CONTENTS

SPECIAL BULLETINS

COMMERCIAL AIR TRANSPORT

FIXED WING

ROTORCRAFT

GENERAL AVIATION

FIXED WING

ROTORCRAFT

None

SPORT AVIATION / BALLOONS

CONTENTS Continued

ADDENDA and CORRECTIONS

(ALL TIMES IN THIS BULLETIN ARE UTC)

INCIDENT

Aircraft Type and Registration:	Airbus A319-111, G-EZAC
No & type of Engines:	2 CFM56-5B5/P turbofan engines
Year of Manufacture:	2006
Date & Time (UTC):	15 September 2006 at 1052 hrs
Location:	Near Nantes, France
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 138
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	8,782 hours (of which 394 were on type) Last 90 days - 211 hours Last 28 days - 77 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was dispatched under the provisions of the operator's Minimum Equipment List with the Auxiliary Power Unit (APU) generator on line, substituting for the No 1 main generator which had been selected off after a fault on the previous flight had caused it to trip off line. During the cruise, the APU generator disconnected from the system, probably because of a reccurrence of the original fault. This caused the loss of a substantial number of aircraft services, including some flight instruments and all means of radio telephony (RTF) communication. Manual reconfiguration of the electrical system should have recovered many of the services but the flight crew was not able to achieve this. Since they were without RTF communications, the crew considered that the best option was to select the emergency transponder code and continue the flight in accordance with the flight plan.

In the light of the initial findings of the investigation, four safety recommendations are made. The investigation is continuing.

History of the flight

On the previous sector, en-route from London Stansted to Alicante, Spain, the No 1 Integrated Drive Generator (IDG1) failed; the crew attempted a reset but it was unsuccessful. The aircraft was subsequently despatched from Alicante for a flight to Bristol with IDG1 selected OFF under the provisions of the operator's Minimum Equipment List (MEL). The APU generator was operating and supplying the AC1 busbar, with IDG2 supplying the AC2 busbar as normal (see 'Electrical system description' below).

The pilots reported that, while the aircraft was in the cruise at Flight Level (FL)320, under the control of Brest ATCC, they heard a 'CLUNK' and a number of services were lost, as follows:

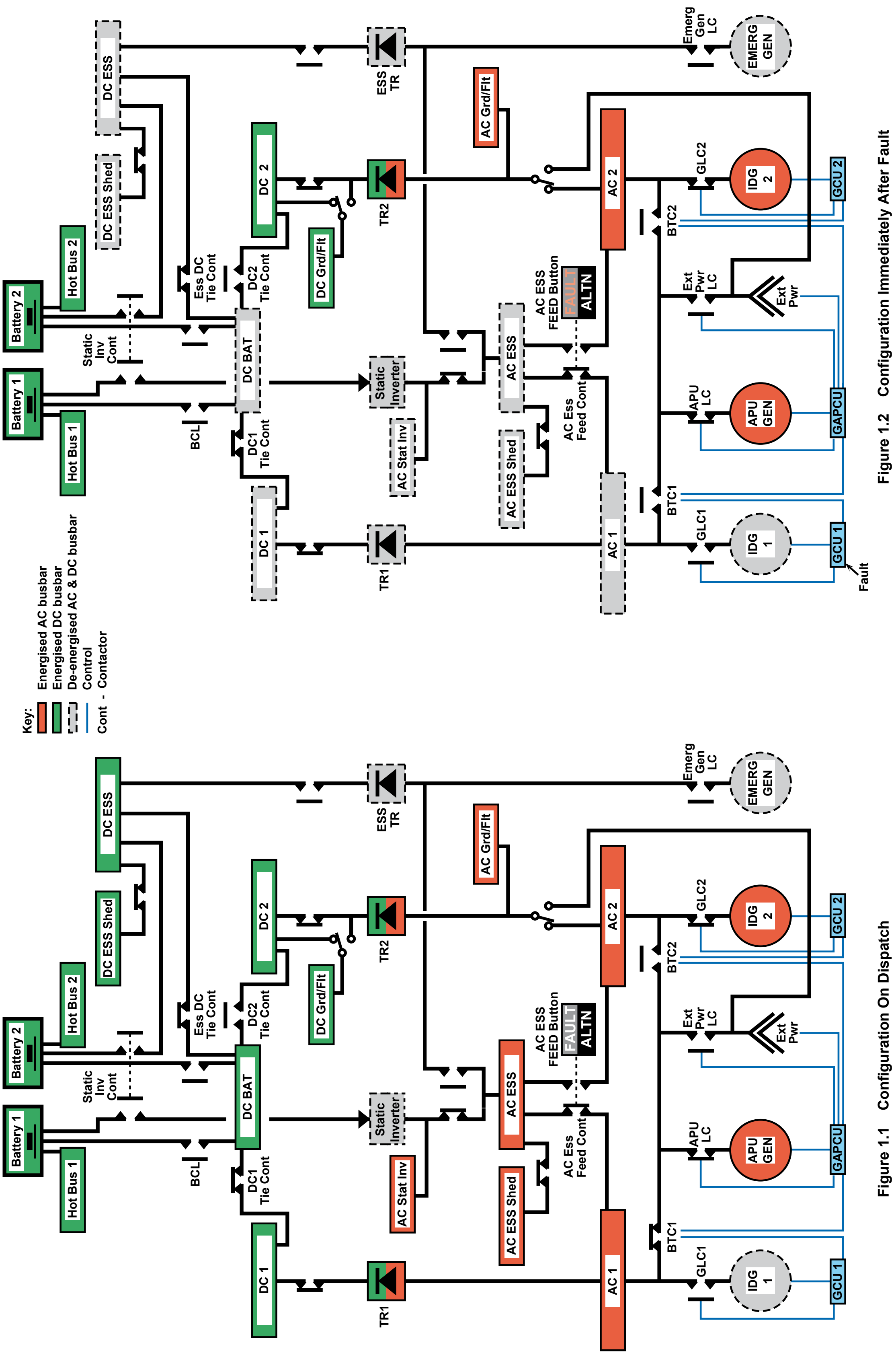
- Captain's Primary Flight Display, Navigation Display, upper Electronic Centralised Aircraft Monitoring (ECAM) display and Multi-purpose Control and Display Unit (MCDU);
- Autopilot; the associated aural Master Warning tone sounded;
- Autothrust; the associated aural Master Caution tone sounded;
- All caption and integral illumination lights on the overhead panel;
- A number of displays and lighting on the centre pedestal.

The commander, who was the Pilot Flying, had no flight instrument displays except the standby instruments. He checked that the co-pilot's instruments were still available and handed him control. The co-pilot noted that the aircraft's flight control system was now in 'alternate law'. The commander proceeded to carry out the ECAM actions, which were displayed on the lower ECAM screen. The first action was to select the AC ESS FEED push button to alternate (ALTN), but this had no effect. He commented that the push button caption was not lit and he was unable to see whether the push button was selected to normal or alternate. Concerned that he was not able to re-establish electrical power, he attempted to transmit a MAYDAY to Brest ATC. He tried both VHF1 and VHF2 on his own Radio Management Panel (RMP), asked the co-pilot to try from his RMP and later also attempted to select VHF3 using the observer's communication equipment. All attempts to re-establish RTF communications were unsuccessful.

Continuing with the ECAM actions the commander selected ATC2, the alternative transponder. The digit display, which had been blank, returned and he selected the emergency 7700 code to alert ATC to the fact that the aircraft had a problem. After considering the options for the flight he decided that the best course of action was to continue to the original destination in accordance with the flight plan. When the landing gear was selected DOWN during the approach, it failed to extend and the crew used the emergency extension system. The aircraft landed safely at Bristol at 1133 hrs.

Electrical system description

Two engine-driven IDGs normally power the aircraft's electrical services (Figure 1.1). Each IDG provides 3-phase Alternating Current (AC) power to an AC main busbar (AC1 or AC2) via a Generator Line Contactor (GLC). The IDG outputs are isolated from each other by two Bus Transfer Contactors (BTC). A Generator Control Unit (GCU) monitors the IDG output and opens the GLC if it detects an out-of-limits condition. The BTCs then close, to supply both AC main busbars from one generator. Selecting an IDG off also opens the respective GLC. In the event of loss of output from



Figures 1.1 and 1.2

Electrical Distribution System Schematic an IDG, a generator driven by the APU can also supply either of the AC main busbars, via the respective BTC. Monitoring and control of the APU generator output is by a combined Ground Power/APU Generator Control Unit (GAPCU). An electrical system control panel is provided in the flight deck overhead panel and system status can be monitored on the lower ECAM display; system operation is normally automatic.

The aircraft manufacturer's Master MEL (MMEL) permits dispatch of the aircraft for non-Extended Twin Operations (ETOPS) with one IDG selected off, provided the APU generator is on line. In this configuration, a fault monitoring facility within the GCU for the inoperative IDG checks for correct opening of the associated GLC by monitoring the generator current in each phase, as detected by Current Transformers (CT) fitted in the generator. If a fault current is detected, the GCU opens the associated BTC. As this function is intended to protect against failure of the GLC contacts to open, it remains in effect even when the associated IDG is selected off.

The distribution system includes an AC Essential busbar (AC ESS), normally powered from AC1; two DC busbars (DC1 and DC2), normally powered from AC1 and AC2 respectively via Transformer Rectifiers (TR), and a DC Essential busbar (DC ESS), normally powered from DC1 via a DC battery busbar (DC BAT). Each essential busbar supplies an associated Essential Shed busbar. Thus, loss of AC1 results in loss of the AC ESS busbar, and hence the loss of the AC Essential Shed, DC ESS and DC Essential Shed busbars (Figure 1.2). DC1 busbar is also lost; after 5 seconds it is automatically transferred to feed from DC2 via DC BAT, but it does not then supply the DC ESS busbar.

Loss of the AC ESS busbar causes an amber FAULT caption to illuminate in the AC ESS FEED push button. The push button operates a changeover contactor to transfer supply of the AC ESS busbar to AC2. This action restores the AC ESS busbar, the AC Essential Shed busbar and, via the Essential TR, the DC ESS busbar and DC Essential Shed busbar, and illuminates a white ALTN caption in the push button.

Loss of the AC1 busbar, prior to transfer of the AC ESS busbar to AC2, will result in loss of all the annunciator lights powered by these two busbars. However, annunciator lights powered by the AC2 or battery busbars should still be operative.

G-EZAC was fitted with an upgraded digital Audio Management Unit (AMU) for all the RTF communications. Unlike earlier versions, its operation depended on a power supply from a single busbar (DC ESS). Airbus advised that this meets present certification standards.

Flight recorders

Data was recovered from both the CVR and FDR. The FDR was powered by the AC2 busbar and remained recording throughout the flight. The data confirmed that at the start of the incident the aircraft was flying at FL320 at an indicated airspeed of 277 kt. At 10:52:40 hrs the AC1, AC ESS and DC ESS busbars de-energised, and did not recover until after landing. The system losses reported by the crew were all consistent with the loss of these busbars. The data showed that BTC2, which was initially open, cycled three times shortly after the loss of the busbars, consistent with the APU generator or IDG2 switching off and on line.

The CVR was powered from the AC Essential Shed busbar and recording ceased at the time of the incident.

Aircraft inspection and testing

Following the incident, inspection and wiring checks of possibly relevant parts of the aircraft electrical system revealed no signs of anomaly. The system functioned normally during engine and APU ground running checks and the indications and functioning of the AC ESS FEED button when AC1 busbar was de-energised were normal. The aircraft system initially failed to accept external electrical power, but eventually did so. Bench testing of the AC ESS FEED button and associated contactors and relays found no signs of anomaly.

However, laboratory testing did reveal an intermittent fault with GCU1, whereby a current was incorrectly detected by one of the CTs within the generator. This corresponded with data recorded for trouble-shooting purposes by the aircraft fault monitoring system when IDG1 had tripped off line on the previous flight. The post-flight report provided by the system included a fault code 'IDG1(E1-4000XU)GEN CT/GCU1(1XU1)'. The data indicated that a similar fault had caused the de-energisation of the AC1 busbar during the flight to Bristol. Initial evidence indicated that the GCU1 monitoring system had incorrectly interpreted the fault in the GCU itself as a fault in the open GLC1. The GCU had consequently locked open BTC1, thus disconnecting the APU generator from the AC1 busbar. The testing also revealed a fault in the GAPCU.

Investigations are continuing into the causes of the GCU1 and GAPCU faults, the possible reasons for the reported anomalies with the AC ESS FEED button captions and function, and the causes of the external power acceptance difficulties.

Other information

During the investigation it became apparent that a manufacturing problem had resulted in a hardware fault within a number of GCUs and GAPCUs of the type fitted to G-EZAC (used on A320 series, A330 and A340 aircraft). It had been found that the contents of a Static Read-Only-Memory (SRAM) component could alter and that this would result in a GCU 'Failsafe' fault and isolation of the associated IDG from the electrical system. The system could usually be reset by cycling the associated generator ON/OFF push button. The aircraft manufacture had issued an Operator's Information Telex (OIT 999.0106/06, issued 24 August 2006) listing the serial numbers of the approximately 2,200 units affected and recommending that each aircraft should have at least two units that had not experienced a failsafe issue in the last 30 days. The OIT was issued for maintenance purposes rather than flight safety reasons and, therefore, was not made available to flight crews.

Discussion, safety action and recommendations

The evidence indicated that a monitoring system had incorrectly interpreted a fault in GCU1 as a GLC1 fault and opened BTC1 as a result. This had disconnected the APU generator from the AC1 busbar, leading to the loss of AC1 and a number of other busbars, including the AC ESS and DC ESS busbars. It was undesirable that the incorrect interpretation of a single fault should cause the loss of a main busbar. At this time the inappropriate action by the GCU appears to have been due to inadequate logic in the monitoring system. Therefore:

Safety Recommendation 2006-142

It is recommended that Airbus should revise, for the A320 aircraft series, the fault monitoring logic of the Generator Control Unit to prevent the monitoring system from incorrectly interpreting a fault within the GCU as an external system fault.

In response to this issue, Airbus has confirmed that the GCU fault monitoring system will be improved. Actions are being taken by Airbus and by the GCU supplier for a software modification, which will be included in the next GCU standard to be released. At present, however, it is not known when this will be issued.

It was a matter of particular concern that repetition of the same fault that had led to G-EZAC's dispatch with the IDG inoperative could subsequently cause isolation of the APU generator that was substituting for the IDG. Airbus has stated that their System Safety Assessment predicts a sufficiently low probability of recurrence of this situation to allow their safety objectives to be met in this dispatch configuration. Therefore the AAIB does not intend to make a safety recommendation regarding this MMEL provision, at this time.

Implications of the potential GCU and GAPCU faults due to a SRAM defect, while not apparently relevant to this incident, also raised concerns about the adequacy of the procedures for dispatching with one IDG inoperative. It was recommended in the OIT that each aircraft should have at least two units that had not experienced a failsafe issue in the last 30 days. This suggested that a lower standard of airworthiness might result if an aircraft was dispatched with one IDG inoperative and with the remaining IDG or APU generator controlled by a unit from the affected batch, and hence of degraded reliability. However, the Operational Procedure associated with such a dispatch by the flight crew, did not require a check of whether the active GCU and GAPCU were from the batch affected by the SRAM defect. Airbus have taken action to retrofit all affected GCUs and advise that it is hoped this can be achieved by the end of 2006. They are also considering issuing a revised OIT to recommend that flight crews should obtain advice from their maintenance organisation before dispatching with IDG1 inoperative. Therefore the AAIB does not intend to make a safety recommendation on this matter at this time.

The aircraft's electrical distribution system is automatic in both normal operation and in some failure situations. It was apparent that the AC1 busbar is a crucial part of the system and its de-energisation results in a major loss of aircraft services, possibly at a critical stage of flight. Because the transfer of the AC ESS busbar did not occur, this resulted in a continued loss of essential services for the remainder of the flight.

It was intended that operation of the AC ESS FEED push button would restore many of the services; Airbus reported that the average observed time for a crew to operate the push button switch in these circumstances is around one minute. It was considered preferable that this should be accomplished automatically. Therefore:

Safety Recommendation 2006-143

It is recommended that Airbus should introduce, for Airbus A320 series aircraft, a modification to automatically transfer the electrical feed to the AC Essential busbar in the event of the loss of the No 1 Main AC busbar.

Airbus have been studying the feasibility of a modification to provide, in such circumstances, automatic transfer of the AC ESS busbar to AC2. The status of this possible modification will be provided at the beginning of January 2007.

The loss of all RTF communication capability was of major concern. It had resulted because the AMU, and thereby the entire RTF communication system, relied on a power supply from the DC ESS busbar. While it was to be expected that in this case the busbar would be restored by transferring the AC ESS busbar to feed from AC2 busbar, other failures could cause the permanent loss of the DC ESS busbar.

Airbus stated that the certification criteria for A320 series aircraft, i.e. a probablity of a total loss of RTF communications of $1x10^{-5}$ per flying hour, is met. The AAIB considers that the reliance of all the RTF communication system on a single busbar is undesirable and is unlikely to be generally known by operators or crews of affected A320 series aircraft. Furthermore, the Flight Crew Operations Manual (FCOM) and existing ECAM procedures do not reflect this configuration. The following two safety recommendations are therefore made:

Safety Recommendation 2006-144

It is recommended that Airbus should advise all operators of A320 series aircraft with Radio Telephony (RTF) communications reliant upon a single busbar of the consequent possibility of loss of all RTF communications.

Safety Recommendation 2006-145

It is recommended that, for A320 series aircraft with digital Audio Management Units, Airbus should take modification action aimed at ensuring that electrical power supplies required for Radio Telephony communications have an improved level of segregation.

Airbus has advised that it intends to inform the airlines concerned. Additionally, even though the current certification standard is met, Airbus is studying the feasibility of modifying the power supply to the digital AMU for A320 series aircraft.

