMU) display on the control pedestal forward panel will automatically switch over to display the ENGINE BACKUP 1 page.

A reversionary panel is located outboard of each PFD. This is used to select the format of the display for the MFD and select the source of the Air Data Computer (ADC), Attitude and Heading Reference System (AHRS), and the IC-600 signal generator for the PFD and MFD. By pressing the symbol generator button (SG) the alternate IC-600 is used as the source for the displays.

Engineering investigation

The operator determined that the smoke had been caused by the failure of the No 1 IC-600 computer. Two circuit breakers (CBs) associated with the No 1 IC-600 computer were found to have ‘popped’. An IC-600 Input Bus Fail message was recorded at 11:54:40 hrs by the Central Maintenance Computer (CMC). The unit was replaced, the aircraft wiring was checked, and the aircraft was returned to service and operated without further incident.

The IC-600 unit, Part No 7017000-82340 Serial No 01013899, which had been removed, was taken to the manufacturer’s facility in the UK and then sent for further examination in the USA. The failure was traced to a ceramic capacitor on the power supply A1 Circuit Card Assembly (CCA) which is one of four filter capacitors used to eliminate noise on the 150 VDC input. The capacitor is not part of an active circuit and its failure alone would not affect unit operation.

There are two possible failure modes for a capacitor: ‘open’ or ‘shorted’. Had the capacitor shorted, the power supply over-voltage protection would have triggered and an immediate shutdown of the IC-600 would have occurred.

The failure mode in this case indicates the capacitor failed 'open' and the 150 V supply line would have continued to 'fuel' the open capacitor causing it to overheat, damaging the power supply card and adjacent analogue interface circuit card, and emitting the smoke detected on the flight deck. Eventually, as the damage developed, the over-voltage safety mechanism was triggered and the unit shut down as indicated by the blanking of the PFDs.

The unit manufacturer considers that this was an isolated component failure event among the combined millions of flight hours on the IC-600 product line and no similar failure within an IC-600 unit has been recorded.

Previous events

An event occurred to another Embraer EMB-145EP, G-ERJG, on 20 February 2005 which also resulted in the loss of flight displays and the EICAS. Subsequent investigation by the manufacturer found that a transistor on the A5 Autopilot CCA had failed and concluded that this was an isolated incident.

The aircraft manufacturer provided information regarding the current reliability of the IC-600 unit. The 'target' Mean Time Between Unscheduled Removals (MTBUR) was 3,500 flight hours (FH). The average MTBUR achieved worldwide was 5,400 FH; the average MTBUR for this operator was 1,715 FH.

Analysis

This incident was as a result of a No 1 IC-600 failure. It appeared, initially, to have been reasonably handled, in that the aircraft was landed and evacuated within 15 minutes of the initial appearance of smoke. However, upon closer analysis of the procedures employed by the crew during the recovery to Aberdeen, a number of important omissions became apparent that could have had very serious consequences.

Crew's actions

The crew did not don their oxygen masks and establish communications at the first sign of smoke, as required in the operator's Operations Manual and the aircraft's QRH. They should have done this irrespective of the amount of smoke present. Had they done this the crew would have been protected from any invisible gases that might have been present during the recovery (the smell persisted for some time). This potentially endangered themselves, the cabin crew and the passengers. If the crew subsequently felt "giddy" they might have become incapacitated and thus been unable to put on their masks without assistance. Once the smoke started to appear, they had no way of knowing whether it would stop quickly or continue to fill the cockpit.

The commander attempted to do the 'Smoke Evacuation' checklist from memory and only completed two items, from the middle of the checklist. He informed the co-pilot that he was doing it, rather than discussing with him whether it was a sensible course of action, thus showing poor Crew Resource Management. Having done this, he did not refer to the QRH to clarify if these actions were correct. The 'Smoke Evacuation' checklist is to be used once the source of the smoke has been identified and extinguished. The aim of the checklist is to increase the airflow through the aircraft so as to evacuate the smoke overboard. If the smoke was still being generated the increased airflow could have fanned the source and exacerbated the situation.

Throughout the descent, while the commander was PNF, he handled all communications with ATC and the cabin crew. Had he given control of this communication to the co-pilot, he would have reduced his workload and probably have given himself time to refer to the QRH.

There was no fault diagnosis of the commander's blank screens. As a result the Display Failure/IC-600 failure checklist was not completed. Had the commander completed this checklist he would have had his PFD, MFD and EICAS restored to him. This would have made it much easier for him to monitor the co-pilot's flying. As they were in IMC, and he landed the aircraft using the standby instruments, this would have been prudent. The commander's request to the co-pilot to contact the cabin crew at 300 ft aal was inappropriate. As the commander landed the aircraft using the standby instruments, the co-pilot should have been closely monitoring the commander during the final stages of the approach.

The crew correctly believed, during the later stages of the descent, that the smoke had stopped being generated, despite the lingering smell. Therefore they had as much time as they needed to complete all the necessary checklists before landing the aircraft.

The crew's actions should have been to don their oxygen masks, establish communications, complete the 'Air Conditioning Smoke' or 'Electrical System Fire Or Smoke' checklist, as they saw appropriate, then the 'Display Failure' checklist, followed by the 'Smoke Evacuation' checklist, if smoke was still present. Once these were complete they could then take their masks off, one at a time, to make sure there were no longer noxious fumes present, or land with their oxygen masks on.

Crew training

Crews train in the simulator, during appropriate situations, with oxygen masks on, so that when it comes to a real incident they are able to operate the aircraft unhindered while wearing them.

The correct use of the QRH checklist is instilled into crews during their initial and recurrent training. These checklists are carefully developed and tested by the aircraft manufacturer and are designed to keep the crew and the aircraft safe. If crews create their own procedures they run a risk of going into unknown situations, for which they do not have training or QRH checklists, that could have serious consequences.

Safety action

Following this incident, the operator conducted a series of simulator exercises with the operating flight crew. As a result, the operator is reviewing guidance on the donning of oxygen masks and other sections of their operating procedures.

INCIDENT

Aircraft Type and Registration:	Sikorsky S-92A, G-CHCK
No & Type of Engines:	2 General Electric CT7-8A turboshaft engines
Year of Manufacture:	2006
Date & Time (UTC):	23 April 2007 at 0750 hrs
Location:	Approximately 65 nm north-east of Aberdeen
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 15
Injuries:	Crew - None Passengers - None
Nature of Damage:	In-flight separation of a tail rotor pivot bearing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	16,390 hours (of which 214 were on type) Last 90 days - 113 hours Last 28 days - 37 hours
Information Source:	AAIB Field Investigation

Synopsis

The helicopter was on a public transport flight to offshore platforms in the North Sea and was over water, approximately 65 nm north-east of Aberdeen, when a heavy vibration began, which continued until the end of the flight. The crew turned back towards the coast and a successful run-on landing was completed about 30 minutes later.

The vibration was found to have been caused by the detachment of a tail rotor blade pivot bearing following a disbond of the bearing retainer from the flexible spar of the blade. Inspections of other S-92 helicopters highlighted other disbonded bearing retainers. Until a final fix is implemented, the helicopter manufacturer has increased the pivot bearing inspection frequency and provided more detailed instructions for inspecting the bearings.

History of the flight

The helicopter departed Aberdeen Airport at 0642 hrs on an Instrument Flight Rules (IFR) flight to transport personnel to offshore platforms in the Forties Field, in the North Sea. Weather conditions en-route were good Visual Meteorological Conditions (VMC), with nil weather, visibility in excess of 10 km and cloud base around 4,000 ft amsl.

The crew reported that at 0710 hrs, when the helicopter was approximately 65 nm north-east of Aberdeen and at an altitude of 3,000 ft in the cruise, a heavy vibration suddenly started. The commander took control, turned the helicopter back towards Aberdeen and initiated a descent from 3,000 ft, whilst the co-pilot radioed Aberdeen Airport to inform them of their intention to return. On noticing the helicopter's descent, Air Traffic Control (ATC) asked if they wished to declare an emergency; the co-pilot responded, stating that they had a technical problem.

The commander descended the helicopter to 1,000 ft and slowed it to below 120 kt. As the vibration had not diminished, he directed the co-pilot to make a 'PAN' call. The descent was continued down to 500 ft and the airspeed reduced to 85 kt, so that the helicopter could be ditched quickly if necessary. ATC advised that a Search And Rescue (SAR) helicopter would be sent to accompany them and asked if they wished to route towards the nearest coastline. The crew agreed that this was the most prudent action and turned the helicopter towards Peterhead. The passengers were kept appraised of developments and the crew's intentions, and the co-pilot reviewed the ditching drill in case this should become necessary.

The Stability Augmentation System (SAS) mode of the Automatic Flight Control System[1] (AFCS) continued to operate normally, but the autopilot hold functions of the AFCS were unavailable and the co-pilot's attempts to re-engage the autopilot proved unsuccessful. When the helicopter was approximately 15 nm from the coast, the Active Vibration Control[2] (AVC) system went into degraded mode. The co-pilot switched off the system in accordance with the checklist actions, but the crew's perception was that the level of vibration increased considerably and so it was switched back on again. At about this time, the Crash Position Indicator signalled that it had deployed and was transmitting.

ATC asked the crew if they wished to land at Longside and with further systems showing distress, this was considered the best option. A successful run-on landing was completed at Longside at 0748 hrs.

Recorded information

Multi Purpose Flight Recorder (MPFR)

The helicopter was fitted with a Penny & Giles Multi Purpose Flight Recorder (MPFR) that recorded the last two hours of flight crew speech and cockpit area microphone sounds and was capable of recording over ten hours of flight data. No data, however, was recorded due to a configuration mismatch between the installed MPFR and the Data Acquisition Unit (DAU), resulting in all the data from the DAU being misinterpreted by the MPFR as a continuous stream of '1's (in the binary format in which the data is stored). The lack of FDR data is discussed later in this report.

Health and Usage Monitoring System (HUMS)

HUMS data was available which showed that during the incident flight, from 0725 hrs onwards, there was a marked increase in the vibration level of the tail rotor. The mean vibration level measured increased from 0.2g to 0.5g and doubled approximately in peak-to-peak amplitude. From the CVR, it was at this time that the crew first felt the vibration. HUMS trend data recorded a single sample of the tail rotor balance during the flight of over 4.5 inches/second, 10 times more than the samples from the previous flight on 20 April, and in excess of the 0.8 inches/second service limit.

Footnote

[1] The AFCS performs flight stability, attitude hold and trim functions, reducing the pilot's workload.

[2] The AVC system controls the level of vibration at the 4-per-revolution main rotor blade passing frequency. It is an electro-mechanical system which employs sensors to measure the levels of vibration in different parts of the helicopter and commands inertial force generating devices which provide controlled vibratory loads to reduce fuselage vibration.

Helicopter information

General

The S-92 is a medium-lift, twin-engine, multi-role helicopter. It is equipped with four-bladed main and tail rotors. This helicopter, serial number 920030, was manufactured in 2006 and at the time of the incident had flown approximately 1,030 hours and completed 1,881 landings since new. The previous scheduled tail rotor inspection was performed 53 flying hours prior to the incident, with no reported defects. The helicopter was not carrying any relevant deferred defects at the time of the incident.

Tail rotor blade construction

The tail rotor blade construction is illustrated in Figure 1. The rotor comprises four individual composite blades attached to a central hub. The main load bearing structure of the tail rotor blade comprises an elliptically-shaped graphite-epoxy torque tube. The leading edge aerofoil contour of the blade is formed by a nickel sheath bonded to the front of the torque tube. The aft part of the aerofoil section consists of a honeycomb structure sandwiched between fibreglass-epoxy skins. The blade is attached to a graphite flexible spar, sometimes called a flex beam, which is inserted inside the torque tube and is attached to it at the mid-span location with four fasteners. The free end of the flexible spar is bolted to the tail rotor hub. The open, root end of the torque tube is covered with a boot to prevent moisture and debris from entering the blade.

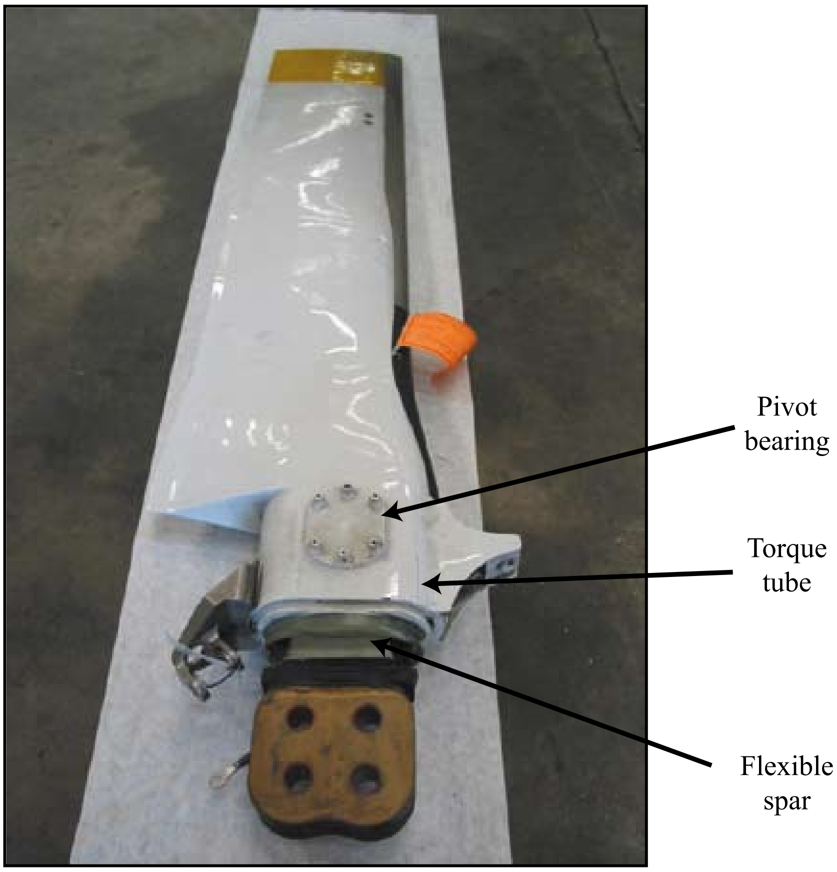


Figure 1

S-92 tail rotor blade

Elastomeric pivot bearing

Two pivot bearings are located on either side of the flexible spar, towards the root of the blade (Figure 2). These are fixed to the torque tube and protrude into the hollow centre section of the blade. The bearings butt up against the flexible spar, which is clamped between them. The bearings are manufactured from an elastomeric material to allow some degree of movement between the flexible spar and the blade, in specific directions. One end of the bearing is bonded to a nut plate, which is attached to the torque tube with six fasteners. An end plate, comprising a metal disc with a central recess, is bonded to the other end of the bearing. This locates on to a retainer, comprising a metal disc with a central spigot, bonded to the surface of the flexible spar. The retainer further constrains the movement of the blade.

G-CHCK tail rotor blade details

The tail rotor blade assembly, part number 92170-11000-044 and serial number A111-00210, was manufactured on 22 November 2005 and installed on G-CHCK at helicopter build. At the time of this incident, it had completed approximately 1,030 flight hours since new. In early 2007, the trailing edge of the blade tip suffered minor damage from contact with staging whilst the helicopter was being manoeuvred in a hangar. The damage was repaired in accordance with a repair scheme approved by the helicopter manufacturer and a tail rotor balance check was performed after reinstalling the blade.

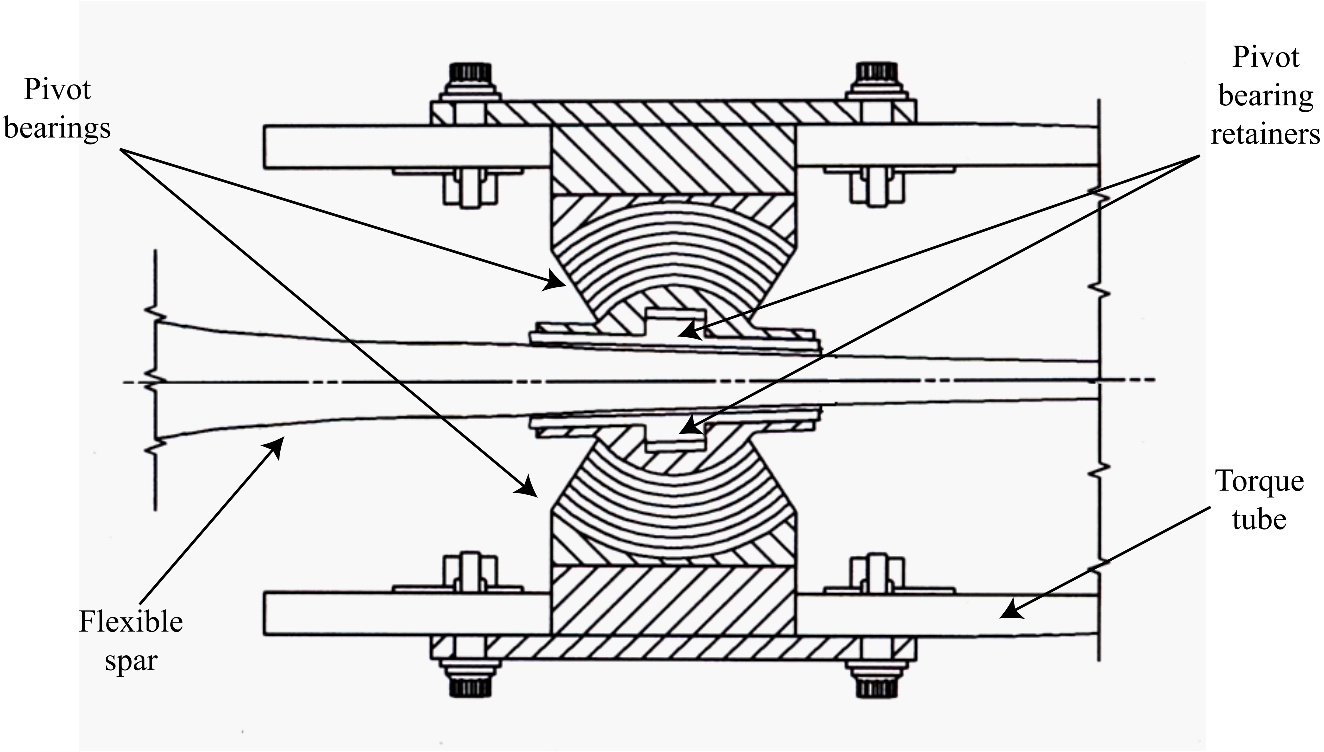


Figure 2

Longitudinal section through tail rotor pivot bearing

Tail rotor blade examination

The affected tail rotor blade was removed from G-CHCK and sent to the AAIB for preliminary examination prior to being forwarded to the helicopter manufacturer for more detailed examination.

It was evident that the larger part of the outboard pivot bearing and its retainer had detached (Figure 3) and migrated outwards inside the torque tube under centrifugal loading, becoming jammed between the torque tube and the flexible spar (Figure 4). The inboard bearing retainer had also detached from the flexible spar and travelled up inside the torque tube, but the inboard bearing was undamaged (Figure 5). Overlapping circular witness marks were visible on both sides of the flexible spar (Figures 5 and 6), corresponding to the original position of each bearing retainer and the newly adopted positions after the retainers had disbonded from the flexible spar. Similar witness marks were found on the flexible spar of another of the operator's S-92 helicopter, serial number 920013, which had also suffered a disbond of a bearing retainer. This blade was also removed and sent to the helicopter manufacturer for examination.

Figure 3 (left)

View inside G-CHCK tail rotor blade torque tube showing missing pivot bearing

Figure 4 (right)

View inside torque tube of G-CHCK tail rotor blade showing detached outboard pivot bearing trapped between torque tube and flexible spar

Figure 5 (left)

G-CHCK tail rotor inboard pivot bearing showing missing bearing retainer and overlapping circular witness marks

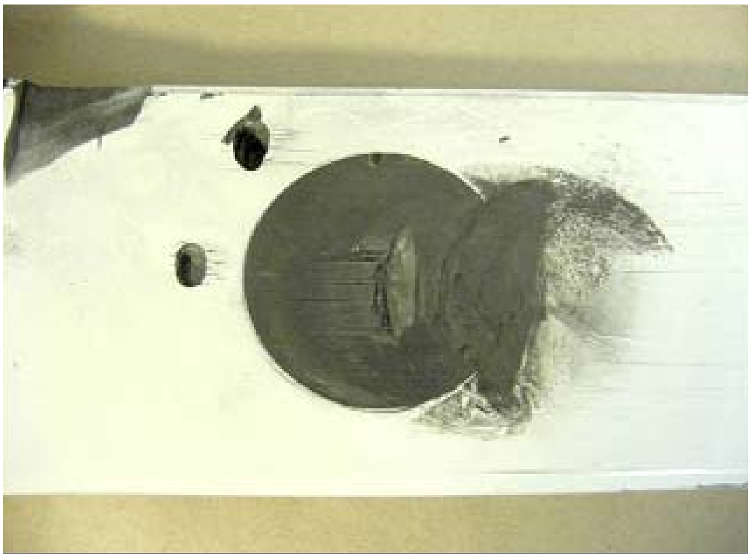


Figure 6 (right)

G-CHCK flexible beam outboard side showing witness marks produced by bearing retainer

Tail rotor inspection requirements

Scheduled inspection requirements

The helicopter inspection requirements are included in the Airworthiness Limitations section of the S-92 Maintenance Manual. The inspection interval for the tail rotor pivot bearing was originally 50 flying hours, but this was later increased to 250 flying hours, as no defects were being reported by operators.

The inspection of the pivot bearing was covered by Item 9 of the 250-Hour Inspection: *'Inspect tail rotor blade elastomeric pivot bearing and retention plate.'* The task cross-referred to the instructions contained in Maintenance Manual task 64-10-01. However these are instructions for an external inspection of the condition of the blade and not an internal inspection of the pivot bearings. Specific instructions for inspecting the pivot bearings are contained in Maintenance Manual section 64-10-06, '*Inspection of Tail Rotor Pivot Bearing*.' Following this incident, the helicopter manufacturer moved the pivot bearing inspection on to the 50-Hour Inspection schedule and amended the Maintenance Manual cross-reference to call up the correct inspection procedure contained in section 64-10-06.

Pivot bearing inspection instructions

Prior to the incident the instructions contained in Maintenance Manual 64-10-06, as listed below, were brief and did not provide specific instructions on inspecting the pivot bearings:

> *'…(2) Visually inspect inside of tail rotor blade.*
>
> *(3) Make sure that the upper and lower pivot bearing retainers are bonded to the flex beam.*
>
> *(4) Make sure pivot bearing is properly seated on pivot bearing retainer.'*

With the tail rotor blade installed on the helicopter, there is limited access to the root of the blade due to the proximity of the tail rotor hub.

The helicopter manufacturer has since issued Temporary Revision (TR) 64-03 to the Maintenance Manual, to provide more comprehensive instructions for inspecting the pivot bearings and, in particular, how to detect a disbonded bearing retainer. It is now recommended that a borescope is used to inspect the pivot bearings if the inspection is performed with the blade installed on the helicopter.