The AAIB is continuing to investigate this incident with the cooperation of the manufacturer and the operator, and will publish a further report when the investigation is complete.

Published December 2006

INCIDENT

Aircraft Type and Registration:	Airbus A320, EI-DIJ
No & Type of Engines:	2 CFM 56-3A3 turbofan engines
Year of Manufacture:	1992
Date & Time (UTC):	29 March 2006 at 1330 hrs
Location:	Ballykelly, County Londonderry, Northern Ireland
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 39
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	14,000 hours (of which 1,800 hrs were on type) Last 90 days - 69 hours Last 28 days - 69 hours
Information Source:	AAIB Field Investigation

Synopsis

The Airbus A320 was operating a scheduled flight from Liverpool (John Lennon) Airport (LPL) to Londonderry/Eglinton Airport (LDY) in Northern Ireland. At 8 nm from LDY, the operating crew reported that they were having problems with the ILS glideslope on approach to Runway 26. They judged that they were too high to carry out a safe landing from the ILS approach and requested permission from ATC to carry out a visual approach. The aircraft then flew a right descending orbit and a visual circuit, from which it landed. Upon landing, the crew were advised by ATC that they had, in fact, landed at Ballykelly Airfield (BKL), 5 nm to the east-north-east of LDY.

History of the flight

The aircraft was operating on behalf of another operator.

The crew reported at 0455 hrs for a four sector day starting and ending at Liverpool (John Lennon) Airport (LPL). Their third sector was from LPL to Londonderry (LDY); the commander was Pilot Flying (PF) and the co-pilot was the Pilot Not Flying (PNF). It was a limitation, set by the operating company, that commanders were to perform the landing and the takeoff at LDY; this was due to the short runway. A feature of this airfield is that a single track railway line crosses the Runway 26 extended centreline, very close to the start of the runway, and aircraft inbound to this runway are sequenced to avoid trains.

The flight from LPL proceeded uneventfully until the crew of the A320 was handed over from Scottish Area Control to Eglinton Approach. Prior to the crew changing frequency, Eglinton Approach was controlling a Beech 200 aircraft, callsign CALIBRATOR, that had just finished calibrating the ILS at LDY and was routing outbound to a position 25 nm east of LDY. The pilot of an an Army Gazelle helicopter then came onto the frequency stating that he was routing from Coleraine (18 nm east-north-east of LDY) to Londonderry City, via Ballykelly Airfield (BKL). The Gazelle pilot was informed by ATC of the Beech 200 and that an A320 would soon be coming onto frequency and was advised to stay below 1,500 ft amsl and to remain south of the ILS centreline. The pilot acknowledged these requests.

Upon making radio contact with Eglinton Approach at 1320 hrs, the A320 crew were instructed to descend to 3,500 ft amsl and to report ILS localiser established at COLRE, a holding fix 15 nm on Runway 26 extended centre line at LDY. ATC advised the A320 crew that a Beech 200 was holding 10 nm east of COLRE, not above 3,000 ft amsl; this was to facilitate their arrival.

At 1322 hrs, the helicopter pilot reported that he was 3 nm north-east of Bellarena gliding site, 9 nm north-east of LDY. ATC asked him to fly the last 3 nm to BKL not above 500 ft agl, as the A320 was on the ILS. Two minutes later, the A320 crew were asked how far they had to go to COLRE; the crew replied they were established on the localiser. ATC cleared the A320 for an ILS/DME approach to Runway 26 and to report "PASSING FOUR DME." They were then advised that they might see the helicopter passing through the BKL overhead from north to south, not above 500 ft.

The crew of the Beech 200 then requested if they might extend outbound to 30 nm before turning inbound. This request was approved and ATC informed them that the ILS traffic was now on the localiser at 15 nm and to report 15 nm inbound.

At 1326 hrs, when the A320 was 8 nm from LDY, the crew transmitted "THE ILS ISN'T REALLY GIVING US DECENT GLIDE PATH INFORMATION. WE'RE GONNA MAKE A VISUAL APPROACH FROM HERE. WE'RE SHOWING 8, BUT IT LOOKS A BIT LESS THAN THAT." ATC cleared them for the visual approach and instructed them to "REPORT ON A 4 MILE FINAL", which they acknowledged. At this point the commander disconnected the autopilot and lowered the nose to increase the aircraft's rate of descent.

The A320 crew then asked that, if they had to fly a missed approach, could they join the visual circuit downwind. ATC informed them that it would be a right hand circuit and added that there was also a rain shower approaching from the northwest. They then said that they would go-around now and join right hand down wind. ATC requested them to keep it "REASONABLY TIGHT", as they were expecting a train in eight minutes and needed to "TRY [to] SQUEEZE YOU IN AHEAD OF HIM." Without changing configuration, or pressing the go-around buttons on the thrust levers, and after having re-engaged the autopilot, the A320 crew started a descending 360º turn and re-positioned onto the right base leg for a visual approach to Runway 26.

The A320 crew then asked for a QNH check, which was passed, and replied "YEAH THAT CONFIRMS THE ILS WAS A WAY WAY OUT." They then added that they had lost the signal for the ILS too. ATC then informed them that they would talk to the electrical engineers, but believed all ILS indications in the tower were normal. The Beech 200 pilot then transmitted that he had indications that the ILS had been turned off and asked the ATCO to speak to the ground crew. They subsequently confirmed that both ILS transmitters were functioning correctly.

As the A320 turned onto right base for Runway 26, ATC instructed the crew to "CONTINUE THE APPROACH AND CALL ON FINAL." Shortly afterwards the A320 crew reported "AT ABOUT TWO MILES NOW." At 1330 hrs, the ATCO, who was visual with the A320, then cleared it to land; this was acknowledged by the crew. Shortly before touchdown the EGPWS Mode 5 "GLIDESLOPE" aural warning sounded, followed by a "TERRAIN AHEAD" alert. Due to the distracting nature of this warning, the co-pilot attempted to silence it by pressing the TERR OFF button in the overhead panel.

About 50 seconds later, the ATCO asked the A320 crew to report their DME; they replied "WE'VE JUST TOUCHED DOWN.", to which the ATCO responded "IT WAS THE WRONG AIRPORT, YOU'VE LANDED AT BALLYKELLY." The A320 crew replied "I KNOW WE HAVE." The ATCO then instructed them to remain on the ground and await further instructions.

After completing the landing roll, the aircraft turned around at the end of the runway. ATC instructed the operating crew to shut down the aircraft's engines and await the arrival of ground handling equipment from LDY. The passengers and baggage were subsequently unloaded and taken by road to LDY.

Approval to fly the aircraft out of BKL, using a different operating crew, was subsequently given by the Irish Aviation Authority, in conjunction with the authorities at LDY and BKL. The aircraft, with just an operating crew on board, departed BKL from Runway 02 at 1925 hrs after the runway had been measured and inspected for debris.

Flight Recorders

The sources of information interrogated during this investigation were the Cockpit Voice Recorder (CVR), the Flight Data Recorder (FDR), the Quick Access Recorder (QAR), the Enhanced Ground Proximity Warning System (EGPWS) and radar recordings.

CVR

The CVR was found to be unserviceable, having failed approximately 16 days before the incident. This had not been detected despite a requirement to carry out a daily test.

FDR, QAR and EGPWS

The FDR, QAR and EGPWS yielded useful information pertaining to the incident and the data correlated well with each other. The following information is an amalgamation of these sources.

After departure, the aircraft climbed to FL220 and headed north-west. For all but the very first part of the 40 minute flight, the ILS frequency (108.30 MHz) for Runway 26 at Londonderry/Eglinton was selected. The aircraft autopilots acquired the ILS localizer and glideslope and tracked them for approximately 2.5 nm before both autopilots were disengaged. The aircraft was then flown, using the commander's sidestick, left of the Londonderry/Eglinton Runway 26 extended centreline and more in line with the centreline for Runway 26 at Ballykelly. The aircraft began to descend below the Londonderry ILS glideslope, following which a descending orbit to the right was carried out. This put the aircraft even further below the glideslope. The first half of the orbit was controlled using the left autopilot and selected HDG/FPA modes, the second half and subsequent landing was flown manually.

A Mode 5 'soft' EGPWS "GLIDESOPE" alert[1] was triggered just before the orbit was complete, at a radio altitude of approximately 592 ft agl. At this time the glideslope deviation was greater than five dots. Before this, the enabling conditions for a glideslope alert had not been met, despite the large glideslope deviations[2]. The descent continued and, ten seconds later, at 509 ft agl, an EGPWS "TERRAIN AHEAD, PULL UP" warning was triggered; which would have repeated continuously whilst the 'threat' existed. At the time of the alert, the commander had 'terrain' displayed on his Navigation Display (ND) and this alert would have highlighted the 'threatening' terrain on his display. The co-pilot did not have terrain displayed on his ND but the alert would have caused that page to appear. Ten seconds later, at 384 ft agl, the EGPWS look-ahead functions were inhibited using the TERR OFF selection on the overhead panel. This inhibited a further three alerts that would have otherwise been given. The aircraft touched down at Ballykelly 34 seconds later. The Flight Management System position indicated that the aircraft was within 175 m of the intersection of the runways at Ballykelly when the aircraft touched down. Figure 1 shows the final section of the flight.

Footnotes

1 Mode 5 provides two levels of alerting for when an aircraft descends below the glideslope, resulting in activation of EGPWS caution lights and aural messages. The first level alert occurs when below 1,000 ft and the aircraft is 1.3 dots or greater below the beam. This turns on the caution lights and is called a 'soft' alert, because the audio message 'GLIDESLOPE' is enunciated at half volume. 20% increases in the glideslope deviation cause additional 'GLIDESLOPE' messages enunciated at a progressively faster rate. The second level alert occurs when below 300 ft Radio Altitude (RA) with two dots or greater glideslope deviation. This is called a 'hard' alert because a louder 'GLIDESLOPE GLIDESLOPE' message is enunciated every three seconds, continuing until the 'hard' envelope is exited. The caution lights remain on until a glideslope deviation less than 1.3 dots is achieved.

2 The alert conditions require the presence of a valid localiser deviation within two dots and a RA below an upper boundary determined by a combination of rate of change of altitude and RA.

On this aircraft, there are no parameters recorded to identify whether the glideslope alerting function has been inhibited, unlike the terrain-ahead warning mentioned above. This function and its associated button are separate from the terrain-ahead warning 'inhibit' status that was recorded. Had the glideslope alerting function not been inhibited then, at 300 ft agl, the status of the alert should have switched from soft to hard and the "GLIDESLOPE GLIDESLOPE" aural warning would have been continuously repeated every three seconds.

Airport information

Londonderry's main runway is orientated 26/08. Runway 26 has a LDA of 1,817 m and its threshold is a short distance inland from the adjacent beach. A single-track railway line passes through the undershoot area, with up to 14 train movements per day, and railway personnel are required to telephone the ATCO at LDY to notify the time of departure and the estimated time that a train will cross the end of the runway.

As a result, the following warning is published in the UK Aeronautical Information Package (AIP):

> *'Aircraft will not be permitted to land on Runway 26 or depart Runway 08 from 5 minutes before the passage of a train until the train is past. Aircraft may experience approach delays of up to 10 minutes where movements conflict with the passage of a train.'*

The approach lighting for Runway 26 is 550 m in length. It initially consists of a line of five high intensity omni-directional sequenced strobe lights, in the water, supplemented with a simple ODALS[3] system, between the shoreline and the threshold.

Footnote

3 Omni Directional Approach Lighting System.

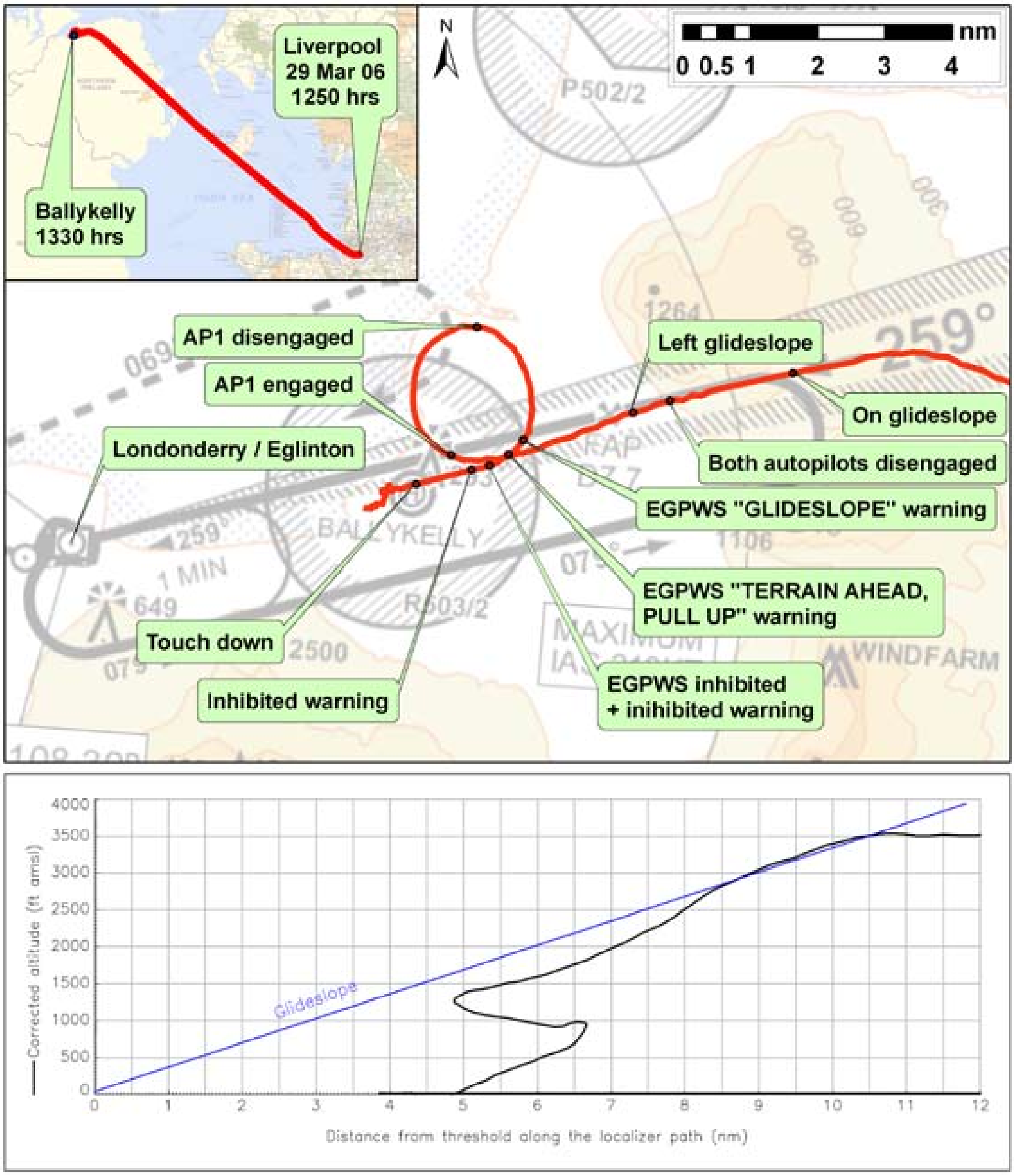


Figure 1

Approach and Landing Section of the Flight derived from the Flight Recorders

Pilots are reported to have commented that Runway 26 at Londonderry is very difficult to see from a distance, as the approach lights apparently do not stand out on a bright day.

Balllykelly, an ex-RAF airfield, is located 5 nm east-north-east of LDY and is now used by the British Army. Until 2003, it was used by C130 Hercules aircraft and, up to that time, the runway was inspected for condition annually. The airfield mostly supports helicopter operations and occasional Islander aircraft training flights and parachute jumping operations. The main runway has the same orientation as LDY, ie 26/08 and Runway 26 is 1,698 m in length with a threshold

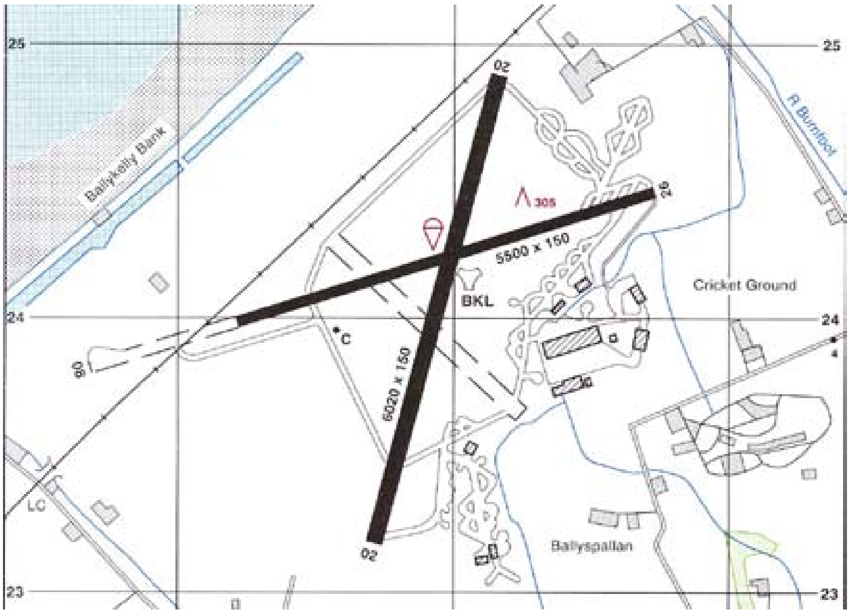


Figure 2

Diagram of the layout of Ballykelly Airfield

displaced by 479 m, giving a useable length of 1,219 m. A railway line, which is fenced off, crosses the far end but there is an additional 372 m of unusable runway the far side of this railway.

Runway 26 at BKL is mostly made of concrete that, in places, was showing signs of break-up. A tarmac section in a good state of repair, 662 m in length, had been laid in the middle of the runway. No runway lights were installed.

Only one set of aircraft touchdown tyre marks were found on the runway, ie two sets of 'double' tyre marks, and these were a short distance past the runway designator numbers. This was close to the touchdown position computed from the FDR data (see paragraph headed Flight Recorders). The spacing between these marks, for both sets of main gear tyres, was measured at 91 cm. The aircraft manufacturer reported that, for the A320, this dimension is 92.7 cm. Given that these were the only tyre marks on the runway, their location and their spacing left little doubt that they had been made by EI-DIJ. Having landed just past the runway numbers, this gave the A320 an adequate amount of runway within which to stop; the Landing Distance Required (LDR) for EI-DIJ, at its landing weight, was 728 m.

Meteorological information

The synoptic situation at 1200 hrs showed a low pressure over northern parts of the British Isles as well as to the west. Generally good weather was affecting much of Northern Ireland although there was a risk of showers in what was essentially an unstable air mass.

The METAR issued just before EI-DIJ landed at BKL showed that the wind was from 250º/15 kt, the visibility was in excess of 10 km, with FEW cloud at 2,500 ft agl and SCATTERED cloud at 3,200 ft agl.

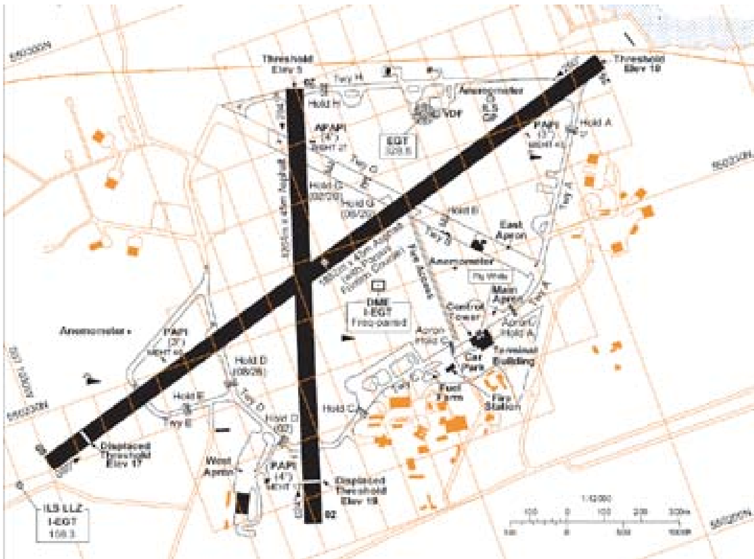


Figure 3

Diagram of the layout of Londonderry Airport

Operating crew's comments

Commander

The operating company had provided the operating crew with airfield charts for LDY that had been published by a commercial provider, Figure 4. For three days prior to the incident flight, the commander tried in vain to obtain a copy of the LDY airfield charts, through the LPL operations office and another commercial provider. This was to be fully prepared for the flight into this limiting airfield. However, he did obtain a copy of these charts the day after the incident and stated that, had he seen these previously, he would have been fully aware of the existence of BKY and would not have landed there. This was due to the different presentation of the data, in particular, the manner in which BKL was depicted, Figure 5. He had been issued with a 'brief' by his company prior to operating the flight, but this contained no reference to BKL.

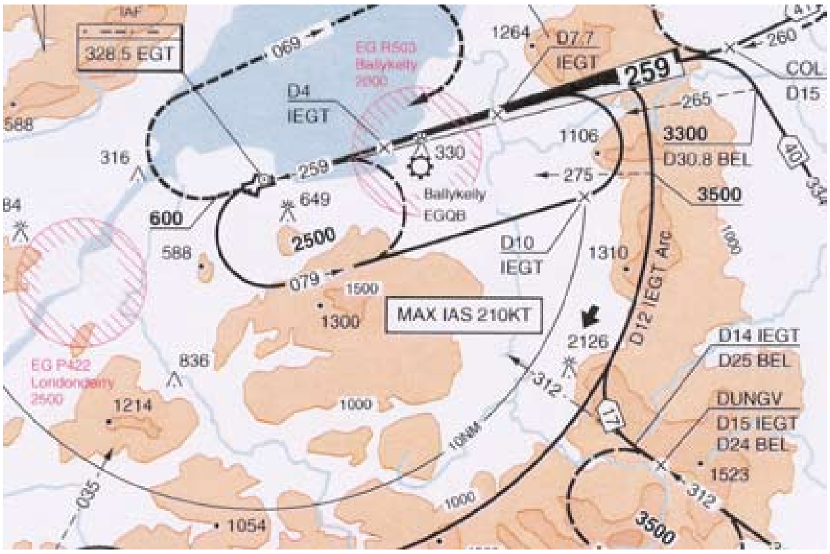


Figure 4

Section of approach chart used by the crew of EI-DIJ

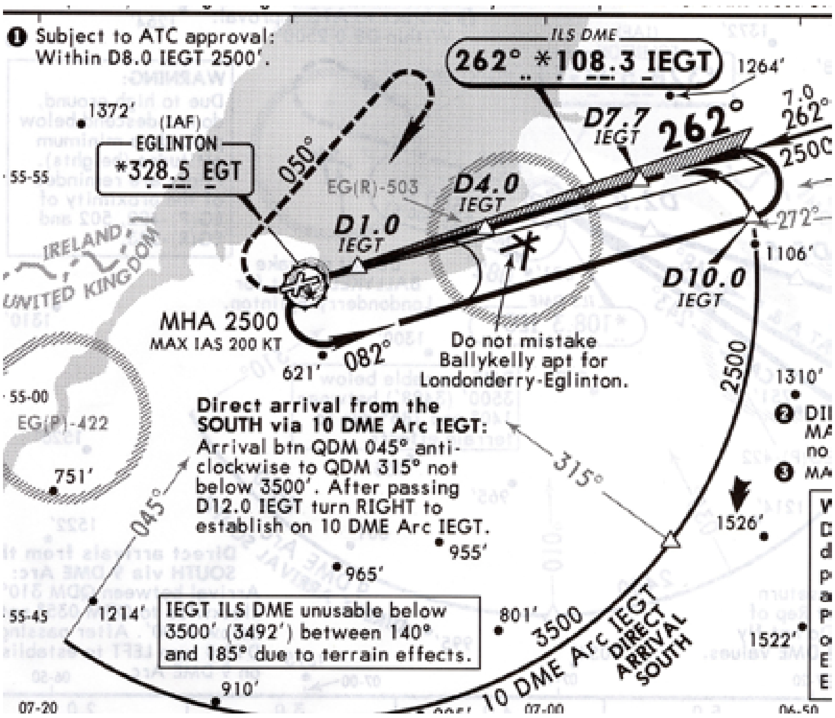


Figure 5

Section of the approach chart that the commander of EI-DIJ attempted to obtain prior to the flight, showing warning note re Ballykelly

Knowing that the runway at LDY was relatively short, he concentrated on flying an accurate approach to ensure that he landed on the threshold at the correct speed. He stated that, once he was visual with BKL, and not knowing there was another airfield in the vicinity, his mind-set was that this must be his destination airfield. At no time did the commander see LDY in the distance and the perceived problem with the ILS and the presence of the ILS calibrator aircraft all reinforced his perception that this was the correct, and only, airfield. He also felt that ATC was slightly 'rushing' him during the approach, due to the showers in the vicinity and the approaching train.

The commander stated that he touched down close to the beginning of the paved surface, well before the marked runway threshold. He was concerned about the length of the runway and wanted to make sure he had the maximum amount of runway ahead on which to complete the landing roll. He added that, after touchdown, he felt he had an adequate amount of runway ahead of him in which to stop. The commander was aware of the "GLIDESLOPE" and "TERRAIN" warnings prior to landing but, as he was visual with the runway, he believed that they were spurious.

Co-pilot

The co-pilot had landed on Runway 08 at LDY twice before. He was not aware of the existence of BKL and stated that, he too, had the same mind-set as the commander. Whilst he remembered trying to cancel the EGPWS "GLIDESLOPE" warning, he did not remember hearing the "TERRAIN" warning or which button he pressed in the overhead panel.

Londonderry ATC procedures

LDY operates two radio frequencies, Approach and Tower. There is no radar facility at the airport, hence the ATC approach service is procedural. When the tower is staffed, it is done so by one ATCO who monitors and controls both frequencies, which are cross coupled. Additionally, he is responsible for carrying out 'domestic' duties that include the taking of landing fees, submitting flight plans and issuing ATC clearances. When the ATCO requires a break, the tower service closes down.

All aircraft landing on Runway 26, whether they are flying a visual or an instrument approach, are required to report at four DME. At this point, BKL would be behind a landing aircraft and would thus be out of sight to the pilots. This is a local order that does not appear in the Manual of Air Traffic Services Part 2.

ATCO's comments

In order to de-conflict landing aircraft from the passage of trains, the ATCO plans on aircraft taking six minutes to fly down the ILS from COLRE to touchdown. If a confliction looks likely, he instructs the aircraft to hold at COLRE to increase the separation between the aircraft and a train.

On being advised by the A320 crew that they had a problem with the ILS glideslope, the ATCO telephoned the electronic engineers on site to ask them to check the serviceability of the ILS. Although he was visual with the A320 when it reported "AT ABOUT TWO MILES NOW" on final approach, the ATCO did not believe that the aircraft was about to land at BKL even though it appeared "slightly low". (At this position, had the aircraft been approaching LDY, it would have been below the glideslope by approximately 400 ft.) With hindsight, the ATCO felt that he had a period of approximately 30 seconds in which it would have been possible to stop the A320 from landing at BKL, but believes that he did not do so because he, incorrectly, prioritised his attention to checking the serviceability of the ILS. Also, he was looking for the Gazelle helicopter at the time the A320 made its final approach to BKL. He added that, in the past, he had stopped both light and commercial aircraft from landing at BKL by using his Direction Finding equipment, and thus noticing the aircraft's unusual relative bearing from the airfield. On one occasion, when he came on duty and was in the process of having the controller's position handed over, he stopped a commercial aircraft from making this mistake. He attributed this to the fact that there were two people in the ATC tower at that time.

UK Aeronautical Information Package

The Aerodromes section of the UK AIP contains detailed information about civil licensed aerodromes. Commercial providers of airfield charts use this information to produce their own version of the charts, which may be supplied to commercial operators and airlines.

The AIP for Londonderry states the following under '*Warnings*':

> *'Pilots are reminded of the close proximity of Ballykelly 5 nm to the east-north-east of this aerodrome. Ballykelly runway lighting may be observed from the final approach to Runway 26. Pilots of aircraft en-route and in the circuit should positively identify Londonderry/Eglinton before committing the aircraft to landing.'*

On the approach plates for LDY in the UK AIP, BKL is depicted by a helicopter landing site symbol. This is an ICAO requirement due to the fact that the main activity is by helicopters. The information in the AIP is depicted by commercial providers in different formats and with varying amounts of information. The airfield charts, that the commander tried to obtain before the incident flight, depict the runway layout at BKL on all of its plates for LDY. They include the note *"Do not confuse Ballykelly with Londonderry*", pointing at this symbol, as illustrated in Figure 5. The AIP and commercial plates available to the crew of EI-DIJ did not have this warning or a depiction of the runway layout. However, the symbol on these plates did indicate that there was an aerodrome at Ballykelly, alongside which its name and ICAO code were printed. On other charts, this commercial provider has a symbol in the chart legend to depict an *'Aerodrome with a RWY parallel to RWY at procedure aerodrome'*. They stated that they had not used this to depict the runway at BKL as "no such information is given anywhere in the UK AIP".

Analysis

Throughout flying training, pilots are taught to believe their flight instruments unless they have good reason to doubt the information being presented. Once visual with BKL, the crew of the A320 were convinced that this was their destination airfield. Distracted by what they perceived was a problem with the ILS glideslope and DME, and the perceived slight sense of urgency from the ATCO, they became focused on landing at the only airfield they could see. Whilst BKL was marked on their approach plates, they failed to recognise the depiction as an airfield.

Not being aware that there was another airfield in the vicinity with a very similar layout, and misbelieving the (correct) ILS glideslope and DME indications, the crew continued towards the only airfield they could see, firmly convinced that they were landing at LDY. This was despite the distraction of the EGPWS warnings during the final stages of the approach. Had the approach been flown in IMC, there is little doubt that the operating crew would have flown the ILS to Decision Altitude and landed, without incident, at LDY.

There are varying degrees of information and formats associated with the approach plates for LDY from commercial providers of this information. Although at least one version of the approach plates contains a warning note for flight crews not to confuse BKL with LDY, it would seem appropriate that the AIP should be amended to add such a note. This should highlight the fact that the runways at BKL have a similar configuration to that of LDY, and this would ensure that commercial providers have all the information they need, to minimise the possibility of BKL being misidentified as LDY.

Following this incident, National Air Traffic Services (NATS) published a NOTAM, No L2352/06, which stated the following:

> *'Pilots are reminded of the close proximity of the Military helicopter site at Ballykelly AD, 5 nm east of Londonderry. Ballykelly AD has similar RWY directions and pattern to Londonderry. Pilots of aircraft en-route and in the circuit at Londonderry should positively identify Londonderry/Eglinton before committing their aircraft to land.'*

Safety action taken

Prior to this event, the operating company had been looking at the merits of changing to another commercial provider of airfield charts. As a result of this incident, they have changed their provider, although their original provider has now amended its charts, including a change to the symbol for BKL, to clarify the information presented to flight crews, Figure 6.

NATS have indicated that the warning contained in the NOTAM will be incorporated in to the UK AIP at the next suitable opportunity.

In view of these actions, it is not considered necessary to make any formal safety recommendations.

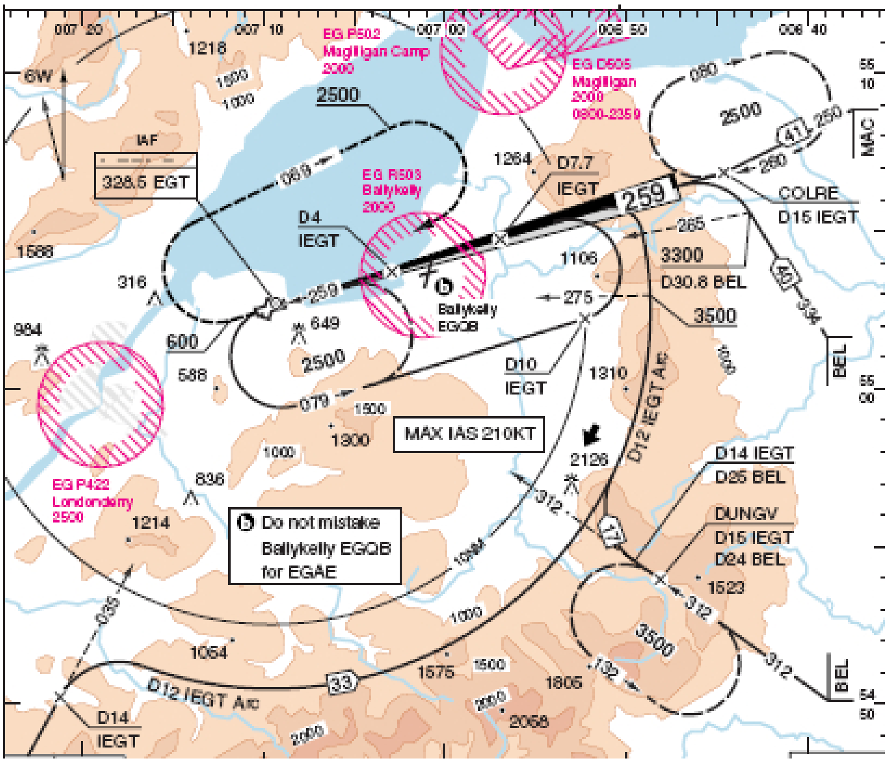


Figure 6

Modified version of the chart shown in Figure 4

INCIDENT

Aircraft Type and Registration:	Airbus A320-A1, EC-GRF
No & Type of Engines:	2 CFM 56-5A1 turbofan engines
Year of Manufacture:	1991
Date & Time (UTC):	4 April 2006 at 0802 hrs
Location:	Stand 203, Terminal 2, London Heathrow Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 110
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to left engine inlet cowl and airbridge protective railings
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	13,256 hours (of which 3,875 were on type) Last 90 days - 157 hours Last 28 days - 49 hours
Information Source:	Aircraft Accident Report Forms submitted by pilot and subsequent enquires by the AAIB

Synopsis

Shortly after commencing the taxi for takeoff, a hydraulic union in the braking system fractured, causing fluid to leak from the Yellow hydraulic system. The departure was cancelled and the aircraft returned to the terminal. After stopping on the allocated stand, the parking brake was selected ON, but the brakes failed to apply as the parking brake is operated by the Yellow hydraulic system. The aircraft then began to move forward under idle engine power. Attempts by the crew to stop using the brake pedals proved unsuccessful, as the other modes of braking are deactivated when the parking brake is selected ON. The aircraft collided with the airbridge, damaging the left engine inlet cowl, before coming to a stop.

History of the flight

The aircraft was pushed back from Stand 209R at Terminal 2, London Heathrow, for a scheduled passenger flight to Madrid. As the aircraft began to taxi away from the stand, the Yellow hydraulic system low fluid level message (HYD Y RSVR LO LVL) appeared on the ECAM[1]. The commander, who was the handling pilot, stopped the aircraft to assess the problem. On looking out of his side window, the co-pilot observed a large pool of liquid

Footnote

[1] Electronic Centralised Aircraft Monitor. This system comprises two electronic displays, located centrally on the main instrument panel, which provide information to the crew on the status of the aircraft systems, including systems that may be inoperative following specific failures. Faults in the aircraft systems are highlighted by warning, caution or memo messages, and checklists of actions to be taken by the crew are displayed automatically following a system failure.

on the taxiway on the right side of the aircraft. The crew performed the ECAM checklist actions and consulted the appropriate procedure in the Flight Crew Operating Manual (FCOM). The departure was cancelled and ATC clearance was obtained to return to the terminal to park on Stand 203.