To date there have been a total of 16 cases of disbonded pivot bearing retainers, nine of which have occurred since this event. With the exception of this event, all have been found during inspection.

Fleet inspection of pivot bearings

After the G-CHCK incident, the operator inspected the tail rotor pivot bearings on other helicopters in its S-92 fleets. One other helicopter, serial number 920013, was found with a disbonded pivot bearing retainer, but the pivot bearing was still intact. This helicopter had flown 2,286 hours since new and the most recent scheduled pivot bearing inspection was completed 116 flying hours previously.

On 23 May 2007, the helicopter manufacturer issued Alert Service Bulletin (ASB) No 92-64-001 to direct operators to perform a one-time visual inspection of the tail rotor pivot bearing retainers within 50 flying hours, or 30 days from the date of issue of the ASB. The inspection required the removal of the pivot bearings to allow access to the bearing retainers for a visual and tactile check of the integrity of the bonding of the retainer to the flexible spar. The AAIB is aware of one helicopter in Denmark that was found with a disbonded pivot bearing retainer when performing the ASB. The affected tail rotor blade, serial number A111-00282, had completed 152 flying hours since new.

MPFR installation

On 18 April 2007, the annual download check of the MPFR fitted to G-CHCK was due to be carried out. However, connections problems between the MPFR and the laptop PC used for the download prevented the check from happening, and in order for the helicopter to return to commercial operations, a replacement MPFR was installed instead. Unfortunately, the replacement MPFR was configured to record at the data rate of 128 words per second (wps) compared with the Data Acquisition Unit's (DAU) rate of 256 wps. This MPFR remained installed until the time of incident, during which G-CHCK had flown a total of 12.5 hours.

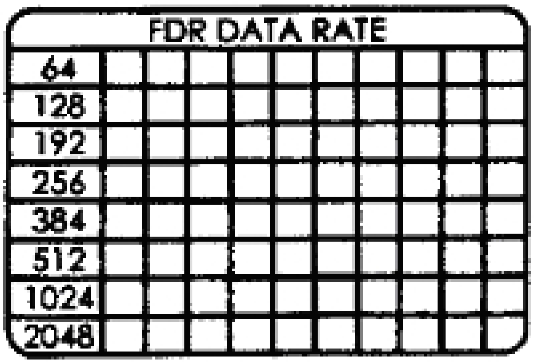
Sikorsky Maintenance Manual SA S92A-AMM-000 (Aug 31/05)

Both the removal and the installation of the MPFRs was carried out in accordance with the Sikorsky Maintenance Manual, SA S92A-AMM-000 (31-31-01 Pages 401-404 dated Aug 31/05), which refers to the MPFR by its part number D51615-102. This practice is quite normal as flight recorders in general that share the same part number are usually interchangeable, with predefined configurations matched to the aircraft's flight recorder system.

Penny & Giles MPFR

The MPFR can, however, be reconfigured via its PC interface, allowing, for example, different recording data rates to be set on different recorders that share the same part number. As there is nothing externally on the recorder to indicate the FDR data rate configuration, the uniqueness of the part number no longer ensures the interchangeability of the MPFR in the aircraft's flight recorder system.

As a result of this incident, Penny & Giles issued a Service Information Leaflet (sil51615-XXX-02) and Service Bulletin (D51615-31-5) to all known customers of the MPFR requiring an FDR Data Rate label (P/N: 111053), illustrated in Figure 7, to be attached to the outer casing onto which the current data rate of the recorder can be marked. This label is also now attached to all new MPFRs.



FDR DATA RATE										
64										
128										
192										
256										
384										
512										
1024										
2048										

Figure 7

MPFR Data Rate label

Flight recorder system – monitoring of proper operation

The design and installation of the MPFR was made in accordance with the EUROCAE document ED-112 (Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems) that specify the continuous monitoring of the data recording system for proper recording of the information in the recording medium. In particular it states in paragraph 2-1.4.2 that:

> *'An acceptable means of compliance would be to provide system status monitor(s) and built-in test functions which would detect and indicate to the flight crew a failure of the flight recorder system due to any of the following:*
>
> *a. Loss of system electrical power,*
>
> *b. Failure of the acquisition and processing equipment,*
>
> *c. Failure of the recording medium,*
>
> *d. Failure of the recorder to store the information in the recording medium as shown by checks of the recorded material including, if reasonably practicable, correct correspondence with the inputs,*
>
> *e. The absence of the recorder and/or the acquisition unit.'*

To meet this requirement, the helicopter is fitted with an FDR fail light, positioned within the cockpit to the left of the left-seat collective control. From the above list of failure cases, it could be argued that if a data recorder were configured to a specific data rate but received data from the acquisition at a different rate, this difference, if detectable, should be interpreted as a '*failure of the acquisition unit*'.

MPFR built-in-test equipment (BITE)

The MPFR, as part of its BITE, is designed to make a data rate check at recorder start-up. If set to the wrong rate a BITE should be identified and flag an FDR fault via the FDR fail light. The FDR fail light, however, did not illuminate. This was due to the MPFR interpreting two consecutive 'zeros' sent from the DAU (set to 256 wps) as 'ones' when the MPFR was set to 128 wps.

CHC Scotia aircraft fleet using the MPFR

CHC Scotia has a mixed fleet of aircraft that each use the MPFR as part of their flight recorder system: the Sikorsky S-92; the AgustaWestland AW139 and the Eurocopter AS332L2. The systems do not, however, share a common data rate. Of the fleet, only the S-92 and the AW139 come fitted with the MPFR as standard fit, and configured for a 256 wps data rate. The AS332L2 has the MPFR installed as a retro-fit (using a CHC Heli-One modification), and configured for a 128 wps data rate.

MPFR functionality checks post-installation

The Sikorsky Maintenance Manual 31-31-01 (Aug 31/05) did not require a functionality check of the MPFR post-installation. A check of this nature would provide a means of capturing an MPFR configured to a different data rate compared to the flight recorder system requirements. As such, Sikorsky have issued a Temporary Revision (No 31-03 dated Sep 30/07) to 31-31-01 (Aug 31/05) that requires a post-installation test to be performed as part of the installation procedure. (Similarly, the AgustaWestland AW139 MPFR installation procedures do not include a functional check of the FDR side of the MPFR post-installation. The CHC Heli-One AS332L installation procedures require a functional check of the MPFR to be carried out, but a specific check of the data rate is not required. AgustaWestland have, however, indicated that they intend to revise their procedure to include such a check.)

Analysis

The sudden onset of vibration during the flight suggests that a rapid in-flight separation of the outboard pivot bearing occurred, causing the greater part of the bearing to detach and migrate further up the torque tube under centrifugal force. The resultant change in the centre of mass of the blade would have caused the tail rotor to become out of balance, producing the reported high vibration levels.

The overlapping circular witness marks on both sides of the flexible spar represented the initial position where the retainer was bonded to the spar and the new relaxed position of the bearing after the retainer had disbonded. Inspections of other S-92 helicopters since this incident have identified other retainers that had disbonded, producing similar witness marks on the flexible spar.

All of the above suggests that the bearing separation on G-CHCK was probably preceded by the disbond of either one or both of the bearing retainers from the flexible spar. This would have caused the inner end of the pivot bearing to become unrestrained, allowing it to deflect outwards in a spanwise direction under centrifugal loading when the tail rotor was rotating. This would place the elastomer under considerable strain. In this case, the elastomer eventually separated, allowing the greater part of the outboard pivot bearing to detach and to be centrifuged up inside the blade torque tube.

It is possible that the impact on the tail rotor blade sustained in the hangar could have compromised the integrity of the bond on the bearing retainer, making it more likely to fail. However, the damage to the blade was very localised and the loads transmitted to the pivot bearings were likely to have been less than those they would be exposed to in normal service. Furthermore, disbonded retainers were found on tail rotor blades without any previous damage, suggesting that the root cause is not damage-related.

It is possible that the tail rotor pivot bearings may not have been adequately inspected prior to this incident, given the incorrect Maintenance Manual cross-reference and the very basic instructions previously contained in Maintenance Manual task 64-10-06. This may have been exacerbated by the difficulties in accessing the inside of the blade when installed on the helicopter. These issues have been addressed by the helicopter manufacturer in recent amendments to the manual. The amended inspection has proved to be effective in identifying disbonded bearing retainers.

The helicopter manufacturer is continuing its investigation into the root cause of retainer disbond. A final fix will be implemented once the root cause has been identified. In the meantime, the more frequent inspections of the pivot bearings and more comprehensive inspection instructions should ensure that disbonded retainers are identified before bearing separation occurs.

The issue concerning MPFR data rate configuration control has been expediently and satisfactorily resolved by the airframe and recorder manufacturers. Therefore it is not considered necessary to make any safety recommendations on this matter.

Conclusions

The helicopter experienced a sudden onset of vibration due to the detachment of a large part of the outboard pivot bearing on one of the tail rotor blades. The separation of the pivot bearing was probably the consequence of the bearing retainer becoming disbonded from the flexible spar, allowing the inner end of the bearing to become unsupported. This would have exposed the bearing to loads for which it had not been designed, causing it to eventually separate in flight.

ACCIDENT

Aircraft Type and Registration:	Bolkow F.207, D-EHUQ
No & Type of Engines:	I Lycoming O-360-AIA piston engine
Year of Manufacture:	1961
Date & Time (UTC):	5 November 2007 at 1405 hrs
Location:	Branscombe Airfield, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Severe damage to left wing and landing gear, bent propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	69 years
Commander's Flying Experience:	715 hours (of which 76 were on type) Last 90 days - 22 hours Last 28 days - 25 minutes
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

On takeoff, the aircraft hit a bump in the grass and became airborne. The aircraft veered to the right and cartwheeled through a wire fence.

History of the flight

The aircraft was taking off from Branscombe Airfield for a flight to Plymouth. The wind was variable at 2 to 3 kt. As the airspeed approached the liftoff speed of 55 kt, with the tail slightly up, the aircraft hit a bump in the grass and became airborne. The right wing dropped slightly and the aircraft veered to the right, heading towards an electricity pole outside the airfield boundary. The pilot tried to correct by applying left aileron, but the right wing stalled, turning and diving the aircraft to the right. It struck the ground and cartwheeled through a wire fence, badly damaging the left wing and landing gear before coming to rest in a neighbouring field.

The pilot and passenger were uninjured and evacuated through the entry door on the left side. There was no fire. The pilot has stated that, after the aircraft became airborne too early, he had not been quick enough to lower the nose and maintain the heading on the runway centreline.

ACCIDENT

Aircraft Type and Registration:	Jodel DR1050 Ambassadeur, G-BXYJ
No & Type of Engines:	1 Continental Motors Corp O-200-A piston engine
Year of Manufacture:	1960
Date & Time (UTC):	16 February 2008 at 1500 hrs
Location:	Welshpool Airfield, Powys
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Both main landing gear legs, propeller, lower engine cowl
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	377 hours (of which 200 were on type) Last 90 days - 5 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After landing, the aircraft began to weave from side to side. During the pilot's attempts to correct this, he applied the right wheel brake which resulted in the collapse of the main landing gear.

History of the flight

After an initially uneventful landing at Welshpool, the aircraft began to weave from side to side down the runway. The pilot stated that this was normal for the aircraft but, on this occasion, the weaving appeared more pronounced. He tried to correct the movement using the rudder but the aircraft continued to weave. Despite the application of full left rudder, it swung to the right and, in an attempt to stop the oscillations, the pilot applied the right wheel brake. He was unable to operate the left foot brake due to the use of full left rudder and this resulted in the collapse of the right main landing gear leg. The propeller then struck the ground followed by the collapse of the left landing gear. The pilot and passenger were uninjured and were able to leave the aircraft unaided.