The commander reportedly checked the Yellow hydraulic system accumulator pressure on the cockpit gauge and noted that it was indicating that pressure was available. During the taxi back to the terminal, the aircraft had to stop a number of times and no problems were experienced with the use of the brake pedals. On arriving at the stand, the aircraft was brought to a halt again whilst the automated parking guidance system was being switched on. The commander then taxied the aircraft onto the stand, stopped on the appropriate mark on the stand centreline and applied the parking brake. However, on looking out of the cockpit again, he noticed that the aircraft was moving forward. Both he and the co-pilot attempted to stop it using the brake pedals, but this proved ineffective, and the engines were quickly shut down in order to minimise any damage. The aircraft continued rolling forward until brought to a halt as its left engine struck the airbridge.

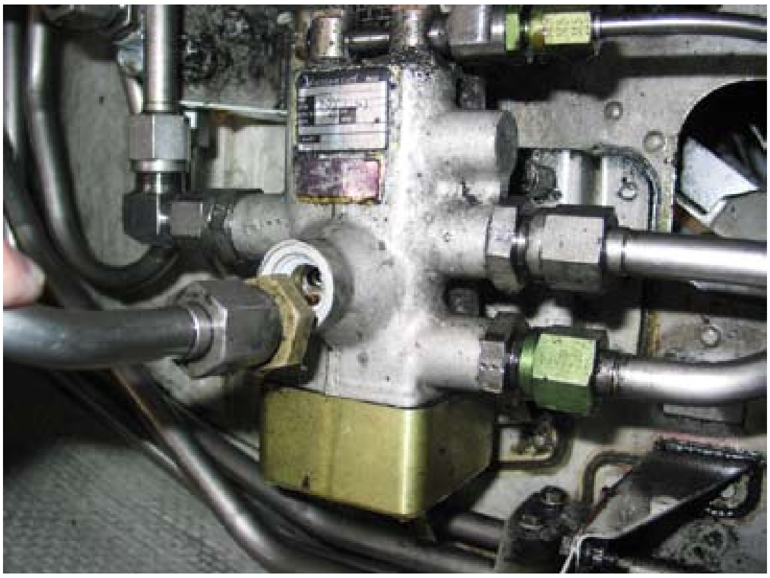


Figure 1

Fractured hydraulic union on the BDDV

Accident scene information

The airbridge, which is believed to have been unoccupied at the time, was in the parked position when it was struck by the aircraft. The top and bottom lips of the left engine inlet cowl were dented from contact with the upper attachment of one of the hydraulic operating rams and the protective steel railings at the base of the airbridge. The railings were heavily deformed by the impact, but there was no visible damage to the airbridge itself.

Examination of the centreline markings on Stand 203 showed that the stop markers for the different aircraft types were clearly identified. Assuming that the aircraft had initially stopped on the correct stop mark, as reported, measurements showed that it had then moved forward a distance of approximately four metres before the left engine struck the railings.

Inspection of the aircraft revealed that a hydraulic reducer union on the brake dual distribution valve (BDDV) had fractured, Figure 1, allowing fluid to leak from the Yellow hydraulic system.

A320 hydraulic systems description

The A320 has three independent hydraulic systems, designated Blue, Green and Yellow, operating nominally at a pressure of 3,000 psi. The Green and Yellow systems are normally pressurised by pumps driven by the left and right engines respectively, and the Blue system is pressurised by an electrically driven pump. The Yellow system is also equipped with an electrically driven pump, which allows the system to be pressurised on the ground when the engines are shut down. An accumulator in the

Yellow system provides pressure for the parking brake system when the hydraulic pumps are not operating.

Should the pressures in the Green and Yellow systems differ by more than 500 psi (35 bar), the power transfer unit (PTU) automatically engages, boosting the pressure in the system experiencing the pressure drop. The PTU comprises a pair of mechanically connected dual action hydraulic motor/pump units; there is no transfer of fluid between the two hydraulic systems.

A320 parking brake system operation

The handle for the parking brake is located on the centre pedestal in the cockpit; the brake is applied by lifting the handle and rotating it 90° clockwise, from the OFF to the ON position. This operates the parking brake control switch, which signals the motors in the parking brake control valve to move the valve to the ON position. This causes Yellow system hydraulic pressure (from either pump, if running, or the accumulator) to be supplied to the alternate brake pistons on the brake units. The pressure in the parking brake system is maintained through the closure of the hydraulic return lines. When the parking brake control valve is in the ON position, ie when the parking brake handle is set to ON, the normal[2] and alternate braking systems are electrically and hydraulically deactivated.

The accumulator pressure and the parking brake system pressure are displayed on a combined triple pressure gauge mounted in the main instrument panel. When the parking brake is selected to ON, a green 'PARKING BRAKE ON' memo is displayed on the ECAM. However, this message only indicates the position of the parking brake control valve and appears whenever the valve is in the ON position, irrespective of whether or not Yellow hydraulic pressure is available to apply the brakes.

Brake Dual Distribution Valve (BDDV)

The BDDV is located on the rear bulkhead of the right main landing gear bay. Its function is to supply the alternate braking system with Yellow hydraulic system pressure. During alternate braking, the BDDV modulates the hydraulic pressure to the brakes in accordance with the level of braking demanded by the flight crew through the brake pedals. The alternate braking system automatically becomes available if the normal braking system should fail.

The BDDV is pressurised by the Yellow hydraulic system, except during normal braking and when the parking brake is applied. This is to ensure that hydraulic pressure is immediately available to operate the alternate braking system if the normal braking system fails. During normal braking, an automatic selector valve (ASV) located upstream of the BDDV cuts off the Yellow hydraulic system supply to the BDDV and supplies Green hydraulic system pressure to the normal braking system. When the brake pedals are released, the ASV restores the Yellow hydraulic supply to the BDDV. When the parking brake is applied, Yellow hydraulic system pressure is supplied to the parking brake circuit and the BDDV is by-passed.

The BDDV is therefore exposed to pressure variations during normal braking and parking brake operation.

Relevant flight recorder data

A copy of the relevant Quick Access Recorder (QAR) data was provided by the operator, which showed that full Yellow hydraulic system pressure was available after

Footnote

2 The normal braking system is operated by the Green hydraulic system, which operates one group of pistons on each brake unit. The alternate braking system and parking brake are supplied by the Yellow hydraulic system and operate a different group of pistons on the brake units.

engine start. However, shortly after the aircraft began to taxi, there was a drop in the Yellow system pressure to just below 2,000 psi followed, about 40 seconds later, by another drop to just below 500 psi. The second, larger, pressure drop triggered the Yellow hydraulic system low pressure warning and, following this, the ground speed parameter showed that the aircraft was stationary for about 75 seconds. The pressure drops were of short duration and, on both occasions, the pressure returned to normal. Approximately 30 seconds after the second pressure drop, whilst the aircraft remained stationary, the Yellow system pressure then fell to zero and did not recover. The aircraft then commenced the taxi to return to the terminal. The data show that the Green hydraulic system pressure dropped coincidentally with the pressure drops in the Yellow system, but to a lesser degree. The Green system pressure otherwise remained nominally at 3,000 psi.

Mandatory Service Bulletin 32-1201

In May 2001, following a previous A320 ground collision incident, the aircraft manufacturer issued Service Bulletin (SB) 32-1201, which modifies the parking brake system so that normal braking is automatically restored in case of low Yellow hydraulic system pressure. This configuration was subsequently adopted as the production standard on new-build aircraft. The SB was made mandatory by the European Aviation Safety Agency (EASA), and must be accomplished on all affected aircraft by 31 March 2009.

On aircraft of pre-service bulletin SB 32-1201 configuration, which includes EC-GRF, in the event of a parking brake failure, the parking brake handle must be moved to the OFF position in order to restore the normal braking system.

On aircraft of post-SB 32-1201 configuration, if the hydraulic pressure in the parking brake system decreases to less than 35 bar (approximately 500 psi), the parking brake control valve will be automatically commanded to the OFF position, irrespective of the parking brake handle position, thus reactivating the normal braking system.

The operator's fleet comprised a mix of pre- and post-SB 32-1201 configuration aircraft.

ECAM abnormal procedures

In the event of low hydraulic fluid quantity in the Yellow hydraulic system, the following ECAM messages and actions appear, which must be reviewed and actioned by the crew:

'HYD Y RSVR LO LVL

- PTU……………………………OFF
- YELLOW ENG 2 PUMP……....OFF
- YELLOW ELEC 2 PUMP……..OFF
- BRK Y ACCU PR .. MONITOR'

The ECAM does not indicate whether the parking brake is operative or not; the pilot must first check the triple pressure gauge to verify that accumulator pressure is available and then check that pressure has been applied to the brakes after setting the parking brake. Even though the Yellow hydraulic system may be unavailable, the 'PARKING BRAKE ON' memo will remain displayed on the ECAM when the parking brake is selected on.

Aircraft manufacturer's operational instructions

Following the previous incident, Airbus issued Operator Information Telex (OIT)/Flight Operations Telex (FOT) SE 999.0079/01/BB, in June 2001, proposing two changes to the A319/A320/A321 Flight Crew Operating Manual (FCOM):

Firstly, the 'PARKING' chapter of the Standard Operating Procedures in the FCOM was to be amended to include a check of the parking brake accumulator pressure prior to setting the parking brake. The purpose of this was to detect accumulator low pressure which could result in parking brake failure. (The existing FCOM procedures already stated that, in the event of a parking brake failure or unexpected movement of the aircraft occurring with the parking brake selected to ON, the parking brake handle must be selected to OFF to restore the normal braking system.)

Secondly, a note was to be added to the FCOM procedure for a Yellow hydraulic system failure to highlight that the parking brake may be inoperative due to low Yellow system accumulator pressure.

These changes were incorporated by Airbus in the July 2001 general revision (Revision 33) of the FCOM.

Operational procedures

The operator's A319/A320/A321 FCOM, which is based on the Airbus FCOM, reflected the changes introduced by Revision 33.

The parking procedure is contained in section 2.01.72 of the operator's FCOM and it states that the triple pressure gauge must be checked prior to selecting ON the parking brake, to verify that Yellow hydraulic system accumulator pressure is available. It also requires a check of the brake pressures on the triple pressure gauge after selecting the parking brake to ON. The procedure also contains the following:

> *'CAUTION*
>
> *If the aircraft begins to move after applying the parking brake, the PARK BRK handle should be immediately selected to off and the brake pedals applied.'*

The operator's FCOM includes the following note in the Yellow hydraulic system failure abnormal procedure:

> *BRK Y ACCU PR MONITOR*
>
> *This check is recommended to cover the case of a pipe, rupture, which could lead to the simultaneous loss of the hydraulic system and the accumulator fluid. If this occurs, the loss of the accumulator should be observed on the indicator within 10 minutes. In that case: the only remaining braking means is normal braking, using green pressure. The parking brake should not be used, since it is not available. And, the chocks should be put in place before Engine 1 shutdown.'*

Prior to the incident, the operator had not provided any specific training to flight crews on parking procedures following a Yellow hydraulic system failure.

Hydraulic reducer union

The failed union, which is of an aluminium alloy material, was located in the Yellow hydraulic system supply port to the BDDV. The part number of the union is MS21902D8 and it is identified as item 070 of Figure 2D in Chapter 32-43-03 of the A319/320/321 Illustrated Parts Catalogue.

The BDDV had completed a total of 29,665 flying hours and 23,871 flight cycles since new, and had not been previously overhauled.

The aircraft manufacturer, Airbus, was aware of two previous failures of hydraulic unions on the BDDV, but there was insufficient information to determine whether these were the same as that which failed in this incident. This union is installed on approximately 2,400 A319/A320/A321 aircraft; these have accumulated a total of more than 40 million flying hours and 20 million flight cycles, with the fleet leaders having attained, at the time of this incident, 55,000 flying hours and 38,000 flight cycles.

Metallurgical examination

The hydraulic union had fractured in the region of the last full thread before the run-out, on the threaded end to which the hydraulic pipe attaches. The fracture was the result of a fatigue crack initiation at the thread root, which propagated to a relatively small crack under low magnitude cyclic stress. Given the small crack advance, the large area of overload was possibly due to the presence of a high static load on the fitting, over which the cyclic loading was superimposed. This was possibly due to separate periods of vibration, or other excitation, as indicated by the presence of wider beach marks between the closely spaced striations. Crack initiation had occurred at multiple sites around the thread root, precluding a defect induced failure. There was no evidence of corrosion on the fitting. The final separation was essentially axial, and therefore unlikely to have been due to an attempt to over-tighten the fitting, which might be expected to produce a torsional separation. The results of the metallographic examination, hardness determinations and chemical analysis, indicated that the fitting had been correctly manufactured from an Al 2024 alloy in the fully heat treated condition.

Discussion

The QAR data show that full Yellow hydraulic system pressure was available after engine start and up to the point the aircraft began to taxi. The first indication of a problem was the initial drop in the Yellow system pressure, to just under 2,000 psi, shortly after taxiing, which probably signified the point at which the hydraulic leak started. The second, larger pressure drop triggered the Yellow system low pressure warning, prompting the crew to stop the aircraft and assess the problem. In both cases, the hydraulic pressure recovered, probably coincident with the automatic engagement of the PTU, which would have restored the Yellow system pressure, if sufficient fluid had remained in the system. The coincidental pressure drops in the Green system pressure were probably indicative of PTU operation.

Application of the parking brake, after stopping to investigate the problem, would have cut off the Yellow hydraulic system supply to the BDDV and reduced the rate of fluid leakage. The data shows however, that by the time the aircraft had commenced the taxi to return to the terminal, the Yellow hydraulic system pressure had fallen to zero and did not recover. The ECAM actions required the crew to turn off the Yellow system pumps and the PTU, after which the Yellow system would have no longer been pressurised.

The aircraft parking procedures require the crew to verify that pressure has been applied to brakes after selecting the parking brake to ON. Given that the aircraft began to move forward immediately after setting the parking brake, it is likely that there was little or no Yellow system hydraulic pressure available to apply the brakes, and this should have been indicated on the brake pressure gauges.

Once the aircraft began moving forward on the stand, the crew could have stopped it by selecting the parking brake to OFF, thus re-activating the normal braking system, before operating the brake pedals. The normal braking system would have been available as, with the engines still running, the Green hydraulic system was pressurised, as indicated by the QAR data. However, this action is not intuitive and the fact that the crew had not practised this particular failure scenario may have been a significant contributory factor.

Although the ECAM action list included an action item to monitor the Yellow hydraulic system accumulator pressure, it gave no specific information that the parking brake might be inoperative. This information was, however, contained within the FCOM, which was consulted by the flight crew. It is possible that the crew, having seen an indication of accumulator pressure on the gauge at some point, assumed that the parking brake was serviceable.

The cause of the fatigue cracking in the failed hydraulic union was not established; however, no evidence was found of pre-existing defects, corrosion, or of an incorrect material specification.

Actions taken by the operator, post-incident

The operator has conducted its own investigation into the incident and took a number of safety actions intended to prevent recurrence. These actions include:

Additional flight simulator training on hydraulic failures for the crew involved in the incident.

The development of an appropriate flight simulator training scenario for all A320 crew members.

The issue of a safety recommendation to its A320 crews, stating that aircraft should be towed to the parking position in the event of a hydraulic system problem.

The operator has requested that the aircraft manufacturer provide the appropriate abnormal procedure for dealing with such a hydraulic system failure on A320-A1 aircraft.

Actions taken by the manufacturer, post incident.

The manufacturer also conducted an investigation into this incident, and has made a number of safety recommendations. These included:

- *'On affected aircraft, operators should embody SB 32-1201*[3]
- *Operators should specifically bring to the attention of flight crews the following:-*

  The condition and response of the parking brake system should be checked on the triple gauge at every ON or OFF selection (FCOM 3.02.25)

  The parking brake should be selected OFF in case of loss of efficiency in order to recover normal braking system (FCOM 3.02.25)

  When arriving at the gate [stand] with Yellow hydraulic system inoperative, use of chocks should be anticipated and demanded prior to release of normal braking system (FCOM 3.02.29)'

Airbus informed its operators of this incident at a Flight Safety Conference held on 17 October 2006.

In view of the above safety actions taken by the operator and manufacturer, it is thought not necessary to make any formal Safety Recommendations.

Footnote

[3] Although the manufacturer originally made the recommendation to embody to SB 32-1201 (up to a/c MSN 1380) in May 2001, and this was mandated by EASA (to be accomplished by 31 March 2009), they have re-iterated it following this incident.

INCIDENT

Aircraft Type and Registration:	Avro 146-RJ100, G-CFAE
No & Type of Engines:	4 Lycoming LF507-1F turbofan engines
Year of Manufacture:	2001
Date & Time (UTC):	11 January 2006 at 0830 hrs
Location:	Edinburgh
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 98
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nil
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	7,300 hours (of which 65 were on type) Last 90 days - 65 hours Last 28 days - 30 hours
Information Source:	AAIB Field Investigation

Synopsis

Prior to starting the second engine on an aircraft with an unserviceable Auxiliary Power Unit (APU), the engine rpm was not increased on the operating engine, as required. Once the start was initiated, the increased load on the operating generator resulted in the operating engine going into a sub-idle condition. The engine was then over-fuelled and the result was a jet-pipe fire, which was reported to the flight crew by a ground handler. The operating generator also went off-line, leaving the battery as the sole source of electrical power for the aircraft. The cabin crew could not establish communications with the flight crew, who were completing the engine fire drill, and were unable to open the locked cockpit door. With visual indications of an engine fire, the cabin crew initiated an emergency evacuation of the passengers.

The incident was initiated when the procedure for engine start, with the APU not available, was not followed. The investigation revealed a lack of knowledge of the communications system under degraded electrical power. The locked cockpit door contributed to a lack of effective liaison between the flight and cabin crew. Shortly after the incident, the operating company reviewed the procedure for starting the engines stand whenever the APU or its generator was unserviceable. The company also conducted a review of the communications information within the company manuals and the information provided during training. The investigation also highlighted the importance of critically reviewing the effects of security requirements on aircraft safety.

Sequence of events

The crew, comprising two pilots and three cabin attendants, prepared the aircraft for a scheduled departure at 0800 hrs for a flight from Edinburgh Airport to London (City) Airport; the aircraft was parked on Stand 22. The commander had noted from the Technical Log that the APU was unserviceable and that there was a minor problem with one row of passenger seats; he briefed the purser accordingly.

With an external power unit connected, and communications established with the ground handler, the crew obtained clearance from ATC to start No 4 engine and then to pushback off stand. The subsequent start was uneventful and, after selecting No 4 generator 'ON', the ground handler was cleared to disconnect the external power unit. The push back was normal and the aircraft was stopped abeam Stand 23 on a heading of approximately 300º; the surface wind was 240º/17 kt. After the tug was disconnected and clear of the aircraft, the commander was cleared by the ground handler to start engines Nos 3, 2 &1 in turn. The commander initiated the start sequence for No 3 engine but, just after pushing the start button, he realised that he had not increased the rpm for the high-pressure compressor (N2), of the No 4 engine, to 65% as required. Almost immediately, the cockpit lights dimmed and the ground handler called that there was a fire on No 4 engine. Neither pilot could see the No 4 engine from the cockpit. The commander could not later recall if he had actually selected the No 3 fuel lever to 'ON' but was certain that it was now 'OFF' and he also switched the starter master switch to 'OFF'. With another more urgent call from the ground handler that No 4 engine was on fire, the commander selected the No 4 fuel selector to 'OFF' and reached for the No 4 fire handle. However, the first officer already had his hand on it and the commander instructed him to pull the handle and fire both extinguishers. The commander then transmitted a 'MAYDAY' call to ATC, which was immediately acknowledged. There had been no cockpit indications of an engine fire. About this time, the commander saw the 'DOOR' warning light illuminate and heard shouts from the cabin to the effect of "get out". He was aware that the aircraft was now only on battery power and he made no attempt to transmit on the Public Address (PA) system or to call the cabin staff on interphone. The commander manually unlocked the cockpit door, and shortly after the purser entered the flight deck to confirm that the pilots were alright and to tell the commander that all the passengers were now off the aircraft.

Within the cabin, the pre-flight checks had indicated that the 'PA' and interphone systems were fully serviceable. Whilst the engines were being started, the three cabin attendants (CA) had been positioned for the emergency equipment demonstration; the purser was at the front of the cabin, CA No 3 was abeam seat row 6 and CA No 2 was abeam seat row 12; all three were facing to the rear. The demonstration was based on an automatic pre-recording system with the cabin attendants demonstrating the use of the equipment. At about the time that the briefing was covering the donning of life jackets, the attendants were aware of the electrical power going off and the emergency lights illuminating. After about five seconds, the power came back but only for about one second before going off again. The purser attempted to contact the commander by using the interphone but the system seemed to have no power. He then tried to open the cockpit door but was unable to do so. As he then turned back towards the cabin, he saw CA No 3 approaching with some passengers behind, saying that there was a fire and that they had to evacuate.

CA No 3 had noticed a flashing light to his left shortly after the second power failure and was then aware of a passenger to his left with a "horrified look" on his face. The attendant looked out of the right side of the aircraft and saw a flame stretching about 6 ft from the rear of an engine. The flame appeared to be constant and he watched it for about 1½ seconds before turning and moving towards the front of the cabin. As he did so, he was aware of the sounds of passengers releasing their seat belts. When he reached the purser, he reported that there was a fire on the right side of the aircraft and that they needed to evacuate.

The purser again tried to contact the commander by interphone but there was still no indication of power. He then tried to select 'PA' but, with no light indication on the panel or handset, did not attempt to speak on the system. He then decided to evacuate the aircraft and having checked that the exterior of the left front cabin door appeared clear, he opened that door. The slide operated normally and the purser moved to open the front right door but was reminded by CA No 3 that there was a fire on that side. Both cabin attendants stayed in position and commenced passenger evacuation by the front left slide only. As they were doing so, the purser attempted to contact the rear of the aircraft cabin, using the interphone, but again there was no indication of power. He also considered using one of the two loudhailers, located in the forward overhead lockers, to communicate with the rear of the cabin but concluded that this was unnecessary as the evacuation was proceeding in an efficient manner.

Towards the rear of the aircraft, CA No 2 had moved to her station at the rear to use the communication system as she became aware of passengers getting up and moving forward. She selected both interphone and PA system but could see no indication of any power. Turning back towards the front of the cabin, she then followed the passengers forward, checking as she did so that each row was clear. Initially, she thought that it was a 'Precautionary Rapid Disembarkation' (using the normal exits) but, as she approached the front she became aware that it was an 'Emergency Evacuation'.

Many of the passengers were also unaware that an emergency evacuation was in progress until they had reached the front of the cabin. Then, when they reached the ground, they moved away from the aircraft but were conscious that there was no-one to direct them where to go. By the time that the three cabin attendants had left the aircraft, which was immediately after the final passenger, the purser could see buses approaching and the passengers were directed towards them.

Within the cockpit, the commander confirmed that the AFRS was on its way and then he and the first officer confirmed that the aircraft was empty before leaving it. By the time they had reached the ground, the AFRS was in attendance.

Operational information

Flight crew procedures

Engine start procedures, with no APU available, were detailed in the company Operations Manual and required that all engines should be started on stand using an external AC power supply or that No 4 engine should be started on stand and then the other engines started after pushback. The latter method was the preferred option. If this method was used, the start master switch should be selected 'OFF' after No 4 engine start in order to allow the generator to be brought on line before reselecting start master to 'ON'. Prior to starting the other engines, the APU generator should be selected 'OFF' and No 4 engine N2 selected to 65% until the other engines have started.

Locked cockpit door policy

JAR-OPS 1.1255(c)(1) requires that the cockpit door of aircraft such as G-CFAE:

> *'shall be closed prior to engine start for take-off and will be locked when required by security procedures or the Commander until after engine shut down after landing, except for authorised persons to access or egress in compliance with National Aviation Security Programme.'*

The company Operations Manual required the flight crew to confirm that the flight deck door was secured in accordance with Department for Transport aviation security regulations.

Cabin crew procedures

The Cabin Crew SEP Operations Manual contained the following information relating to evacuation initiation:

> *'Any unusual or abnormal occurrence, either visual, e.g. refuelling truck fire, cabin fire, engine fire, smoke in the cabin, etc, or audible, e.g., noise, vibrations, etc, on any part of the aircraft, internal or external, must be reported to the Captain. However should a Crew Member become aware of a situation which is clearly catastrophic they should initiate an evacuation. He/She shall alert all Crew Members by verbal communication, passenger address, interphone or loud hailer and immediately proceed with an evacuation as soon as the aircraft has stopped.'*
>
> *'The good judgement of cabin crew is imperative in order to evaluate the situation before initiating an evacuation.'*

> ***'Unless there is immediate danger Cabin Crew should wait 15 seconds.*** *This period of time allows the Flight Crew to perform shut down checks and establish whether an evacuation is required. If no flight deck command is received after 15 seconds the SCCM (Purser) should investigate by either calling on the interphone or visiting the flight deck.'*
>
> *'Emergency conditions, which would require Cabin Crew to initiate evacuation, include:*
>
> 1. *A self-sustaining aircraft fire*
> 2. *Dense smoke in the cabin*
> 3. *An extreme and unusual aircraft attitude*
> 4. *Any time the passengers are in immediate danger*
> 5. *Unusual sounds prior to stopping (loud scraping or tearing of the aircraft structure)'*

At the time of the incident, there was no information in the Cabin Crew SEP Operations Manual relating to the aircraft internal communications system under degraded electrical conditions. Furthermore, many personnel, including the crew of G-CFAE and some of the company training personnel, were not fully aware of the capabilities of the communication system under these conditions.

Recorded information

Cockpit voice recorder

The solid state cockpit voice recorder (CVR) provided 30 minutes of high quality four-channel recording and two hours of mixed channel recording. On this aircraft, the CVR records when power is available on the aircraft and the avionic master switch is on. The high quality recording covered the five and a half minute period between the activation of the avionic master switch and the incident. From the recordings, it was evident that before the incident there were good communication channels in the cockpit, between the cockpit and the ground engineer, between the aircraft and ground control and between the cockpit and the cabin.

Initially, ground power was supplied to the aircraft because the APU was inoperative. Permission was granted to start engine No 4 on the stand, push the aircraft back, and then start up the remaining engines using a 'cross start' from engine No 4. The crew followed the engine start checklist and the aircraft was then pushed back. When the pushback had been completed the crew discussed the appropriate N2 setting for an engine being used to start another engine; the value of 65% N2 was agreed. They had a further conversation regarding a takeoff performance calculation. The start of engine No 3 was initiated immediately afterwards; power to the CVR was then lost.

Flight data recorder

The flight data recorder (FDR) was successfully downloaded. The FDR recording of parameters on this type of aircraft is only enabled when the low-pressure compressor speed (N1) from any engine reaches 20%. The recording in this case started only once engine No 4 had started and lasted for just over three and a half minutes. The parameters of interest were engine related. Unfortunately, the useful parameters in this case were limited to N1 values and the Thrust Lever Angles (TLAs). Play in the mechanism used to measure the TLAs meant that the accuracy of these parameters was limited to ±6º.

The relevant recording started at 0807 hrs, with the N1 for engine No 4 reading 26%, the remaining N1s read between 1% and 2%, indicating no power. At this time, the TLA for engine No 4 was at 16° with the other TLAs reading 0º. During the next 40 seconds, the N1 for engine No 4 fluctuated between 24% and 27% and then settled to approximately 26% for a little under three minutes. The Operations Manual stated that, after engine start, the expected stable N1 and N2 values should be 25% and 50% respectively. Given the recorded N1 value, it is considered reasonable to assume that the N2 during this period was in the region of 50%.

Figure 1 shows the FDR recording just prior to the loss of power. The TLA for engine No 4 did not change until after the N1 for engine No 4 started dropping. The FDR recording stopped for less than a second and then restarted briefly, operating for approximately three further seconds before it stopped again.

Within the limitations of data being recorded only once every second, there is no indication that the N1 of engine No 4 was increased above the idle state. Therefore, it is reasonable to conclude that the N2 of engine No 4 was below the required value of 65% when the start of engine No 3 was attempted.

Throughout the recording, the engine control systems were active and not indicating any faults. No indications of fire or overheat were recorded.

ATC recording

A recording was available of Edinburgh Ground radio transmissions on frequency 121.725 MHz. This confirmed that the crew contacted Edinburgh Ground at 0806 hrs to request clearance for a push and start and for clearance to start one engine on stand. ATC approved this request and the next transmission was at 0812.40 hrs when the commander declared a 'MAYDAY' and reported that they had a fire on No 4 engine and that they were evacuating the aircraft.

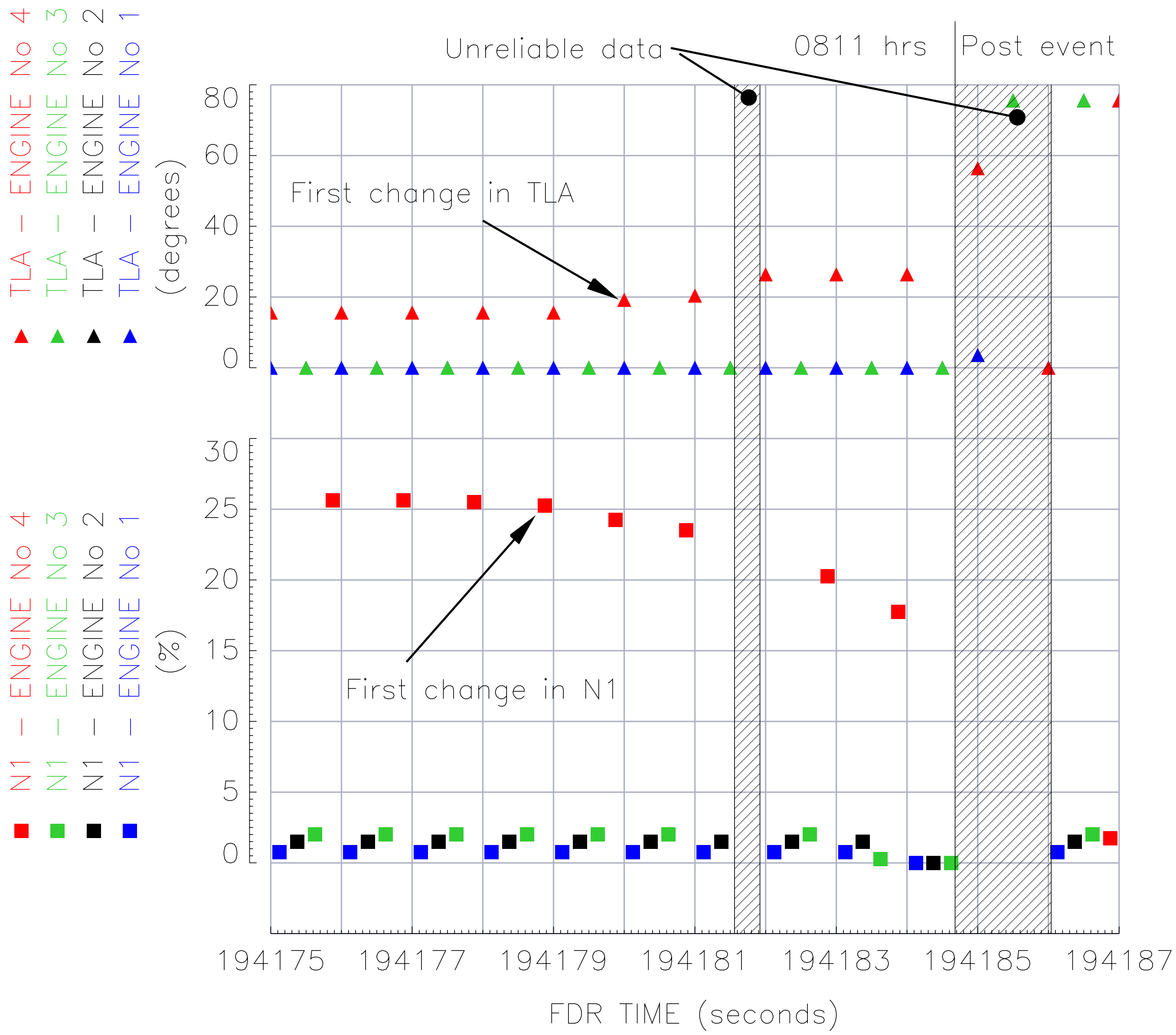


Figure 1

FDR recorded N1 and TLA parameters. Note that TLA No 2 is hidden behind TLA No 3

Then, at 0814.27 hrs, the commander made a further transmission asking ATC to confirm that the AFRS were on the way; this was confirmed by ATC. At 0816, the AFRS asked ATC to relay a request for the crew to contact them on frequency 121.6 MHz but there was no response as the crew had already left the cockpit.

Aircraft information

Electrical generation and engine starting

The aircraft was equipped with four Honeywell LF507-1F turbofan engines and a Sundstrand APU. All of the main engines are fitted with electric starter motors. The two outboard engines (Nos 1 & 4) and the APU are each equipped with an AC generator to supply the aircraft's electrical requirements.

In normal operations, the APU provides the electrical supply to start the main engines. In the event that the APU is inoperative, all of the main engines can be started from a ground electrical power supply, or an outboard engine can be started from the ground power supply and the remaining engines started using a 'cross start' from the operating engine. During a 'cross start' the operating engine provides all of the aircraft's AC electrical power requirements.

The procedure for carrying out a 'cross start' requires the engine providing the electrical supply to be accelerated from idle to 65% N2 speed prior to initiating the starting procedure. This prevents the operating engine being 'dragged' into a sub-idle condition as the load on the generator increases. In that condition, the air flow though the engine would be reduced, resulting in over-fuelling of the engine. Unburnt fuel could then pass out of the combustion chamber and ignite within the engine's turbine resulting in a plume of flame from the exhaust nozzle. At the same time, the increased load on the generator would result in the generator tripping off-line.

Engine examination

Analysis of the aircraft's engine health monitoring system confirmed that the No 4 engine started normally and reached a stabilised ground-idle condition. FDR data confirmed that the engine remained at this speed until the initiation of the No 3 engine start. Immediately after the initiation of the start procedure, the FDR data showed that the engine's N1 speed began to decrease below the normal ground idle level. The forward movement of the No 4 engine thrust lever recorded on the FDR as the N1 speed decreased would have increased the amount of fuel being supplied to the engine. This would have resulted in a corresponding increase in the size of the exhaust flame.

An inspection of the engine immediately after the event confirmed no signs of external fire or damage. Additionally, no fault codes were identified during the download of the engine Full Authority Digital Engine Control memory. After replacement of the fire bottles, a series of engine starts were carried out. No problems were observed during the start of the No 4 engine or the subsequent 'cross starts' of the remaining engines.

Internal communications

The aircraft was fitted with an interphone system that allowed communication between the forward and rear cabin crew stations and the flight deck. A PA facility was also integrated within the communications system to allow broadcasts to be made from any station to the aircraft cabin. Both the forward and rear cabin crew stations were equipped with a handset with an integral push button selector panel and a 'press to talk' button for use during PA broadcasts.