The pilot attributed the incident to his familiarity with operating the aircraft from grass surfaces which lead to the use of excessive rudder inputs on a paved runway.

ACCIDENT

Aircraft Type and Registration:	Kolb Twinstar Mk3 (Modified), G-BYTA	
No & Type of Engines:	1 Rotax 582 piston engine	
Year of Manufacture:	2000	
Date & Time (UTC):	16 November 2007 at 1450 hrs	
Location:	Kilkeel, County Down, Northern Ireland	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Minor)	Passengers - 1 (Minor)
Nature of Damage:	Aircraft damaged beyond economic repair	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	53 years	
Commander's Flying Experience:	37 hours (all of which were on type) Last 90 days - 0 hours Last 28 days - 0 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and meteorological aftercast provided by the Met Office	

Synopsis

About 10 to 15 minutes after takeoff the engine failed. During the forced landing the aircraft encountered an area of 'sink' and collided with a hedgerow that contained an embedded barbed wire fence.

History of the flight

The accident flight was a continuation of an exercise that had started with a flight that morning. About 10 to 15 minutes after takeoff, the pilot, who was also the owner, noticed that the left exhaust gas temperature gauge was falling towards zero. He immediately turned the aircraft towards the airfield and informed his passenger, who was an experienced pilot. The aircraft flew towards the airfield for about 10 to 15 seconds, when the engine stopped. The pilot handed control of the aircraft to his passenger, as he was considerably more experienced as a pilot and had more recent flying practice. He immediately turned the aircraft into wind towards a large field; the only one within gliding range that did not contain livestock. The glide approach was progressing very well until the aircraft was about 20 to 30 feet from the field boundary when they encountered an area of 'sink'. This resulted in the aircraft colliding with the field's boundary hedgerow. The hedgerow was mounted on a raised bank and had a barbed wire fence embedded within it. Both the pilot and his passenger received minor injuries and were admitted to hospital.

Engineering investigation

A friend of the pilot removed the aircraft from the accident site. During this removal he noted that there was a reasonable quantity of fuel in the tank and that the engine was free to rotate. A few days after being released from hospital the pilot inspected the aircraft and, from external inspection, could find no reason why the engine had failed. He successfully started and ran the engine and no fault was found. In his opinion the engine failed due to the build-up of icing within the carburettor.

Meteorological aftercast

A meteorological aftercast was obtained from the Met Office for the area and date of the accident. There was a high pressure system centred over the Cherbourg Peninsula which resulted in a light to moderate south-westerly flow over Northern Ireland. Although there were no fronts, slight precipitation was recorded over the west of Northern Ireland and a layer of stratocumulus covered the area. The following temperatures and humidity were recorded from a radiosonde ascent that was launched, at 1115 hrs GMT, into the same air mass that prevailed over the accident site at the time of the accident.

Height amsl ft	Temp °C	Dew point °C	Humidity %
515	8.7	6.2	84
751	8.5	5.9	83
1020	8.8	5.1	77
1512	7.7	4.1	78
1995	6.9	3.3	78

These temperature and humidity readings were plotted on a carburettor icing probability chart and the result, shown at Figure 1, indicates that there was a possibility of serious icing at any power.

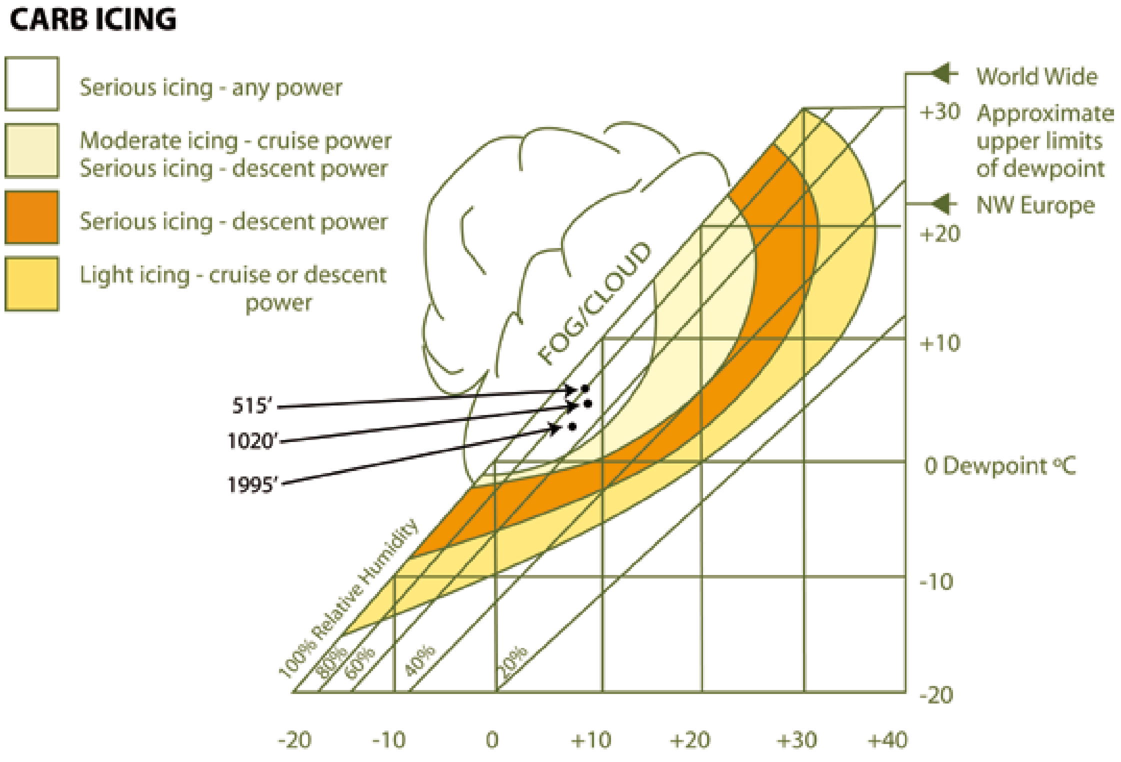


Chart taken from:
CAA Safety Sense Leaflet No 14b

Figure 1

Carburettor Icing Probability Chart

ACCIDENT

Aircraft Type and Registration:	Piper PA-25-235 Pawnee, G-ASVP	
No & Type of Engines:	1 Lycoming O-540-B2C5 piston engine	
Year of Manufacture:	1964	
Date & Time (UTC):	17 June 2007 at 1355 hrs	
Location:	Hinton-in-the-Hedges, Northamptonshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Major damage to engine propeller and cockpit area. Minor damage to one wingtip	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	49 years	
Commander's Flying Experience:	385 hours (of which 50 were on type) Last 90 days - 2 hours Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent AAIB enquiries	

Synopsis

After a normal landing, the aircraft's tail began to rise and the propeller struck the ground. As a result, the aircraft pitched onto its back. Two Safety Recommendations have been made with regard to the survivability of this accident.

History of the flight

The pilot was a regular volunteer tug pilot for the gliding club operating at the airfield and was returning to the airfield from the eighth aerotow launch of the day. The weather was fine with a light westerly breeze. Runway 27 was in use for launching and Runway 33, although subject to a slight crosswind, was being used for landing; both runways have grass surfaces.

This was the pilot's second landing on Runway 33 with the first causing no difficulty. The pilot reported that the approach and landing seemed normal, although witnesses recalled seeing a slight bounce on landing. As the aircraft decelerated, its tail began to rise and, at a speed estimated by the pilot to be about 30 mph, the propeller struck the ground. The aircraft continued pitching and fell slowly onto its back.

The aircraft was fitted with a rotating anti-collision beacon, mounted in the roof above the pilot's seat. As the aircraft pitched onto its roof, the anti-collision beacon broke through the cockpit roof, and impacted the pilot's head, causing lacerations. Additional injury was caused by the pilot's head hitting the internal attachment bolts for an aerial.

The cockpit had two doors, one on each side, each hinged on its lower edge and latched at the top. The pilot attempted to open each side door of the aircraft but was unable to do so as the doors were jammed against the ground under the aircraft. Other members of the gliding club arrived and lifted one of the aircraft's wings, enabling a cockpit door to be opened. The pilot exited the aircraft and received first aid from a club member whilst another member reached into the cockpit and switched off the master and magneto switches. There was no fire.

The pilot's recollection

The pilot stated that he thought he placed his feet too high on the rudder pedals prior to landing and that he may have inadvertently applied some brake pressure during the landing roll. He also commented that the general public have access to the airfield near the Runway 33 threshold and a high degree of awareness is required to avoid the possibility of the cable causing injury during the approach.

The club investigation

An accident report, produced by the gliding club mentioned:

> *'distinct signs of two lines of flattened grass from both wheels where the grass was laid down due to braking effect.'*

It also stated that the pilot had described the *'stick position'* during the landing as *'mostly back'*. The pilot reported to the AAIB that the stick was *'back for landing'*.

Aircraft information

The Piper Pawnee is a low-wing, tailwheel configured monoplane used throughout the world as an agricultural and glider-tugging aircraft. It is tail-heavy and does not have a propensity to pitch onto its back during landing, provided that the control column is held fully back.

Analysis

The pilot was relatively experienced but not in current flying practice. Although the Pawnee aircraft is not known for a tendency to pitch over on landing (as some other types are), the accident itself was relatively benign. The probable cause of the pitch over was a combination of inadvertently applied brake pressure and the stick not being fully back during the rollout.

Survivability

The anti-collision beacon

The head injuries sustained by the pilot were caused by the anti-collision beacon being forced through the roof of the cockpit. Survival of aircraft occupants in accidents depends, essentially, on three things: the occupant must be appropriately restrained, contained within a protective 'living volume' (which must not be breached) and the forces experienced must be survivable.

Other Pawnee aircraft on the UK register have various different anti-collision light installations, with at least eight aircraft having the light mounted directly on the roof of the cockpit. The remainder either have the light installed in a fairing to the rear of the cockpit or on the spine of the rear fuselage. The two latter installations are situated such that, in the event of an accident such as this, they would not compromise the living volume of the cockpit, nor cause direct injury to the occupant. Lights have been installed, over the years, in different places, either by the manufacturer at build or through later modifications. However there are no recommendations on moving the light assembly from the roof of the cockpit to another part of the aircraft. The following Safety Recommendation is therefore made.

Safety Recommendation 2008-011

It is recommended that Lavia SA (the present Type Certificate holder) produce a modification for aircraft that have the anti-collision light assembly on the roof of the cockpit, which moves the light to a position which would not compromise the living volume of the cockpit in the event of an accident and that Direccion Nacional De Aeronavegabilidad ensure that Lavia SA produce the relevant modification and consider making it mandatory.

Escape

The design of the doors prevented the pilot from vacating the aircraft after the accident until assistance arrived. The doors on G-ASVP were to the original Piper design. In aircraft manufactured after serial number 25-4172 (in 1967), Piper changed the door design and introduced an emergency door release system so that pull handles release hinge pins in the lower hinges of the door. Once the pins are released the door can be opened. Despite this design change, Piper did not issue any retrofit modifications for older aircraft, such as G-ASVP. Had G-ASVP been fitted with the emergency door release system, the pilot would have been able to exit the aircraft without assistance. This is particularly important because any fire occurring would not only have endangered the pilot's life but also prevented others from rendering assistance. The following Safety Recommendation is therefore made.

Safety Recommendation 2008-012

It is recommended that Lavia SA produce a retrofit modification for the installation of an emergency door release system on Piper PA-25-235 aircraft manufactured prior to serial number 25-4171, and that Direccion Nacional De Aeronavegabilidad ensure that Lavia SA produce the relevant modification and consider making it mandatory.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-140 Cherokee, G-ATMW	
No & Type of Engines:	1 Lycoming O-320-D2A piston engine	
Year of Manufacture:	1966	
Date & Time (UTC):	1 November 2007 at 1750 hrs	
Location:	Hinton-in-the-Hedges, Northamptonshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Nose landing gear broken, both wing skins damaged, propeller damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	152 hours (of which 14 were on type) Last 90 days - 12 hours Last 28 days - 12 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB inquiries	

Synopsis

The pilot considered that the aircraft was low on fuel and he decided to land at an unlit airfield in the dark. He asked a person on the ground to position their vehicle in such a way as to indicate where the aircraft should land; the pilot misidentified this vehicle's lights and landed at the wrong position. Just prior to touchdown the aircraft struck a fuel bowser before falling heavily on its nose landing gear, which then collapsed.

History of the flight

The pilot had bought the aircraft two weeks prior to the accident. On the day of the accident he planned to fly with a friend to Belgium, where he would drop off his friend and return alone. This was to be his first international flight from the UK, as a pilot, and he purchased a new GPS unit to assist him with the navigation.

At 0630 hrs, the pilot flew, with his passenger, from the aircraft's base at Hinton-in-the-Hedges to Cambridge, landing at 0702 hrs. They refuelled the aircraft, filed a VFR flight plan to Braaschaat Airfield, near Antwerp in Belgium, and set off again at 0747 hrs. As they approached the eastern coast of the UK they encountered some low cloud, so they flew over the sea at an altitude between 300 and 500 ft: the sea temperature was about +13ºC. The pilot and his passenger were not wearing survival suits, the aircraft carried lifejackets, but no life raft, and the aircraft was not fitted with an emergency locator beacon. The pilot reported that he did not have R/T communications with anyone for the sea crossing. As they approached Antwerp he requested radar vectors to Braaschaat, where they landed at approximately 1040 hrs.

Braaschaat is a private airfield and is not a recognised Port of Entry for Belgium. There was some confusion as the pilot had not asked for the necessary prior permission to land there. The local flying club were, however, able to provide fuel, and the aircraft was refuelled to full tanks (approximately 40 imperial gallons). The pilot and his passenger wanted to visit the local town, but since it was a public holiday in Belgium there was no public transport available, they therefore walked into the town. This delay meant that the pilot arrived back at his aircraft later than he had intended and he recognised that some of his return flight would be in darkness. He reported that he asked someone to file a VFR flight plan to Coventry for him at Braaschaat, before getting airborne as quickly as possible to minimise the amount of time he would spend flying in the dark. No flight plan was filed for the return trip to Coventry. The aircraft left Braaschaat at approximately 1350 hrs.

The weather over the North Sea had improved for the return flight, and the aircraft was able to maintain an altitude of between 500 and 1,100 ft. The pilot did not establish R/T communications with anyone whilst crossing the sea. On reaching the UK the pilot attempted to call the London Flight Information Service (FIS), but he received no reply. London FIS did receive the aircraft's initial call, but they were unable to establish communications with the aircraft. The pilot reports that at around sunset, the new GPS unit lost its waypoints; from the GPS recorded track this appears to have been in the area approximately 15 nm south-east of Cambridge. He also reported that whilst his left fuel gauge appeared to be registering as expected, the right gauge was still indicating full. The pilot thought that he had been using the fuel equally from both tanks, and he therefore concluded that the right tank contents gauge was not working properly. The pilot then circled for 20 minutes while he attempted to rectify the problems with his GPS unit. He was now unsure of his position and was also having some difficulties in reading the aircraft instruments with the aircraft's dim internal lights. After approximately 20 minutes he continued towards Towcester.

The pilot was now so concerned about the aircraft's fuel state that he considered it would be safer to land back at Hinton-in-the-Hedges rather than fly on to Coventry. Since the airfield at Hinton-in-the-Hedges was unlit, he used his mobile telephone to call his son and asked him to position his pick-up truck at the threshold of Runway 06 at Hinton-in-the-Hedges. The pickup truck was fitted with additional rearward facing spot-lights, and the pilot briefed his son to use the vehicle's headlights to illuminate the undershoot, and to use the rearward facing spot lights to illuminate the runway. On reaching the Hinton area, the pilot commenced circling and in the darkness saw what he thought was the vehicle that he was looking for. He made an approach, down to about 50 ft agl, when he realised that this vehicle was in fact a farm vehicle working in a field some distance from the airfield. The aircraft overshot and repositioned back towards Hinton-in-the-Hedges. The pilot then saw more lights, which appeared to him to be car headlights on approximately the right heading and so he made another approach.

Meanwhile, some members of the resident flying club were preparing for a night flight from Hinton-in-the-Hedges. They were near their hangar, which had two illuminated security lights located on the front door about six feet apart. They saw an aircraft flying so low that they assumed it was trying to land, despite there being no lights on the runway. They had a vehicle loaded with runway lights that they were planning to use for that evening's flight, so they drove their vehicle towards the runway with the intention of getting the aircraft to hold, whilst they quickly placed their runway lights in position. They attempted to contact the aircraft on the Hinton-in-the-Hedges air to ground frequency, but received no reply. They saw a vehicle parked on the threshold of Runway 06 with its headlights on and asked the driver if he had any communications with the aircraft that was trying to land.

The pilot meanwhile had decided to land and he selected 30º flap. He reported that just prior to touchdown he saw the shadow of a fuel bowser ahead and so he applied full power and pulled back on the control yoke. The aircraft's left flap struck a rotating beacon on the top of the fuel bowser, and scraped along the bowser's cabin roof, before the aircraft landed heavily on its nose, approximately 30 m beyond the bowser. The nose landing gear collapsed and the right wing struck the ground yawing the aircraft about 40º to the right. The aircraft then pitched forward, coming to rest with the aircraft's nose and propeller on the ground and its tail in the air. The pilot received a minor cut to his chin. The engine had stopped so the pilot switched off the electrics and vacated the aircraft normally.

The witnesses who were talking to the driver of the vehicle on the threshold, saw the aircraft fly low over their hangar then abruptly pitch up, then down, before it stopped with its tail in the air; they immediately drove over to the aircraft to offer assistance.

An inspection of the aircraft after the accident showed that the fuel tanks contained sufficient fuel for approximately one hour of flight.

Analysis

A CAA study into the causes of fatal accidents (*CAP 667 - Review of General Aviation Fatal Accidents 1985-1994*) concluded that many accidents are as a result of the decisions that pilots make. It was also common to find a chain of events where one shortcut or example of poor judgement leads to another.

Preparation

When planning an international flight it is necessary to establish the national requirements for the countries that are being visited. Normally, the first landing in a new country should be at an airfield that is a designated Port of Entry and which therefore allows the necessary customs formalities to be completed. It is also necessary to obtain permission, in advance, from any airfield where it is intended to land, which stipulates 'Prior Permission Required'.

Pilots should familiarise themselves with all of the aircraft systems, including such apparently simple systems as the lighting controls, prior to placing themselves in a position where they need to use them. They should also be familiar with the navigational equipment that they intend to use. It would be sensible to practise using the GPS on the ground, and in the air with a safety pilot, before using it as an aid to navigation.

Flying at night requires more preparation and thought than flying during the day. If, because of unforeseen circumstances, a planned daytime flight is delayed such that completing it will involve flying at night, then the best response is not to rush to get airborne, but instead to consider carefully all options, perhaps even deciding to stop the night and continue the next day.

Conduct of the flight

During the flight to Belgium, the aircraft crossed the North Sea at an unusually low altitude for a single engine aircraft. If the aircraft had suffered an engine failure whilst at 500 ft, with no radio contact, the pilot would have had little time to establish radio communications whilst simultaneously preparing the aircraft for a ditching. Nobody would have been immediately aware of his predicament. In the event of a ditching the likely survival times for a person in calm water at a temperature of +13ºC, with no liferaft or survival suit, is a little over an hour. Even if the pilot had made a successful distress call, without an emergency locator beacon the rescue agencies would have had little chance of locating a person in the water in less than an hour.

A GPS system should never be used in isolation. The pilot should prepare a map and log in the normal way, and crosscheck the GPS with other navigational cues. If a pilot is uncertain of his position then the CAA advice is to tell someone. Transmit first on the working frequency, and do not mince words: say that you are lost. If there is no working frequency, or it is not possible to make contact on that frequency, then change to 121.5 MHz and make a 'PAN' call.

A pilot should not rely solely on his fuel gauges. Including reserves, this aircraft had approximately five hours endurance with full fuel and an inspection of the aircraft after the accident showed that the fuel tanks contained sufficient fuel for approximately one hour of flight. This accident occurred after four hours of flight when the pilot committed to a dangerous landing in the dark because he was concerned about his fuel state.

Landing at an unlit airfield in the dark is something that should only be done when all other options have been exhausted. A 'PAN' call, made at the time the pilot became unsure of his position, followed by radar vectors, would have allowed the aircraft to land safely at Coventry Airfield in less flying time than it took to arrive at Hinton-in-the-Hedges.

Comment

Ultimately, it seems that this accident was caused by the pilot confusing the security lights on the hangar with his son's vehicle, whilst attempting to land at an unlit airfield. However, during the sequence of events that lead up to this accident there were many opportunities where sound airmanship could have prevented the pilot being faced with such an option.

INCIDENT

Aircraft Type and Registration:	Slingsby T67M260 Firefly, G-BYOB	
No & Type of Engines:	1 Lycoming AEIO-540-D4A5 piston engine	
Year of Manufacture:	1999	
Date & Time (UTC):	3 August 2007 at 1030 hrs	
Location:	Stapleford Tawney Airport, Essex	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Left brake pedals disconnected	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	58 years	
Commander's Flying Experience:	6,900 hours (of which 156 were on type) Last 90 days - 70 hours Last 28 days - 39 hours	
Information Source:	AAIB Field Investigation	

Synopsis

As the crew carried out functional checks of the flight controls while taxiing for takeoff, the left wheelbrake master cylinder became detached from the rudder/brake pedal mechanism. The failure was consistent with the effects of previous overload and consequent weakening of the mechanism as a result of inadvertent exceedence of the maximum allowable nosewheel steering angle during ground towing.

The aircraft manufacturer had taken a number of measures aimed at reducing the likelihood of the pedal mechanism being damaged during towing. A relatively minor aircraft modification could probably eliminate the possibility of such damage. Three Safety Recommendations are made.

History of the flight

The planned flight was an instructional sortie with an instructor in the left seat and a student in the right seat. While taxiing for departure, the student carried out rudder functional checks, as usual. The instructor reported that rudder operation was normal when the student applied full right pedal. However, when the student pushed his left pedal there was a loud bang and both left pedals appeared to be disconnected. The flight was cancelled.

Aircraft description

The Slingsby T67 Firefly is a single-engined low-winged monoplane, designed to be fully aerobatic (Figure 1). It is constructed principally of glass reinforced plastic (GRP) and fitted with a tricycle landing gear with a steerable nosewheel leg. Two side-by-side seats are provided. The

Firefly was first certificated in 1983 as the T67M, and a number of other versions were subsequently developed, including the 260 shp T67M260. In total, 280 T67 aircraft have been built. Maximum takeoff weight of the T67M260 is 2,550 lb (1,157 kg).

Primary flight controls are conventional, operated by dual cockpit controls. Rudder/brake pedal assemblies are numbered from 1 to 4 across the aircraft from left to right (Figure 2). The pedals are mounted on crank arms welded to two rotatable cross-shafts in the cockpit, known as rudder bars, with the left pedal of each pair (Nos 1 and 3) fixed to the left bar and the right pedals (Nos 2 and 4) fixed to the right bar. A crank arm on each bar is connected by a cable-fairlead system to operating levers attached to the rudder. The two bars are thus interconnected by the loop formed by the cables and the pivoting rudder. Two springs maintain the rudder bars centralised when the pedals are unloaded. An adjustable primary stop provided for each rudder bar limits the forward rotation of the bar (ie forward displacement of the respective pedals); these stops form the primary travel limiters for the system.