Normal operation

With AC electrical power available, when a cabin crew handset is lifted from its cradle, the integral push button selector panel is illuminated. Pressing a button selects the appropriate mode of operation, and allows the crew station to communicate with the other station and with the cockpit. Each cabin crew station can also operate the PA system by pressing the 'PA' button and then using the 'press to talk' switch when speaking. The flight crew can communicate with the cabin crew on interphone and can broadcast on PA. The system produces an audible chime to alert the cabin crew and flight deck when someone wishes to communicate with them.

Operation on battery power

When operating on battery power, the functions of the internal communication system are severely restricted. The push button selector panel in the cabin crew handsets are no longer illuminated and the push button functions are disabled. However, if the 'push to talk' button is depressed, a PA broadcast can still be made throughout the aircraft cabin. The flight crew also retain the ability to broadcast a PA message from the cockpit and can also speak to either the headset operative or the cabin crew using the interphone. However, the system does not produce an alert 'chime' to indicate that the flight crew wish to communicate, and in the event that a handset is picked up whilst the flight deck are attempting to contact the cabin crew, the limited functionality of the system means that the flight crew are unable to hear any response.

Tests were carried out on several aircraft, which confirmed that the function of G-CFAE's interphone and PA on battery power was 'normal' for a BAe RJ100. The system was compliant with the current EASA certification requirements, CS 25.1423.

Cockpit door

G-CFAE was fitted with a ballistically reinforced cockpit door. When locked, there was no means of opening the door from the passenger cabin. The door can be unlocked from the cockpit either by manually releasing it, which would normally involve a crew member leaving their seat, or through the use of a remote electrically operated release switch at the rear of the centre instrument pedestal. Power for the remote cockpit door release is provided by the aircraft's AC electrical power supply and the loss of AC power renders the remote door release system inoperative.

Neither the operators Minimum Equipment List nor the manufacturers Master Minimum Equipment List allow the aircraft to be dispatched with the remote door release switch inoperative.

Analysis

Flight crew actions

The initial start of No 4 engine was normal but the crew did not then follow the required procedure of increasing the engine N2 to 65% prior to starting the next engine. An engine start with no APU available is not an unusual event and both crew members had previously experienced this procedure. It may be relevant that the crew had become aware of the need to review their takeoff performance calculations just after the discussion about the starting procedure. Nevertheless, such a distraction is not an unusual occurrence on an aircraft and pilots should be aware of the vital importance of systematic checks prior to initiating an action such as an engine start.

The consequences of the incorrect procedure were a loss of normal electrical power and a flame from the exhaust nozzle of No 4 engine. The flight crew were aware of the electrical power degradation and were twice advised by the ground handler that there was a fire on No 4 engine. Although the crew could not see the affected engine and had no cockpit indications of a fire they acted in accordance with their procedures to complete the appropriate drill, relying upon the information provided by the ground handler. Having completed the appropriate actions they then advised ATC of the engine fire. Thereafter, they would normally have initiated liaison with the cabin attendants, but by then the evacuation was underway.

Following this incident, the operating company changed the starting procedures, with effect from 23 March 2006, to require that, with an unserviceable APU or APU generator, all engines should be started on stand. This directive remained in place until the company had changed the flight deck copy of the working checklist to include the procedure for cross-bleed starts.

Cabin attendant actions

The purser was aware that the APU was unserviceable, but that this involved no safety-related implications. With the No 4 engine started on stand, the cabin attendants commenced the normal passenger briefing during the pushback. During engine starts, it was not unusual to experience electrical power interruptions and none of the attendants were alarmed by the initial loss of electrical power. However, the second and permanent loss of AC electrical power affected the actions of all three cabin attendants. CA No 3, positioned near the centre of the cabin was alerted to an apparent engine fire by the actions of a passenger. When he saw the extent of the flames, which he had never seen before during his flying career, he immediately moved towards the purser to report the situation. His view was that the situation was critical and that an evacuation was required. This view may have been reinforced by the sound of passengers undoing their seat belts and following him. Meanwhile, the purser had tried to contact the flight crew by interphone and then by opening the cockpit door. However, in the extant electrical condition of the aircraft the interphone was severely restricted and the cockpit door could only be opened manually from inside the cockpit. Once CA No 3 had reported the fire, and expressed his view that an evacuation was required, and with no apparent means of contacting the flight crew, the purser had to make the decision to evacuate or not. In a situation where the aircraft was off stand and reportedly on fire, the only practical solution was to commence an evacuation. After checking that the left side of the aircraft was clear of obstacles and with the fire on a right engine, it was sensible to utilise only the left emergency exit at the front of the aircraft. The evacuation appeared to the two attendants to be progressing effectively and the purser considered that the use of the loud hailer was unnecessary. This decision left some passengers and CA No 2, positioned at the rear of the cabin, unaware that an emergency evacuation was taking place. The use of the PA to announce the evacuation was possible but, with no power indication on the handsets, none of the cabin attendants thought that it was operable. Nevertheless, the evacuation proceeded effectively and the passenger cabin was checked to be clear before the cabin crew left the aircraft. Prior to the cabin crew leaving the aircraft, the purser had reported the passenger evacuation to the commander, since the cockpit door had now been opened by one of the pilots.

Following this incident, the operating company changed the procedures for cabin attendants, with effect from 7 March 2006, to require that the safety demonstration would not commence until after the aircraft moved under its own power. In addition, following representations from the company, the Department for Transport issued an aircraft type variation adjusting aviation security measures in respect of locking the flight deck door.

Post evacuation

Once outside the aircraft, there was some confusion amongst the passengers who were not sure what to do. The situation was resolved once the cabin crew had joined them and transportation arrived. While accepting the difficulties of planning for every eventuality, such as an evacuation from an aircraft on the ground whilst not on a stand, there should be some form of guidance. Complications include the facts that the prime responsibility of the cabin crew is to ensure that all the passengers leave the aircraft and that personnel first on the scene, such as the AFRS, normally have other priorities. Nevertheless, following an incident to a Boeing 777, registration AP-BGL on 1 March 2005, the AAIB made a Safety Recommendation (2005-131) to the CAA to review the advice given in CAP 168 relating to the evacuation of passengers away from the scene of an incident. The CAA accepted this recommendation and amended CAP 168 in May 2006 to include the following wording to highlight the need for effective passenger handling immediately after evacuation.

> *'The Aerodrome Emergency Plan shall include procedures for leading passengers, evacuated from aircraft, to secure areas away from the scene of an incident, and shall ensure that the relevant Aerodrome Emergency Orders suitably address this topic'.*

The CAA has also confirmed that during their routine audits, the Aerodromes Standard Department will ensure that an airport's Emergency Plan addresses this issue.

Communications

While the incident was initiated by the flight crew not following the correct procedures for engine starting, the subsequent evacuation resulted from a lack of communication between the flight and cabin crew. A jet pipe fire can be very alarming, particularly to the occupants of the affected aircraft, and the resultant desire to leave the aircraft can be very strong. Therefore, the commander would need to take an early decision not to evacuate and to communicate this clearly to the cabin occupants. In this incident, the only indication to the flight crew of a serious problem was when they were advised by the ground handler that there was an engine fire. The first priority for the flight crew was then to complete the appropriate actions to contain the fire. However, during this time the purser was unable to establish communications with the commander or to enter the cockpit. While accepting that evacuation may still have been the best option, the lack of effective communications resulted in the flight and cabin crew operating in isolation from each other and, within the cabin there was a further breakdown in communication, effectively isolating the CA No 2 and a number of passengers at the rear of the aircraft. This lack of effective communication resulted from a combination of insufficient knowledge of how the internal communications worked on degraded electrical power and the locked cockpit door.

The current regulations required that the cockpit door be locked before engine start. While this was based on security considerations, there was a need to critically review the consequences of this policy to ensure that appropriate safety considerations were taken into account. Since there was no means of opening the door from the cabin, a full understanding of the capabilities of the communications system was essential. With the lack of information in the Operations Manual, it was not surprising that the cabin attendants were not fully prepared for the situation in which they found themselves. Early in this investigation the operating company was alerted to the correct operating conditions of the internal communications system and has now reviewed and expanded the information available to their flight and cabin crew and included these aspects in the initial and recurrent training of their crews.

Conclusion

The incident was initiated by the flight crew not following the correct procedure for engine start with the APU not available. However, the subsequent loss of normal electrical power resulted in no effective liaison between the flight and cabin crew. The investigation revealed a lack of knowledge regarding the communications system in degraded electrical conditions, which the company has taken action to rectify. The communication difficulties were compounded by the cockpit door being locked, with no means of operating it from the cabin. The situation required the flight crew to unlock the door or for the cabin and flight crews to establish communications. With the flight crew dealing with the reported engine fire, unlocking of the door was not their first priority. With no communication between the flight and cabin crew, the purser made the correct decision to evacuate the aircraft.

The investigation has highlighted the essential need for any new procedure, such as locking the cockpit door, to be properly evaluated to ensure that security requirements do not have an unduly adverse effect on safety aspects.

INCIDENT

Aircraft Type and Registration:	Boeing 737-36Q, G-THOJ
No & type of Engines:	2 CFM 56-3C1 turbofan engines
Year of Manufacture:	1997
Date & Time (UTC):	13 August 2006 at 1640 hrs
Location:	In the cruise at FL350 from Cardiff to Malaga
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 145
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	6,053 hours (of which 1,076 were on type) Last 90 days - 188 hours Last 28 days - 82 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent inquiries by the AAIB

Synopsis

On 11 August, the aircraft suffered an in-flight failure of the DC Battery Bus, resulting in the loss of several aircraft systems including the standby ADI. Subsequent examination identified no defects with the aircraft but, during a flight to Malaga on the 13 August, the DC Battery Bus failed again. Despite further investigation, no defects were identified and the aircraft departed on the return flight. Whilst taxiing, the aircraft suffered a third failure and, after returning to the stand, it was confirmed that the R1 relay had failed. A previous AAIB investigation into a similar incident (G-EZYN, AAIB Bulletin 4/2006) resulted in the publication of AAIB Safety Recommendation 2005-65, which is directly relevant to the failure experienced by G-THOJ. Therefore no further safety recommendations are made.

History of the flight

On the 11 August, the aircraft was at FL340 en-route Malaga to Cardiff when the flight crew noticed a yellow '*SPD LIMIT'* caution on both EADIs[1]. On checking the overhead panel, the flight crew found the following captions illuminated; '*SPEED TRIM FAIL*' '*MACH TRIM FAIL*' and '*AUTO SLAT FAIL*'. In addition, the engine N1 and fuel flow indications were lost, the standby ADI, both clocks and the master caution panel (MCP) failed, the DC Battery Bus showed zero voltage and both EADIs had become monochromatic. Although the 'equipment cooling supply' OFF light was not illuminated, the crew recognised the monochromatic EADI displays as indicating a loss of their cooling air

Footnote

[1] Electronic Attitude Direction Indicators.

flow. The cooling fan power supply was switched to 'ALTERNATE', which restored the displays to normal operation. After reviewing the status of the remaining systems, the flight crew confirmed that there had been no degradation to the aircraft's approach and landing capabilities and elected to continue to Cardiff. Due to the aircraft's interphone becoming inoperative, the flight crew briefed the senior cabin crew member directly and further communications were relayed through another member of the cabin crew. As the landing gear was deployed during the approach to Cardiff, all of the aircraft's systems previously lost were restored and the aircraft carried out an uneventful landing. Subsequent inspection and testing of the aircraft's systems, however, failed to identify any defects and the aircraft was returned to service.

On 13 August, the aircraft was at FL350, flying from Cardiff to Malaga when a 'click' was heard from the P6 circuit breaker panel in the cockpit and the DC Battery Bus failed. This produced the same symptoms and loss of systems as in the event of 11 August. The flight crew referred to the QRH[2] but later reported that it was of limited use in isolating the failure and restoring systems. After establishing an HF[3] link with their engineering department, the crew were able to restore some systems and the aircraft continued to its destination without further incident.

Investigation

After landing, a company engineer inspected the R1 relay, the suspected cause of the DC Battery Bus failure, and found it to be apparently serviceable. The engineer completed the Technical Log and the aircraft was dispatched for its return flight. However, whilst taxiing, the aircraft once again suffered a failure of the DC Battery Bus and returned to the stand. A replacement R1 relay was dispatched from the UK and, after installation and appropriate satisfactory system checks, the aircraft was returned to service, with no further problems being reported.

The EADIs are designed to operate without cooling for a minimum of 90 minutes. However, should an overheat condition be detected, the displays will shut down immediately, leaving the flight crew with the Standby Attitude Indicator (SAI) as the sole source of attitude information. In selecting the alternate power supply for the cooling fans, the flight crew restored the cooling airflow, thereby preventing the EADI symbol generators from overheating.

In the event of the loss of the DC Battery Bus, the B737-300/400/500 series does not produce a discrete warning to alert flight crews. Failure of this Bus results in the loss of several aircraft systems, but should not prevent the aircraft from continuing to operate safely. However, in addition to the loss of normal power to the equipment cooling fans, power to the equipment cooling air low-flow sensors is also lost. This prevents the equipment cooling OFF light illuminating, which would normally alert the flight crew to the need of selecting the alternate cooling fan power supply. The loss of cooling air results in a build up of heat within the EADI symbol generators, which then automatically switch to a monochromatic mode to reduce heat generation.

The SAI fitted to G-THOJ was powered by the DC Battery Bus and, when the relay failed, power to the SAI was lost, although there was a delay between the loss of power and the toppling of the SAI gyroscope. Had the flight crew failed to recognise the monochromatic EADI displays as symptomatic of a loss of equipment cooling

Footnote

2 Quick Reference Handbook.
3 High Frequency radio link.

air it was possible that they would have eventually lost all attitude information.

Information from the manufacturer confirmed that there are approximately 1,400 B737-300/400/500 aircraft currently fitted with SAIs powered by the DC Battery Bus.

Defect history

On 20 July 1997, a similar incident occurred to a B737-500, EI-CDT, which was investigated by the Danish Air Accident Investigation Board. Their report made two Safety Recommendations, which resulted in the publication by the manufacturer of Flight Operations Technical Bulletin 737-300/400/500 98-1, concerning 'Battery Bus Failure'. This provided advice for operators on how to construct a non-normal procedure for a R1 relay failure, taking into account the specific electrical configuration of their own aircraft. Also, a manufacturer's Service Letter, No 737-SL-24-120, was issued which identified relays with specific part numbers that were recommended for installation in the 'R1' position, in order to improve reliability of the system. However, the R1 relay that failed on G-THOJ was one of the 'recommended' types. It was not established from the aircraft's maintenance records how long the relay had been fitted to the aircraft.

The relay used in the R1 position is an electro-mechanical device which, despite improvements over the years to increase their reliability, suffer occasional mechanical failure. Such failures may not be straightforward; the restoration of electrical systems following landing gear deployment in the first event and after the flight crew's actions on the subsequent flight, may have been a coincidence, but illustrate the intermittent nature of the defect prior to the complete failure of the R1 relay.

On 22 March 2005, B737-300 G-EZYN suffered a similar failure of the R1 relay and this incident was investigated by the AAIB (Bulletin 4/2006). As a result the manufacturer issued Alert Service Bulletin 737-21A1156 in June 2006. This Service Bulletin provides instructions for a modification to separate the normal power supply to the equipment cooling fans from that for the equipment bay low air flow sensor, for those aircraft with a SAI powered from the DC Battery Bus. After embodiment, the low flow sensors would remain powered after a DC Battery Bus failure. This ensures that the equipment cooling OFF light illuminates, thus giving the flight crew a positive indication of the loss of equipment cooling air flow and, possibly, failure of the DC Battery Bus.

The AAIB investigation into the G-EZYN incident resulted in the following Safety Recommendation:

'Safety Recommendation No 2005-65

It is recommended that the Federal Aviation Administration require that the Boeing Airplane Company examine the various electrical configurations of in-service Boeing 737 aircraft with the intention of providing operators with an Operations Manual Procedure that deals with loss of power from the Battery Busbar'

Conclusions

Following the issue of this safety recommendation, the manufacturer has taken the view that as there are a relatively high number of different electrical system configurations on affected aircraft, it is not practical to develop a procedure to cover all such aircraft. The Flight Operations Technical Bulletin 737-300/400/500 98-1, concerning 'Battery Bus Failure', already provides advice for operators on how to construct a non-normal procedure for a R1 relay failure, taking into account the specific electrical configuration of their own aircraft. This, in conjunction with the release of Alert Service Bulletin 737-21A1156, which ensures that the crew are alerted to a failure of EFIS cooling airflow and the possibility of a DC Battery Bus failure, would appear to address the potential problem of loss of all attitude information following a R1 relay failure. Therefore, no further safety recommendations are made.

ACCIDENT

Aircraft Type and Registration:	Boeing 737-45D, SP-LLB
No & Type of Engines:	2 CFM56-3C1 turbofan engines
Year of Manufacture:	1993
Date & Time (UTC):	20 February 2006 at 1140 hrs
Location:	Stand 114, London Heathrow Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 89
Injuries:	Crew - None Passengers - None
Nature of Damage:	Wing tip light and some structural damage to wing tip
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	11,725 hours (of which 7,680 were on type) Last 90 days - 160 hours Last 28 days - 65 hours
Information Source:	AAIB Field Investigation

Synopsis

While taxiing onto its assigned parking stand, the aircraft struck a vehicle which was parked in a prohibited area. The member of ground staff whose responsibility it was to ensure that the stand was unobstructed was unable to see the whole stand from his assigned position in the jetty. Members of ground staff who saw the potential conflict were unable to alert the pilots. Three Safety Recommendations were made.