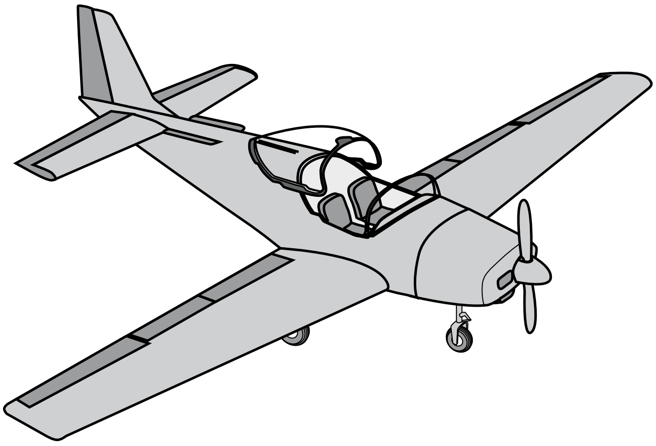


Figure 1

Rotation of the rudder bars also steers the nosewheel leg, via a control rod driven by a crank arm fixed to the right bar (Figure 2).

A slider mounting mechanism allows each pedal to be individually adjusted fore and aft to cater for variation in pilot build and then locked by a pin that locates in one of four holes in the slider.

For each pedal, a pin-jointed parallelogram-type linkage pivoted to the respective rudder bar (Figure 3) maintains

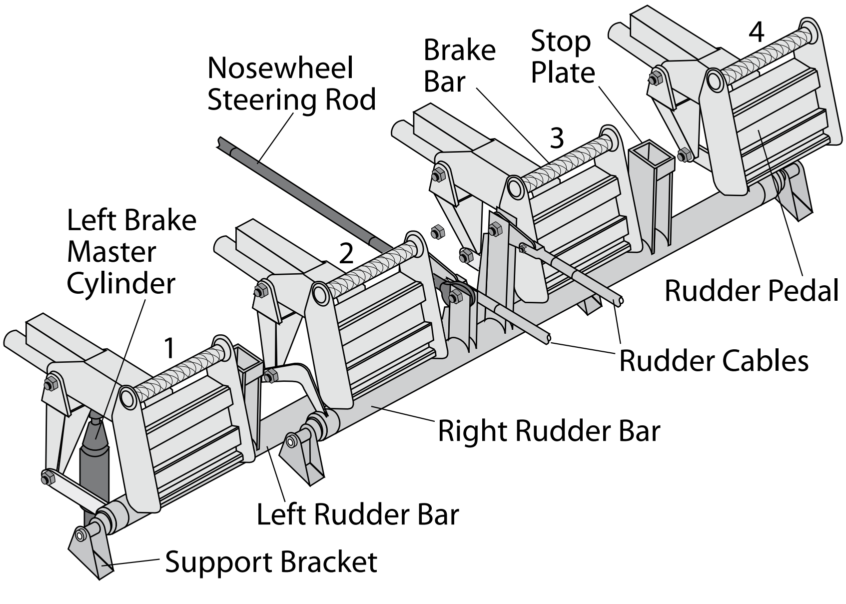


Figure 2

the vertical orientation of the pedal constant as it is displaced fore and aft to operate the rudder (Figure 4). The linkage allows each pair of pedals to be pivoted, by pushing a brake bar at the top of one of the pedals, to drive the master cylinder piston (Figure 5) and hence apply hydraulic pressure to the brake on the respective main wheel.

Aircraft examination

Examination by the operator's maintenance organisation revealed that the left wheelbrake cylinder had detached from the No 1 pedal mechanism. It was also found that the composite floor panel had suffered delamination damage in the area where the left mounting bracket for the left rudder bar attached and that the bracket had tilted to the left as a result. The aircraft manufacturer considered that both damage features had been caused by overload as a result of exceeding the maximum nosewheel steering angle while towing.

Aircraft towing

The aircraft can be towed, by hand or by a vehicle, using a towbar fixed to the nose landing gear. When the aircraft is being towed, any steering displacement applied to the nosewheel by the towbar is transmitted to the rudder pedals via the steering control rod, causing the pedals to displace. Two turn limitation lines painted on the lower part of the engine cowl indicate the maximum permitted steering angle in either direction. The limiting angle is reached when the towbar is visually aligned with the appropriate line. A towbar design approved and recommended by the aircraft manufacturer incorporated a device to limit the steering load applied to the nose landing gear.

Excessive nosewheel steering angle

Should the aircraft be towed using a towbar without the load-limiting feature, it is possible that excessive loads would be applied should the limiting steering angle be exceeded during a turn. The nosewheel leg is provided with non-adjustable steering stops but these act as secondary stops only. Travel limiters within the rudder/brake pedal mechanism form the primary stops, which are contacted first when the steering angle exceeds its limit, as follows.

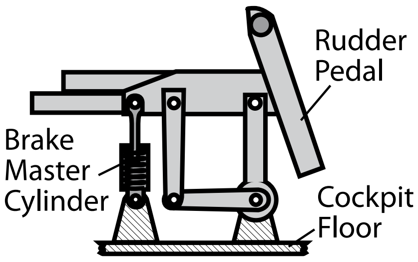


Figure 3

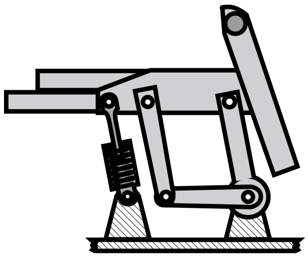


Figure 4

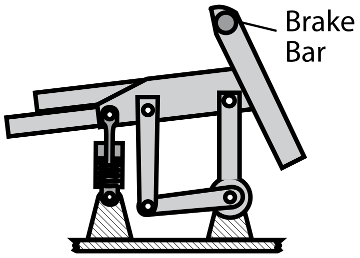


Figure 5

If the maximum allowable nosewheel angle to the right is exceeded while the aircraft is being towed, the steering control rod rotates the right rudder bar forward onto its stop. At the same time the left rudder bar, connected to the right bar by the loop formed by the cable and rudder, is rotated backwards. A further exceedence of the permitted steering angle would apply excessive loads to the right rudder bar stop and could cause it to deform as a result. The rearward over-travel of the left rudder bar would result in the No 1 pedal mechanism applying an upward load to the left brake master cylinder, which would be bottomed, and additional excessive loading on the pedal mechanism can result. The aircraft manufacturer believed that this could damage the left rudder bar support brackets, the floor at the bracket attachment points, and/or the left brake master cylinder.

The system behaves somewhat differently when the aircraft is towed in a turn to the left. In this situation the steering control rod rotates the right rudder bar backwards. Exceeding the allowable steering angle to the left would apply excessive loads to the right brake master cylinder and could result in damage to the right rudder bar support brackets, the floor and/or the right brake master cylinder. In this case the left rudder bar will not be rotated, as the rudder cable would not transmit a compressive force, and so no excessive loads would be applied to the left pedal system or its stop.

Towing typically involves the use of a 2 metre long towbar pulled by a powerful 4-wheel drive vehicle. The manufacturer noted that if a towbar without the load-limiting feature were used, the loads on the pedal mechanism caused by exceeding the towing angle limits could therefore be exceedingly high. It was considered impractical to redesign the rudder mechanism to withstand such loads.

Airworthiness improvement measures

The manufacturer issued a User Experience Report Action Form on G-BYOB's accident (UER No T67-1253, issued on 29-08-07) which noted that:

> *'The use of specialised towing vehicles which "carry the nosewheel" of the aircraft are not recommended for use with SACL T67 aircraft because it is, at the very least, very difficult to see when you are approaching the maximum towing angle.'*

The UER recommended inspection of G-BYOB's nose landing gear, rudder/brake pedal mechanism, cockpit floor and rudder for damage and recommended a review of towing practices.

The manufacturer also issued an Advance Information Leaflet (AIL No 01/2007, issued 15 November 2007) as an attachment to the T67M260 Maintenance Manual (MM). It was intended that the AIL content would be incorporated in the MM when next reissued, anticipated to be during the first quarter of 2008. The AIL included the following:

> *'Towing*
>
> *CAUTIONS*
> *THE USE OF NON-SLINGSBY TYPE VEHICLE OR HAND TOW BARS OR TROLLEY/CART ARE PROHIBITED FOR USE ON SLINGSBY T67 TYPE AIRCRAFT.*
>
> *WHEN TOWING WITH A VEHICLE THE DRIVER MUST HAVE A CLEAR VIEW OF THE TOW BAR TURN LIMITATIONS MARKINGS ON THE AIRCRAFTS COWLING.'*

The AIL also noted that:

> *'The limits for the nose wheel steering angle are marked on the lower engine cowling. Care should be taken (particularly when the aircraft is being towed by a vehicle) that the nose wheel angle does not exceed that shown.*

WARNING
EXCEEDING THE TOWING ANGLE LIMITATIONS MARKINGS CAN CAUSE DAMAGE TO THE RUDDER SYSTEM WHICH MAY CAUSE AN IN FLIGHT AIRWORTHINESS SITUATION AND POSSIBLE DEATH TO THE OCCUPANTS.'

In addition, the manufacturer re-issued a Service Bulletin (SB No 187, previously Issue 2 of 10 May 2007). This SB originally dealt with the correct installation and adjustment of the rudder/brake pedal mechanism, together with required inspections for damage and the presence of specified clearances for moving parts of the system. The SB re-issue (Issue 3 of 16 October 2007) added requirements, remarks and warnings concerning towing similar to those in the AIL.

European Aviation Safety Authority (EASA) had previously mandated incorporation of the SB by means of an Airworthiness Directive (AD 2007-0132, issued on 11 May 2007). This followed an incident where the pilot of a T67M260 aircraft (registration G-EFSM) had initially been unable to move the rudder pedals when attempting to recover from a spin (AAIB Bulletin 11/2007). Recovery from the spin had been delayed by an estimated two and a half turns. The Bulletin identified an excessive steering angle during towing as a possible cause of the problem. A recommendation was made (AAIB Safety Recommendation 2007-077) for the EASA to review the rudder pedal system of the Slingsby T67 aircraft, including consideration of requiring means to limit the loads applied to the rudder system during towing. The AD required some of the SB measures to be carried out before further flight and some within the next 50 flight hours and for checks to be repeated at intervals of 300 flight hours or 12 months, whichever occurred first.

The above action applied to the T67M260. Discussions indicated that the manufacturer had also re-issued SB No 188 at Issue 3 together with a further AIL to promulgate similar information relevant to the other T67 models.

Further measures aimed at reducing the possibility of damage to the rudder/brake pedal mechanism on all the T67 models had also been taken. These included the development of an improved towbar design, also with a load-limiting device, expected to be released to aircraft operators in early 2008. The manufacturer considered that it was impossible to overload the rudder mechanism when a Slingsby-approved towbar was used.

Modification to convert the nosewheel leg steering stops into the primary stops was considered to be impracticable and could have created difficulties in ensuring the required rudder travel, which is essential for effective spin recovery. The manufacturer had studied a scheme for incorporating a load-limiting device into the nosewheel steering rod in order to preclude the possibility of excessive loads being transmitted to the rudder/brake pedal mechanism. However, the manufacturer considered that the published warnings, to remain within the towbar turn limitations and to use only a Slingsby-approved towbar, would be sufficient to prevent recurrence of rudder mechanism damage.

EASA, in their response to AAIB Safety Recommendation 2007-077, considered the warnings in Issue 3 of SB Nos 187 and 188 and in the AILs to be adequate for preventing further damage to the rudder system during towing. The response noted that SACL had not agreed to implement an aircraft modification to prevent overloading of the rudder system whilst towing.

Discussion

The evidence was consistent with the failure of the rudder/brake pedal mechanism having resulted from overload generated by an excessive nosewheel steering angle during ground towing. Although positive evidence was not available, the manufacturer's researches strongly indicated that the damage had resulted from such an exceedence and it was concluded that this was the most likely cause of the failure.

Towing damage could weaken the rudder/brake pedal mechanism and/or distort it, thereby affecting the clearances of its moving parts from other components; in some areas these clearances are quite small. Such damage could apparently be caused inadvertently, without the towing crew being aware of the problem, and could well remain undetected for a considerable time.

Inadequate clearances, or a subsequent failure as a consequence of damage having weakened the mechanism, as apparently occurred in G-BYOB's case, could severely affect rudder and/or brake operation. In some situations the results would be potentially disastrous. A loss of wheelbraking could be hazardous and any compromise of rudder operation could have severe consequences, particularly as the aircraft type was extensively used for aerobatic flying, including spinning. In the case of G-EFSM's incident a foul of the pedal mechanism, possibly due to distortion caused by overload during towing, had seriously delayed spin recovery.

The design had provided the primary stops for the nosewheel steering system within the rudder/brake pedal mechanism in order to ensure that the accurate achievement of full rudder travel could not be compromised. However, locating the stops in the pedal mechanism, rather than on the nosewheel leg, appeared most unsatisfactory, given the relatively high forces that could be applied through a towbar. Modification to rectify this feature of the system appeared, to the manufacturer, to be impracticable.

It was likely that the manufacturer's specification for towing to be carried out using only a towbar with a load-limiting device and their further emphasis on not exceeding the allowable steering range would reduce the probability of damage. Nonetheless, the manufacturer is not in a position to enforce these prohibitions. It therefore does not seem practicable to ensure that only an approved towbar will always be used or that a vehicle driver will always be in a position to monitor reliably the orientation of a towbar relative to the limit markings. However, it does appear possible that a modification to incorporated a load-limiting element into the aircraft's nosewheel steering rod would eliminate the possibility of the pedal mechanism being vulnerable to inadvertent damage during towing. In view of this, the following Safety Recommendations are made.

Safety Recommendation 2008-006

It is recommended that the UK Civil Aviation Authority ensure that the prohibition by Slingsby Advanced Composites Ltd on using a non Slingsby-approved towbar with T67 aircraft, is made mandatory.

Safety Recommendation 2008-007

It is recommended that Slingsby Advanced Composites Ltd develop modifications for the T67 aircraft, aimed at eliminating the possibility that forces generated during ground towing could cause undetected damage to the rudder/brake pedal mechanism.

Safety Recommendation 2008-008

It is recommended that EASA require the development of modifications for the Slingsby Advanced Composites Ltd T67 aircraft, aimed at eliminating the possibility that forces generated during towing could cause undetected damage to the rudder/brake pedal mechanism.

ACCIDENT

Aircraft Type and Registration:	Airborne Edge XT912-B/Streak III-B, G-CEHH
No & Type of Engines:	1 Rotax 912 piston engine
Year of Manufacture:	2005
Date & Time (UTC):	28 March 2007 at 1220 hrs
Location:	Blunts Lane, Potters Crouch, St Albans
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 1 (Fatal) 1 (Serious) Passengers - N/A
Nature of Damage:	Substantial
Commander's Licence:	Private Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	4,960 hours (of which 50 were on type) Last 90 days - 59 hours Last 28 days - 35 hours
Information Source:	AAIB Field Investigation

Synopsis

The flying instructor was demonstrating an 'engine-off' approach to his pupil, when the aircraft (a flex-wing microlight) struck a tree close to the final approach. Post-mortem toxicology indicated that the instructor's blood alcohol level was 137 mg/100 ml. The UK prescribed limit for pilots is 20 mg/100 ml; that for driving is 80 mg/100 ml.

History of flight

The aircraft departed on an instructional flight with the instructor, who held a CAA Microlight Instructor rating, in the front seat and the student in the rear; the intention was for the instructor to demonstrate an engine-off (or 'dead stick') landing to the student, who was to undertake a General Skills Test two days later.

Other microlight pilots at the airfield observed the aircraft take off normally from Runway 30, before climbing out with a right-hand turn towards the airfield overhead. From a height of approximately 2,000 ft, the aircraft entered a glide descent in a left-hand circuit pattern for a landing on Runway 33.

The approach appeared normal at first, with the witnesses describing the aircraft being slightly high (as they expected in an engine-off condition) before the speed increased and a series of S-turns was commenced. The aircraft flew to the east of the extended runway centreline and onto a right base leg. At this stage the witnesses assessed that the aircraft was rather low.

The aircraft's left wing then impacted the top-most branches of a tree, some 50 to 70 ft agl and 200 m from the runway threshold. The aircraft's flight was significantly disrupted by the impact with these branches, and it fell to the ground some 80 m from the tree. Members of the public who were nearby ran to give assistance, and were then joined by pilots from the airfield.

The pilot of G-CEHH sustained fatal injuries in the ground impact. The student was severely injured and could later recall very little of the day of the accident.

Post-mortem examination and toxicology

A post-mortem examination was carried out on the pilot by a specialist aviation pathologist and a toxicological investigation was conducted.

The pathologist's report stated:

> *'Toxicological examination of the pilot's blood revealed a blood alcohol level 137 mg/100ml. The prescribed limit for a blood alcohol level for an individual acting as the pilot of an aircraft during flight, as laid down in the Railways and Transport Safety Act 2003, is 20 mg/100ml. This contrasts with the legal limit for driving which in the UK is 80 mg/100ml. Toxicology revealed alcohol levels of 183 mg/100ml in the vitreous and 235 mg/100ml in the urine.'*

The report also contained calculations related to alcohol consumption and the rate at which alcohol is metabolised in the human body, taking into account a number of variables:

> *'These calculations suggest either that [the pilot] had consumed a quantity of alcohol the previous evening which would be sufficient to induce stupor or coma in most individuals, or that he had continued to consume alcohol at some stage in the 12 hours prior to his death.'*

Commenting on the pilot's liver, the pathologist noted that it was *'fatty'* and that this *'most likely represents the effect of chronic alcohol use'*. With regard to the fatal injury sustained by the pilot, the pathologist reported that:

> *'It is unlikely, given the nature of this type of aircraft, that any additional or alternative safety equipment would have prevented this injury.'*

Accident site

The impact site was in a field of young crop and was approximately 166 metres from, and on the extended centreline of, Runway 33 at Plaistows Farm Airfield. To the east and west of the site the ground rises to approximately 85 feet above the height of the accident site. The area to the east was grazing land and to the west a mixture of woodland and agricultural land, with a line of power cables, mounted on tall pylons, running in a north-west to south-east direction. Approximately 80 metres to the east of the impact site there was a lone deciduous tree, the upper branches of which were 50 to 70 feet above ground level. The area to the south-east of the accident site consisted of agricultural fields interspersed with farm buildings.

Impact parameters

Examination of the accident site showed that the left outer wing of the aircraft initially impacted a substantial branch at the top of the lone deciduous tree.

This impact substantially damaged the structure of the left outer wing. At the time of the impact with the tree it is estimated that the aircraft was on a heading of about 270º, flying at a speed in the region of 65 mph, in level flight and possibly banked to the left. At some point, after this impact with the tree, the aircraft's left outer wing collapsed upwards, which would have caused the aircraft to become unstable and, probably, uncontrollable. The damaged aircraft continued, on an approximate heading of 260º, until it struck the ground some 80 metres from the tree. The aircraft's nacelle impacted the ground with virtually no forward speed, banked to the left by almost 90º and in an almost level pitch attitude. The force of the ground impact severely disrupted the structure of the nacelle. All the parts of the aircraft were present at the accident site.

Engineering examination

There was good evidence to indicate that the propeller was not rotating at the time of the ground impact. The engine ignition switches were found in the ON position. There was a smell of fuel around the wreckage and a quantity of fuel was found in the fuel tank. The fuel cock was found to be selected to the ON position. There was no post-impact fire.

A detailed examination of the aircraft's structure and engine systems found no evidence of disconnections or restrictions prior to the impact with the tree. The engine was taken to the manufacturer's UK agent's facility for examination and testing; external and internal examination showed no evidence of a failure, disconnection or seizure. Both carburettor bowls contained fuel and both they and the fuel filter were free of contamination. The engine was installed onto an airframe mounting, a replacement propeller fitted and a successful engine test run was carried out. It is, therefore, likely that the engine would have started correctly if this had been initiated before the collision with the tree.

Possible visual illusion and perspective

The tree, which the aircraft struck, had a clearly defined top, with some additional growth above it; it was this additional growth with which the aircraft collided. The possibility was considered that, as the aircraft approached the tree, these uppermost branches might have appeared to blend in with other trees, further away. To test the theory, the tree was viewed from the direction of the aircraft's flight, using a helicopter, and photographs were taken. Whilst there was no doubt that the line of sight took in both the top branches of the tree, and other trees behind, the illusion was not clearly apparent, and the test was inconclusive.

Engine-off landings

Pilots of single-engined aircraft are trained to carry out forced landings, to enable them to deal successfully with an unexpected engine failure in flight. In microlight flying, the exercise is carried out either with the engine running at idle power or with the engine switched off. If the engine is left running, it is possible for the pilot to advance the throttle at any time and gain thrust. However, the residual thrust from an idling engine means that the aircraft handles somewhat differently from an aircraft whose engine has stopped, and also means that the aircraft's rate of descent is somewhat less than that following engine failure. If the engine is switched off, the propeller stops rotating, there is no residual thrust, and the rate of descent is as it would be in the event of a genuine engine failure. It is usual for the engine to be stopped by switching the ignition system OFF, and once the engine and propeller have stopped, to select the ignition ON again, so that activation of the electric start (where fitted) will cause the engine to run again. G-CEHH was fitted with a serviceable electric starter.

Factors involved in engine-off landings were discussed with the British Microlight Aircraft Association (BMAA) executive. They stated that engine-off landings were not prohibited, but that in their opinion, such landings are best carried out at airfields where substantial areas suitable for landing are available, so that a misjudged approach will not hazard the aircraft and its occupants. The discussion highlighted the fact that engine-off landings require precise judgement; if the aircraft descends below the approach path, the desired touchdown area may not be reached without re-starting the engine. They offered the opinion that Plaistow's Farm was quite a small airfield and was not ideally suited to engine-off landings during pilot training.

Analysis

The aircraft struck a tree close to the final approach to the runway; the tree would not have presented a hazard in the course of a normal approach but the S-turns resulted in the aircraft being flown to one side of the final approach, at very low height, and towards the tree. The investigation examined the possibility of some visual illusion causing the tree to merge with other trees, in the distance (as perceived) but this was inconclusive.

It was apparent that, as the aircraft flew towards the final approach, the pilots were probably focussing their attention on the runway threshold, to their right. The tree, on the left, would not have been a point of focus. It is logical that the student pilot would have been relying on the commander's expertise, and would have been unlikely to have intervened.

The accident occurred in the course of an engine-off approach. The discussion with the BMAA indicated that, whilst there were no specific rules about engine-off landings, best practice would be to carry out such exercises only where significant areas, suitable for landing, exist. Then, a misjudged approach would not result in the aircraft and occupants being put at risk.

The level of alcohol in the instructor's body at the time of the accident was such that his judgement was likely to have been seriously impaired.

Safety Action

The BMAA has undertaken to publicise to its members the hazards inherent in flying under the influence of alcohol or drugs.