History of the flight (flight crew perspective)

The aircraft departed Warsaw, Poland at 0758 hrs on the first leg of a scheduled service to London Heathrow Airport and return. The departure had been delayed by approximately two hours due to snow clearance, but the commander and co-pilot considered themselves well rested, having started their duty at 0545 hrs after a preceding rest period of 15 hours and 48 hours respectively. After landing at Heathrow Airport at 1130 hrs, the aircraft proceeded as instructed to Stand 114 at the head of the Kilo cul-de-sac of Terminal 1 (shown in Figure 1). As the aircraft approached the stand the co-pilot noted that a van was parked on the right side of the stand, in an area marked with painted 'hatched' lines, but did not consider that it would present a hazard to the aircraft. The commander stated that he was aware of the confined nature of the stand and that this may have caused him to commence his turn onto the stand earlier than indicated by the yellow lead-in line painted on the taxiway adjacent to the stand. As a result, the aircraft did not gain the centreline before it crossed the stand threshold. Shortly afterwards, before the aircraft had reached the normal stopping position adjacent to the stand's manoeuvrable jetty, its right wingtip hit the van, causing damage to wing tip fairings and the rear of the van. The commander, who was aware of the impact, shut down the aircraft and ordered a normal disembarkation using mobile steps.

History of the flight (ground crew perspective)

A dispatcher, employed by another airline on behalf of the aircraft operator, arrived at Stand 114 shortly before the aircraft. In accordance with his duties, he checked that the stand area was clear of obstructions before activating the stand guidance system. Having done so, he climbed a set of external steps to the head of the jetty (known as the cab) and positioned himself at the controls in order to manoeuvre the jetty when the aircraft arrived. As he did so, he noticed that a vehicle had moved onto the right hand side of the stand. When the aircraft entered the stand he was no longer able to see the parked position of the van from his viewpoint in the jetty. He noted, however, that several employees of the handling agent, whose vehicles and equipment were parked in the non-hatched area to the right of the stand, appeared to have seen the aircraft approaching and were attempting to signal it to stop by crossing their arms above their heads. He discovered later that they had been unsuccessful.

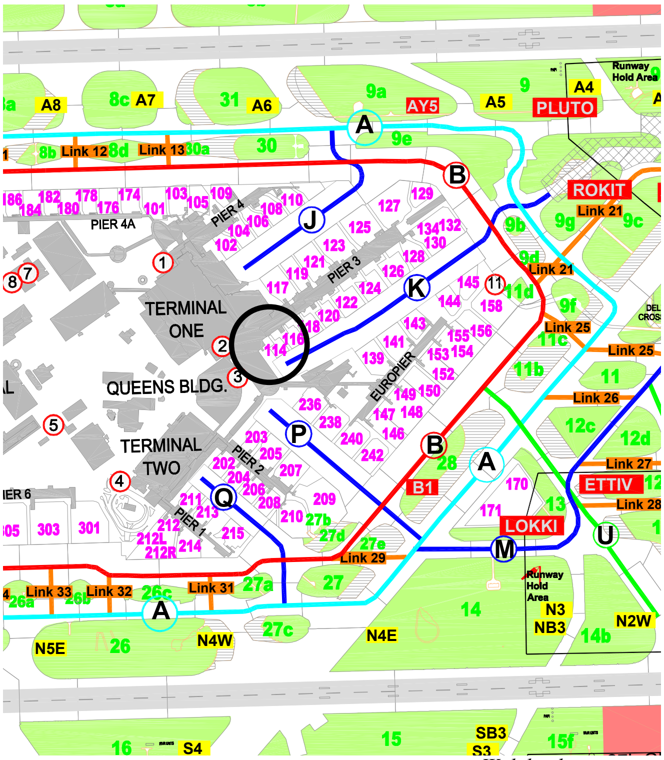
The driver of the van, a ramp agent, was employed by the handling agent assigned by the aircraft operator to assist the loading and servicing of its aircraft at London Heathrow Airport. He drove onto the stand from an airside road adjacent to the terminal and intended to park on the right side of the stand, facing away from the approaching aircraft. As he did so he saw that other employees of the handling agent were attempting to manoeuvre baggage trolleys into the same area and decided to reverse temporarily into the hatched area of the interstand clearway in order not to obstruct them. He kept the engine of the van running and, aware that the aircraft was approaching, intended to return to the non-hatched area as soon as the baggage trolleys were in place. He was unable to do so before the aircraft hit the van.

Stand characteristics

Stand 114 is located at the end of a cul-de-sac, between Pier 3 and the 'Europier' of Terminal 1 (Figure 1). To its left is a baggage storage area adjacent to a part of the terminal building which forms the cul-de-sac, and to its right is another stand of similar dimensions. Due to the confined nature of its location it is restricted to the operation of Boeing 737 or smaller aircraft. A yellow lead-in line, painted on the taxiway leading to the stand, is intended to indicate to pilots the safe approach course to the stand centreline. The history of successful manoeuvring on to this stand demonstrates that a safe approach will result if the nose wheel of the aircraft is steered over this lead-in line.

Guidance along the centreline of the stand is provided by an Azimuth Guidance for Nose-In Stands (AGNIS) system. The system is designed to be viewed from the left pilot's seat and displays two closely spaced vertical light bars mounted in a box, as illustrated in Figure 2. The light bars display one red bar and one green bar as illustrated in Figure 2 (i) & (iii), indicating that the pilot should steer away from the red towards the green bar, or two green bars, indicating correct alignment, as illustrated in Figure 2 (ii).

The correct stopping position is indicated by a mirror system, which is also designed to be viewed from the left pilot's seat. It consists of a mirror mounted to the left of the stand centreline facing the approaching



With kind permission from the CAA

Figure 1

Location of Stand 114 (in black circle)

aircraft and angled so that the pilot can see the reflection of the aircraft's nose wheel during the last few metres of the parking manoeuvre. The correct stopping position is indicated by a yellow line, labelled with the appropriate aircraft type, which is painted on the stand surface perpendicular to the centreline. Stand 114 had only one such line, labelled 'B737'.

An emergency stop light, located beside the AGNIS indicator, will illuminate if either of two emergency stop buttons is pressed. One button is located in the jetty cab and the other at the head of the stand, to the left of the stand centreline. Members of ground staff who were best able to see the potential conflict between the aircraft and the van were working to the right of the stand centreline.

The incident aircraft had not reached the normal stopping position, nor had it gained the stand centreline, when it struck the van. When viewed from the commander's seat in the cockpit immediately after the incident, the AGNIS indicated that the aircraft was right of the centreline.

Damage to aircraft and vehicle

The aircraft and vehicle were examined by the AAIB before being moved from the positions in which they had stopped. The right wingtip of the aircraft had struck the upper left corner of the rear of the truck, causing relatively minor damage to the vehicle but crushing the wingtip of the aircraft and destroying the navigation and strobe lights.

It was noted that the aircraft was slightly to the right of the stand centreline marking (the left nosewheel tyre was just touching the right side of the line) and that the aircraft heading was a few degrees to the left of the line, indicating that it was still in the process of turning right. As the crew reported no system or other malfunctions prior to contact with the truck, no technical examination of the aircraft was deemed necessary.

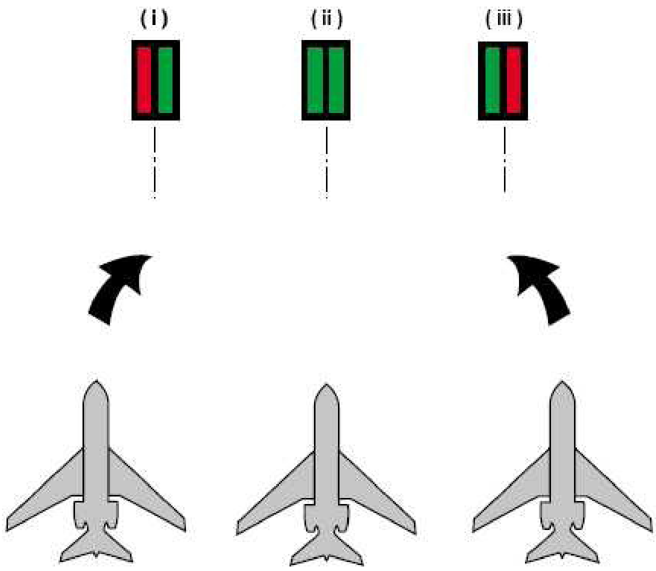


Figure 2

AGNIS

Recorded data

The Flight Data Recorder was not recovered as the investigation did not require the data. The Cockpit Voice Recorder was recovered and might have been useful but had been overwritten. Ground radar recordings were reviewed and found to be of no value to the investigation as the event occurred in a radar shadow.

Ground staff responsibilities

The *Airside Safety and Driving Code* handbook, produced by the handling agent, provides information to its employees who are required to drive airside. It states:

> *'On either side of an aircraft stand you may find an interstand road/clearway. You are not permitted to park there but you may wait provided the driver remains in the cab so as the vehicle can be driven away to prevent obstruction – caution must be observed at all times.'*

It also states

> *'Never obstruct hatched areas'.*

The van driver was aware of this information. He believed, however, that it was acceptable for him to wait in the hatched area at the end of the interstand clearway with the engine running.

CAP 637 – *Visual Aids Handbook,* published by the CAA, contains the diagram shown in Figure 3.

The *Airside Safety and Driving Code* handbook contains an almost identical diagram.

Additional information

Rule 37 (2) of the Air Navigation Order states:

> *Notwithstanding any air traffic control clearance it shall remain the duty of the commander of an aircraft to take all possible measures to ensure that his aircraft does not collide with any other aircraft or with any vehicle.*

Analysis

Stand markings

Diagrams explaining stand markings, produced in CAP 637 and the *Airside Safety and Driving Code* handbook, showed hatched areas associated with the jetty manoeuvring area only and it was not clear from these diagrams or related text that hatched areas were

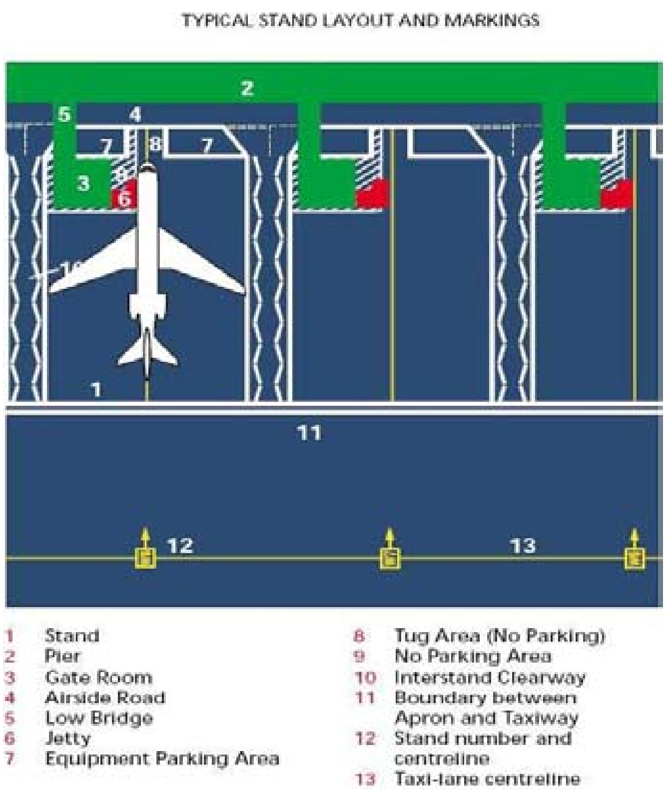


Figure 3

Typical stand layout and markings (extract from CAP 637) also to be found in the interstand clearways, as in the case of Stand 114. Consequently, it was not clear that parking might be prohibited altogether in some parts of an interstand clearway. Therefore, the following two recommendations are made.

Safety Recommendation 2006–138

It is recommended that the Civil Aviation Authority should amend CAP 637 – *Visual Aids Handbook,* to clarify those areas where parking is prohibited.

Safety Recommendation 2006–139

It is recommended that Aviance UK should amend the *Airside Safety and Driving Code* handbook to clarify those areas where parking is prohibited.

Provision and use of emergency stop signals

Conflicts between moving aircraft and obstructions on the ground can develop very quickly and it may be necessary to alert pilots at a moment's notice to avoid a collision. The emergency stop signal at the head of a stand is the recognised means of alerting pilots in such circumstances. It follows that any delay or difficulty in operating this signal will reduce the effectiveness of the signal itself.

A button for operation of the emergency stop signal was provided at ground level and in the jetty. The jetty operator was not able to see the entire stand once the aircraft entered it and so was not aware that a conflict existed. Those ground staff who were aware of the potential conflict attempted to signal the aircraft to stop using hand signals but apparently were unsuccessful. The pilots might have been alerted more effectively had one of the ground staff been near enough to an emergency stop button to press it as soon as the conflict was recognised. The following safety recommendation is therefore made:

Safety Recommendation 2006–140

It is recommended that the BAA should examine the practicability of requiring a member of the ground crew to assume the responsibility of being adjacent to the ground level emergency STOP light button, and of monitoring the arrival of the aircraft on to the stand, whenever ground crews are present on a stand whilst an aircraft is manoeuvring to park.

Conclusion

The right wingtip of the aircraft struck a van which was parked in an area of the stand which should have been free from all obstructions. The driver of the van was aware that he should not park there and had intended to move to a different position prior to the arrival of the aircraft. Congestion in the baggage handling area of the stand prevented him from doing so. The pilots were aware that the van was parked incorrectly but elected to continue onto the stand, believing that it would not be an obstacle. This would have been the case if the aircraft had been lined up on the stand centreline before entering the stand. However, the commander, aware of the confined nature of the stand, made a tighter turn onto the stand than that indicated by the lead-in line painted on the ground and remained at all times to the right of the stand centreline.

Members of ground staff who were aware of the potential conflict were not able to operate the emergency stop signal button because it was located on the other side of the stand centreline and not within immediate reach of their normal working area. From his position in the jetty cab, which was also equipped with an emergency stop button, the member of ground staff responsible for ensuring the stand was clear before the aircraft arrived was not able to see the entire stand after the aircraft entered it. He could not see the van, which had entered the stand after he completed his ground check, and consequently did not appreciate the potential conflict.

INCIDENT

Aircraft Type and Registration:	Boeing 737-528, G-GFFE
No & Type of Engines:	2 CFM56-3C1 turbofan engines
Year of Manufacture:	1995
Date & Time (UTC):	3 September 2005 at 0920 hrs
Location:	Stand 110, North Terminal, London Gatwick Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	APU failure with extensive axial ejection of turbine debris
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	Not known
Commander's Flying Experience:	18,500 hours (of which 9,400 were on type)
Information Source:	AAIB Field Investigation

Synopsis

During ground operation, the cast inflow turbine of the APU suffered a radially contained failure. This resulted in vanes separating from the casting as its two liberated halves came into rapid contact with the containment structure. The hot vane debris was ejected through the jet pipe and spread across the rear of the stand and the width of the adjacent taxiway. The failure was one of nine broadly similar events to the type of turbine wheel, each attributed to a casting defect. Efforts have been made to improve the manufacturing process, without proven success, and no reliable method has been found to detect the defect in new or existing turbines. No method of establishing a safe in-service life has been determined for this component but the hazard to airport staff remains very low.

History of the event

The aircraft was parked on Stand 110 adjacent to Pier 6 facing in a northerly direction. Immediately to the south of the stand was Taxiway K and beyond that were Stands 134 and 135 upon which aircraft are parked facing in a southerly direction. The orientation of the stands is shown in Figure 1.

G-GFFE was being refuelled and prepared for departure with the flight and cabin crew aboard. The passengers had been called for boarding but had yet to reach the aircraft. The commander instructed the co-pilot to start the APU and continue the associated checklist items. The commander then entered the cabin with the intention of carrying out the internal checks followed by the external inspection. Soon after entering the cabin, the lights

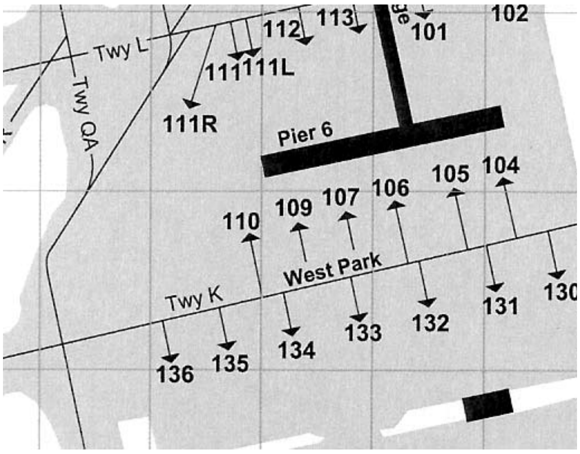


Figure 1

Orientation of Stands

extinguished so he returned to the flight-deck to be told that the APU had automatically shut down.

The flight crew then became aware of a commotion at the rear of the aircraft. On returning to the cabin the commander was informed by a cabin crew member that a sound of impact had been heard, the rear part of the aircraft had lurched, and a catering truck was presumed to have struck the fuselage. On looking out of the rear door, however, the commander observed members of the ground staff kicking bits of hot metal off the stand area and adjacent taxiway and realised that a major malfunction must have occurred to the APU. Having confirmed there was no sign of fire, the commander returned to the flight deck to supervise the co-pilot in making appropriate radio calls and completing APU failure procedures.

On completion of these activities, the commander went outside the aircraft to check the damage and to establish whether any personal injuries had occurred. None were observed or reported. Debris was observed extending over some 90 m (295 ft) aft of the aircraft, completely crossing the taxiway behind the aircraft. Larger items were collected by flight and ground crew and placed below the rear of the aircraft. A sketch diagram of the distribution of the remaining debris was made on part of a large-scale chart of the apron area before the smaller debris was swept up by the airport authority to bring the taxiway back into use. The diagram and some debris items were subsequently passed to the AAIB. It was noted that the general distribution formed a fan-shaped pattern extending behind the aircraft. A few fragments had travelled as far as the northern part of Stand 135 but none reached Stand 134. A photograph of the fragments collected is shown at Figure 2.