ACCIDENT

Aircraft Type and Registration:	Chaser S, G-MVVU	
No & Type of Engines:	1 Rotax 462 piston engine	
Year of Manufacture:	1988	
Date & Time (UTC):	28 August 2007 at 1115 hrs	
Location:	Burton on the Wolds, Leicestershire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Serious)	Passengers - N/A
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	54 years	
Commander's Flying Experience:	43 hours (of which 11 were on type) Last 90 days - 0 hours Last 28 days - 0 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The weight-shift microlight aircraft encountered a gust just prior to the intended landing. Despite the application of power and moving the control bar forwards, the pilot was unable to prevent the aircraft from landing short of the runway.

History of the flight

The pilot had planned to fly early in the day to take advantage of calmer conditions but he was persuaded to fly later in the morning so that he could fly at the same time as another pilot in another aircraft.

The takeoff and climb out were uneventful. However the pilot reported that he became unhappy with the rough and thermic conditions and decided to turn back to his departure point. The last eight miles or so were at low level due to the proximity of East Midlands Airport airspace, and the pilot reported that the conditions were deteriorating, with strong thermals and rough air.

The pilot made five approaches and go-arounds to the runway, which is in a northerly direction, and on his sixth approach he felt that he was correctly positioned to land. Just before the anticipated touchdown the aircraft encountered severe sink and, despite the application of full throttle and moving the control bar forwards, the aircraft struck the ground approximately 30 ft before the start of the runway, in an area of steep upslope. The aircraft collapsed on impact and bounced before coming to rest on the runway, with the pilot trapped underneath and fuel leaking from the tank. The pilot, who was wearing a lap harness and a helmet, sustained two broken legs, but managed to scramble clear of the wreckage unaided, in the absence of any assistance.

Aircraft information

The Chaser S is a single seat, weight-shift microlight with a 'Pterodactyl' wing. As with all microlight aircraft the wing loading is low, and they are susceptible to gusts.

Weather conditions

The pilot reported the weather as hot and sunny with more than 20 miles of visibility and with the wind from the north-north-west, gusting at more than 10 kt, with increasing thermic activity.

The forecast conditions for Nottingham East Midlands around the time of the accident were wind variable at 4 kt, unlimited visibility with scattered cloud at 3,000 ft (lowering to 1,800 ft later) and broken cloud at 4,500 ft.

The reported conditions for Nottingham East Midlands at about the time of the accident were: at 1120 UTC, wind variable at 2 kt, unlimited visibility, few clouds at 800 feet, broken cloud at 1,800 ft, surface temperature 16ºC, dew point 11ºC, surface pressure 1023 hPa. The observation at 1050 UTC had been the same, except that the wind had been variable at 3 kt and the dew point had been 12ºC.

An isobaric analysis carried out by the Met Office concluded that the surface wind was variable at 2 kt.

The conditions measured by the (Watnall) Nottingham weather balloon, launched at 1115 UTC, were very representative of those at the time and location of the accident. This was used by the Met Office to assess temperature and cloud formation. The surface temperature was estimated to be 16°C and, whilst there was convective activity associated with cumulus development, it was doubted that any maximum wind gust would be greater that 10 kt in any direction, a little lower than that reported by the pilot.

Comment

The pilot's low experience and low recency appear to be the main factors affecting his ability to deal with the conditions. The information from the Met Office would indicate that the wind was lighter than the pilot reported although there was clear evidence of convective activity which could have led to the gusty conditions. Peer pressure to fly at a later time, rather than earlier when it would probably have been calmer, may also have been a factor.

ACCIDENT

Aircraft Type and Registration:	Gemini Flash IIA, G-MTIA	
No & Type of Engines:	1 Rotax 503 piston engine	
Year of Manufacture:	1987	
Date & Time (UTC):	18 April 2007 at 1700 hrs	
Location:	Caernarfon Airport, Wales	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to keel, front strut and left side strut	
Commander's Licence:	Student pilot	
Commander's Age:	69 years	
Commander's Flying Experience:	65 hours (of which 2 were on type) Last 90 days - 5 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

During his first solo flight, the student misjudged the flare and the aircraft landed heavily and bounced. The student initiated a go-around and during the subsequent circuit the aircraft handled normally. On landing, the front strut and the trike keel failed, and the aircraft came to a halt on the runway.

History of the flight

The aircraft was being flown by its owner, who was a student pilot on his first solo flight. The weather was good, with a light wind and good visibility. The student had just completed two circuits for Runway 26 with his instructor; the circuits and landings were assessed as satisfactory. The student was then briefed for a solo flight using the same runway.

The solo circuit progressed normally until after completing the final turn. The student then decided that rather than flying the circuit as he had done when flying with his instructor, he would remain high above an area on the approach which he considered might contain turbulence. He reported that after the area of possible turbulence, he steepened the approach so he could land in the normal place. As he came over the threshold the airspeed and rate of descent were higher than normal The student reported that he made insufficient allowance for this increased rate of descent during his landing flare. This resulted in a very heavy landing from which the aircraft bounced up to a height of around 20 ft. The student applied power and initiated a go-around.

During the subsequent circuit the aircraft handling was normal. The next approach was flown with a normal approach angle. During the landing, there was no cushioning from the suspension and the front strut and the trike keel broke. The aircraft came to a halt and the pilot exited the aircraft unhurt.

The pilot considers that there may have been a pre-existing partial crack in the keel which may have contributed to its failure during the heavy landing.

ACCIDENT

Aircraft Type and Registration:	Ikarus C42 FB80, G-SJEN	
No & Type of Engines:	1 Rotax 912-UL piston engine	
Year of Manufacture:	2004	
Date & Time (UTC):	17 July 2007 at 1815 hrs	
Location:	¼ nm east of Strathaven Airfield, Lanarkshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to propeller, engine, engine cowling, landing gear and fuselage .	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	36 years	
Commander's Flying Experience:	255 hours (of which 145 were on type) Last 90 days - 67 hours Last 28 days - 22 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft was making an approach to land on Runway 09 when the pilot assessed that the wind had shifted and favoured a landing on Runway 27. He carried out a missed approach and, having raised the flaps, entered a right turn for a short circuit to the south, to position the aircraft on final approach for the reciprocal runway. During the turn the aircraft stalled and landed heavily in an almost level attitude in a field of long grass. The aircraft was extensively damaged but neither the pilot nor his passenger was injured.

History of the flight

The aircraft, which was operating close to its maximum total weight authorised (MTWA), was returning to the airfield after a short flight in the local area. The surface wind was reported as having been from the east at 4.5 kt to 9 kt; towering cumulus and cumulonimbus clouds were nearby, over a ridge of hills 4 nm to the south. The visibility was greater than 10 km and the broken cloudbase overhead the airfield was at 3,000 ft agl. The pilot planned to land beyond the normal touchdown point, touching down on the smoother part of grass Runway 09. On final approach, he noticed from the airfield's windsock that, in the short period of time since being on the downwind leg of the circuit, the wind had shifted through 180º and was now favouring a landing on Runway 27. A go-around was commenced and the flaps were retracted; during the go-around lightning was observed over the hills to the south.

The intention was to carry out a short circuit to the south of the airfield, over lower ground, before establishing the aircraft on left base for Runway 27 at 500 ft agl. As the aircraft turned to the right over some trees, at a height of approximately 300 ft agl, the pilot reported that the controls became ineffective. Witnesses at the airfield saw G-SJEN descend steeply before it disappeared from view behind trees. The pilot has no recollection of the sequence of events between the controls becoming ineffective and seeing the propeller striking the ground as the aircraft slid to a halt in a field ¼ nm to the east of the airfield.

Having made the aircraft safe, the pilot and his passenger, who were both wearing four point harnesses, vacated the aircraft through their respective doors. They were uninjured and were soon joined by staff and members from the airfield. Witness marks in the well established long grass indicated that the aircraft had been in a left wing low attitude just before making a heavy three-point landing on its landing gear. During the landing the nose and left main landing gear collapsed and the aircraft came to a stop after slewing through about 90° to the left.

The aircraft suffered damage to the propeller, the nose and both main landing gear, the fuselage, the engine mounts and the engine cowling.

Meteorological observations at 1820 hrs at nearby Glasgow and Prestwick Airports recorded surface winds from 240º at 11 kt and from 260º at 8 kt, respectively. The aircraft weighed 440 kg; close to its MTWA of 450 kg.

The pilot concluded that the aircraft had stalled in the turn. He considered that possible windshear, associated with the nearby cumulonimbus clouds, a downdraught in the lee of the trees over which he flew and concern about the lightning were contributory factors.

ACCIDENT

Aircraft Type and Registration:	Thruster T600N 450, G-REDZ	
No & Type of Engines:	1 Jabiru Aircraft Pty 2200A piston engine	
Year of Manufacture:	2003	
Date & Time (UTC):	15 July 2007 at 1450 hrs	
Location:	Redlands, Wiltshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Minor)	Passengers - 1 (Minor)
Nature of Damage:	Damaged beyond economic repair	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	39 years	
Commander's Flying Experience:	84 hours (of which 83 were on type) Last 90 days - 6 hours Last 28 days - 2 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

Whilst carrying out a practice engine failure after takeoff (EFATO), at about 100 feet agl the aircraft developed a steep nose-down attitude. The pilot attempted to arrest the descent rate by pulling back on the control stick. The aircraft's nose struck the ground and the aircraft came to rest inverted.

History of the flight

After a short uneventful local flight, the aircraft landed at Redlands, Wiltshire. The pilot then decided to carry out a practice engine failure after takeoff (EFATO). The intention was to use the full length of Runway 06 and to carry out the EFATO before landing back on the remaining runway and stopping within its 650 metre length. The pilot had carried out this manoeuvre several times before, but not with a passenger.

The takeoff and initial climb were uneventful. At about 100 feet agl the pilot closed the throttle and began the practice EFATO. The aircraft then descended in a steep nose-down attitude and, in an attempt to slow the descent rate, the pilot pulled back on the control stick. There was little response from the elevator, the aircraft's nose struck the ground and the aircraft came to rest inverted. Fuel was leaking from the fuel cap but there was no fire.

The pilot and passenger, who had been wearing four-point harnesses, were uninjured in the accident. The pilot managed to release his harness, before assisting his passenger with hers. Whilst exiting the aircraft both the pilot and passenger suffered grazes to their shins.

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2007

2/2007	Boeing 777-236, G-YMME on departure from London Heathrow Airport on 10 June 2004. Published March 2007.
3/2007	Piper PA-23-250 Aztec, N444DA 1 nm north of South Caicos Airport, Turks and Caicos Islands, Caribbean on 26 December 2005. Published May 2007.
4/2007	Airbus A340-642, G-VATL en-route from Hong Kong to London Heathrow on 8 February 2005. Published September 2007.
5/2007	Airbus A321-231, G-MEDG during an approach to Khartoum Airport, Sudan on 11 March 2005. Published December 2007.
6/2007	Airbus A320-211, JY-JAR at Leeds Bradford Airport on 18 May 2005. Published December 2007.
7/2007	Airbus A310-304, F-OJHI on approach to Birmingham International Airport on 23 February 2006. Published December 2007.

2008

1/2008	Bombardier CL600-2B16 Challenger 604, VP-BJM 8 nm west of Midhurst VOR, West Sussex on 11 November 2005 Published January 2008.
2/2008	Airbus A319-131, G-EUOB during the climb after departure from London Heathrow Airport on 22 October 2005 Published January 2008.
3/2008	British Aerospace Jetstream 3202, G-BUVC at Wick Aerodrome, Caithness, Scotland on 3 October 2006. Published February 2008.
4/2008	Airbus A320-214, G-BXKD at Runway 09, Bristol Airport on 15 November 2006. Published February 2008.

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