No airframe damage had occurred but on opening the APU access door, it could be seen that an internal failure had bulged and partly split the external casing of the unit. One of the two side-mounts had separated from the unit as a result of the deformation of the casing. Looking down the jet-pipe it could be seen that the turbine was damaged and displaced from its axis, whilst the exhaust duct within the APU had been seriously deformed by contact with high energy rotating turbo-machinery.

Figure 2

APU fragments

Component description

The APS 2000 APU utilises a centrifugal compressor feeding air to a reverse-flow annular combustion chamber. The combustion gasses are directed into a radial plane, flowing inwards into the vanes of a one-piece, cast, inflow turbine. The turbine is mounted directly behind the compressor and drives it via a curvic coupling[1]. The turbine turns the combustion gas flow through 90º enabling it to exit aft through a duct formed by the cylindrical inner face of the combustion chamber.

The manufacturer produces a number of different APU types having a similar layout and utilising cast inflow turbines of varying dimensions and power output. The APS 2000 and the APS 2100 are the largest units having this layout and they share identical turbine wheels. The APS 2100 is used in Boeing 717 aircraft.

The material of all the wheels of this class is IN 792 Mod 5A. It is an alloy developed specifically for this type of application. Turbine wheels are cast by a specialist company that also produces an inflow turbine of very similar mass and profile for another APU manufacturer. The other manufacturer developed its APU for a similar application considerably earlier than the development date of the APS 2000. Originally the other manufacturer's unit used a turbine cast from a different alloy. Following a series of turbine failures, however, the casting supplier recommended manufacturing future turbines from IN 729 Mod 5A. At about this time, the casting company also recommended this material to the manufacturer of the APS 2000, the type of unit installed in G-GFFE, an APU type which was then under development.

Footnote

[1] A joint between driving and driven shaft systems which transmits torque. It allows for small errors in alignment or angle but does not secure one shaft to the other. In its simplest form, it comprises two sets of meshing radial teeth of smooth curving profile.

Detailed examination

The damaged APU was removed from the aircraft and shipped to the European service and overhaul centre for the type. It was subjected to a strip examination in the presence of an AAIB Inspector. The gearbox and compressor section of the unit had suffered light damage but the turbine wheel was in two halves. Most of the housing, external casing and combustion chamber were severely damaged. The containment ring was severely deformed into an approximately oval shape but had successfully prevented any in-plane departure of turbine debris. Following separation from the wheel, most extremities of the inflow turbine had exited via the exhaust duct. This was the result of multiple impacts of the wheel casting halves with adjacent boundaries of the flow path. The two halves of the core of the turbine casting remained in the unit, were of approximately equal size and had separated as a result of a fracture at a face parallel with the casting axis.

The main fracture faces of the turbine appeared to exhibit overload characteristics. It was noted, however, that the failure appeared to have developed radially across the fracture face from a point on the centreline approximately mid-way along the longitudinal axis of the component. This was at or close to the centre of mass of the casting.

Information supplied by the APU manufacturer indicated that a number of similar failures had been experienced on other APS 2000/2100 units. All the failed turbines exhibited generally similar characteristics on their fracture faces. The fractured halves of the wheel from G-GFFE were forwarded to the manufacturer's laboratories in California for detailed analysis. The results of this analysis and a programme of earlier work were fully discussed during a subsequent visit to the manufacturer's plant by AAIB engineering personnel.

Similar events

The manufacturer has identified nine turbine failures in this type of wheel within APS 2000 and APS 2100 units. These occurred between February 1999 and January 2006. The service lives of the turbine wheels at the time of failure ranged from 890 to 14,931 hours and from 1,386 to 14,578 cycles. No reported failures have occurred in smaller turbine wheels of this geometry utilising similar materials and installed in other types of APU produced by this manufacturer. An earlier event at London Heathrow Airport, during which the complete turbine of an APS 2000 exited the rear of the unit and travelled a considerable distance across the apron, was the subject of an AAIB investigation which identified bearing failure as the cause. All reported turbine bursts have remained radially contained and the major portions of the failed turbines have remained within the unit. No information was received on the extent of the distribution of smaller debris following earlier failures.

As previously mentioned, another manufacturer produced a series of APU models which pre-dated the APS 2000 series and examples were extensively utilised in Boeing 737 aircraft. These units utilised an inflow turbine wheel design similar in mass and general profile (although different in detail design) to the component in the APS 2000 and 2001 units, cast by the same supplier. This original wheel design, manufactured from a Marum 247 casting, suffered a number of wheel failures. As a result of these problems, the casting supplier changed the material of the wheel to IN 792 Mod 5A and supplied IN 792 Mod 5A wheels for all APS 2000 and 2001 APUs, a family of models which entered production at about the time of the material change. None of the wheels manufactured from IN 792 Mod 5A in the other manufacturer's APUs are known to have failed in service. The highest working stress level in their APU turbines is, however, not known.

Manufacturer's action

The earlier bearing failure event at Heathrow Airport described above was the subject of modification action and no further departures of complete turbines from APUs have been reported.

The unit manufacturer reports that it has been working closely with the casting supplier over a number of years to eliminate the wheel failure/bursting problem on new turbines; this was the type of failure that occurred in G-GFFE. Also, in conjunction with the supplier, it has been reviewing possible NDI (Non Destructive Inspection) procedures to detect the initiating casting defects.

Examination of all the failed wheels returned to the manufacturer confirmed that the failures originated at small film inclusions of aluminium-magnesium oxides within the core of the casting. These led to initial fatigue crack growth before rapid failures occurred across the remainder of the cross-sections. Both failures involving separation into two approximately equal halves (bi-wheel) and into three approximately equal sized portions (tri-wheel failures) have occurred. In all instances the containment rings performed as designed.

The casting process is carried out to a specification aimed at preventing oxide formation during the melting, pouring and solidification process. An extensive laboratory programme of analysis of the manufacturing process was carried out, ending in 2003, using a large number of castings produced specifically for this purpose. These 'test' castings were sectioned and metallurgically analysed. This work showed that substantial deviations from the process specification had to be made in more than one parameter for detectible oxide inclusions to form within the wheel.

The material of the upper 'head' section of a number of test castings, a region to which impurities would be expected to migrate during the solidification process, revealed no correlation with oxide inclusions within the cores of the wheels. The head is subsequently removed during the finish machining process of the wheel.

As a result of the extensive process analysis completed in 2003, the casting supplier made a series of changes to redefine and improve the tolerances of the parameters of their casting procedures with a view to eliminating all conceivable causes of oxide inclusions. This more demanding production regime was introduced in 2003. Since then a further wheel, cast to this revised specification, has failed in service.

The possibility of adopting an NDT process to detect such inclusions was considered. The complex geometry of the turbine casting rendered most such processes unlikely to be effective whilst the nature of the particular defect leading to such failures, being a local lack of adhesion (ie not a homogenous microstructure) rather than a void, made it even less likely that any such process would be reliable. In particular an advanced Phased Array inspection method failed to detect a known Al/Mg inclusion in a wheel cast for test purposes.

It was noted that the two progressively smaller turbines of similar geometry used by the unit manufacturer in other APUs, although operating at similar working stresses, had no recorded history of failures.

It is also interesting to note that no instances have been reported to the casting supplier of any failures of the corresponding turbine wheel of similar mass and proportions cast in the same plant and of the same material for the other APU manufacturer. The working stresses of these wheels are, however, not known and it is possible that they could be sufficiently lower for the largest oxide inclusions, if present, not to be exploited.

None of the wheel failures known to the APU manufacturer, other than the G-GFFE failure, were accompanied by reports of significant amounts of debris being projected a large distance behind the aircraft concerned.

Jet aircraft flight statistics

Airclaims Limited provided the AAIB with estimates of the number of flights undertaken by western-built jet aircraft during the years 1999 to 2005 inclusive. The estimate for 1999 was 18.89 million rising to 23.53 million for 2005. The total number of flights during the seven year period was 145.75 million (1.4575×10^8). It was assumed that an APU was used on the ground during 90% of these flight departures. This assumption leads to an estimated APU usage on 1.31×10^8 occasions (departures only) in the 7 year period.

Discussion

The practical effect of this phenomenon was that turbines could be manufactured which were apparently free from significant defects whilst defective turbines manufactured during the same period succeeded in accumulating a varying but sometimes large number of operating cycles before failing without warning. No safe operating life for a defective turbine can be determined. No presently utilised method of NDI is thought to be capable of detecting this type of defect at this location before failure. In view of the high number of cycles achieved before failure by a number of in-service turbines, it is not clear whether and at what time during the production history of castings, that the first wheels were manufactured with the problem present. Neither is it easy to establish if and when process improvements significantly reduced the number of defects in all new production turbine wheels.

Smaller turbines can apparently be cast without defects, whilst a turbine of generally similar proportions, cast by the same supplier, using the same casting equipment and personnel, is either being cast without defects, operates at a significantly lower stress level or suffers failures which are not being effectively reported.

Neither this, nor any previous reported failures, have resulted in non-containment of the turbine, although hot fragments were ejected from the jet-pipe at considerable velocity on this occasion. These effects do not appear to constitute an airworthiness hazard and are within the certification requirements for such a unit. They can, however, pose a potential hazard for ramp personnel and for any aircraft, vehicle or person passing reasonably close behind an aircraft with this type of APU in use. This hazard remains and no short term method of eliminating it can be envisaged, given that no fully effective NDI method has been devised and guaranteed defect-free castings cannot be manufactured. It is understood that the 2000 series APU remains in production so the active population of such units is increasing. Although the amount of APU operation is being reduced at some locations for environmental reasons, it is not clear whether the world-wide number of fleet operating cycles is being similarly affected. There is thus no assurance that instances of such failures will decrease and, without a guarantee that the casting problem has been successfully eliminated on new turbines, the frequency of such failures may increase. This frequency is, however, low in terms of total number of cycles accumulated by this type of unit and the failure is not flight critical. Any attempt to carry out design or process changes cannot be guaranteed to reduce the already low risk of failure. On the contrary, design or process changes have the inherent possibility of increasing that risk.

Risk assessment

Since none of the 2000 series APU failures resulted in radial penetration of the APU casing, airport ground staff and crews were only at risk from such failures if they were downstream of the APU exhaust when hot, metallic debris was released. Of the nine failures between 1999 and 2005, none resulted in reports of injuries to staff.

Most western-built jets have the APU mounted in the tail section at heights well above the level of people working in close proximity to the aircraft. Consequently, the area of risk to staff is an ill-defined, fan-shaped region starting aft of the aircraft's tail and extending out to some 300 ft from it on either side of the aircraft's extended centreline. Staff may occasionally have to traverse this region in vehicles but they are not often required to work in or remain within the region because much of it is beyond the stand zone. However, staff working on one aircraft might be at risk from debris ejected by another aircraft's APU if the two aircraft were parked 'tail-to-tail', as they are at some airports.

Apron areas where aircraft are parked in a 'tail-to-tail' orientation usually have the aircraft well spaced to allow for pushback onto a central taxiway centreline. The minimum distance between Stand 110 and the stand opposite was 85 metres. No aircraft tail should protrude beyond the stand area so the minimum distance between aircraft tails would exceed 85 metres. Consequently, although in this incident the debris pattern extended across the adjacent taxiway, none penetrated the area of the opposite stands by more than few feet. Normally, staff would not be standing in this region whilst the APU was running.

Consideration was given to recommending procedures that minimised the risk to staff presented by hot metallic debris ejected from APU exhausts. However, staff could not be expected to know which aircraft were fitted with 2000 series APUs so any procedures would have to be relevant to all aircraft types. During the period of nine APU failures there were an estimated 138.5 million flight departures when an APU was run. Consequently, the risk of an APU disintegrating in a comparable manner to the APU fitted to G-GFFE would appear to be in the order of 1 in 15.4 million departures (1.539×10^7). Moreover, given that nobody was hurt during any of the nine failures, the injury risk to staff was considered to be too small to warrant special procedures aimed at protecting them solely from ejected debris.

Notwithstanding the minimal risk to people, airport operators could usefully remind ground staff not to linger downstream of APU exhausts.

Conclusions

The casting process of the turbine of APS 2000 and 2001 APUs produces occasional and unknown quantities of oxide films within the turbine core. The size and orientation of these films occasionally leads to fatigue crack initiation and growth to failure under working stresses. However, the number of hours/cycles to failure of turbines with such defects cannot be predicted.

Considerable experimental and analytical work has been carried out over an extended period by the APU manufacturer and the casting supplier to eliminate the oxide film problem. These efforts have not been successful.

APUs utilising cast inflow turbines have a history of occasional radially contained turbine bursts. No direct hazard to an aircraft is understood to have resulted from such contained failures of an installed APU and current certification requirements for containment appear to have been met. No other reports of large quantities of high speed debris travelling equivalent distances behind APS 2000 equipped aircraft have been received and nobody has been injured by ejected debris.

No changes to the design or manufacturing process of the APS 2000/2001 turbine can be envisaged that can be guaranteed to reduce the number of such failures without running the risk of making the situation worse. Revised apron procedures to protect staff from ejected debris were not considered necessary but staff could usefully be reminded to avoid lingering within 300 ft downstream of an operating APU.

INCIDENT

Aircraft Type and Registration:	Britten-Norman BN2A Mk III-1 Trislander, G-LCOC
No & type of Engines:	3 Lycoming O-540-E4C5 piston engines
Year of Manufacture:	1974
Date & Time (UTC):	7 June 2006 at 0530 hrs
Location:	Saint Brieuc, Brittany, France
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - None Passengers - None
Nature of Damage:	Baggage door damaged
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	40 years
Commander's Flying Experience:	2,900 hours (of which 205 were on type) Last 90 days - 75 hours Last 28 days - 27 hours
Information Source:	Aircraft Accident Report Form

Synopsis

Shortly after takeoff there was a loud bang. On inspection after landing the pilot found that the baggage door had been forced inwards into its aperture. The locking mechanism functioned normally and it is likely that the door was not properly secured prior to departure. The operator intends to change ground handling procedures to avoid a repeat occurrence.

History of the flight

The aircraft was operating a scheduled passenger service from Saint Brieuc to Guernsey. Shortly after takeoff from Saint Brieuc, after the aircraft had climbed to approximately 200 ft agl, there was a loud bang. The commander could not identify the cause but, after establishing that all three engines were operating normally and that the aircraft was under control, he returned to Saint Brieuc. The landing was uneventful and as the aircraft vacated the runway, neither the ATCO nor the AFRS, which was immediately in attendance, reported anything unusual about its appearance. After disembarking the passengers, the commander inspected the aircraft and found that the baggage door, though still attached to the aircraft, had been forced into the baggage compartment. An inspector from the DGAC who attended shortly after the incident found that the baggage door locking mechanism functioned normally.

Aircraft information

The Trislander is a stretched derivative of the Britten-Norman Islander twin-engined aircraft and differs primarily in having a longer fuselage and an additional engine mounted on the vertical stabiliser. It is unpressurised. The two designs share many components, including the outward-opening rear baggage door which on both types is mounted on the left hand side of the rear fuselage. The door is constructed of glass-reinforced plastic and is attached to the fuselage by two hinges mounted on its forward edge. When closed, the door is secured by a plain latch which is operated from the outside by rotating a lever. Neither the lever nor the latch is sprung, so the latch must be rotated to the secure position by hand when the door is fully closed. The door is not fitted with any device, such as a warning light in the cockpit, to indicate to the pilot that it is not shut and its security can only be assessed by visual inspection of the door itself. However, a device fitted to each of the four passenger doors will illuminate a light in the cockpit if any of these doors is not closed.

Damage to the aircraft

One of the operator's engineers, who inspected the aircraft at St Brieuc, judged that the door had not been secured prior to flight and had been forced through its aperture by aerodynamic forces when the aircraft became airborne. The door lip, which normally would rest against the outside of the door frame, had been deformed sufficiently to allow the door to move inwards. One of the three rivets attaching each door hinge to the outer skin of the fuselage had been loosened by lever action. The engineer considered that the hinges were sufficiently secure to allow a new door to be fitted for the non-revenue return flight to the operator's base at Jersey Airport where the rivets were replaced before the aircraft was returned to service.

Previous occurrences of the baggage door opening in flight

Several Trislanders are in service with three operators in the United Kingdom and both Islanders and Trislanders have been exported widely. None of the four documented instances of baggage doors opening in flight were attributed to failure of the door or its locking mechanism.

Ground handling procedures

The operator provides staff to conduct the ground handling of its flights at all of the airports to which it flies except St Brieuc, where the airport provides this service. The operator stated that handling staff at each location have access to a copy of the company Ground Handling Manual (GHM) which describes the correct procedures for loading and dispatching the aircraft.

To avoid tipping the aircraft on its tail during loading, the procedure at the time of the incident was to place a trestle under the tail and embark passengers before baggage. The operator considered that it was not good practice to leave the cockpit unattended with passengers onboard and that consequently, a commander could not leave the aircraft interior to check the baggage door when loading was complete. Therefore, although a commander would bear ultimate responsibility for ensuring the safe conduct of the flight, responsibility for checking the security of the baggage door was delegated to a ground handler, whose duty it was to report to a commander that all the doors were secure prior to the engines being started.

Follow-up action

Another Trislander operator reported that, as a result of a similar incident several years ago, it introduced a procedure intended to ensure that a satisfactory check of baggage door security was made prior to flight. Judging that an unsecured baggage door could be identified more readily from behind (because it opens forwards, exposing the latch mechanism and parts of the irregular inner door structure on its trailing edge) the operator instructed ground staff to walk clockwise around the aircraft from its starboard to its port side, checking each door in turn. The new procedure has been successful in eliminating this type of occurrence. The operator of G-LCOC stated that it intends to introduce a similar procedure, the relevant text of which is reproduced below together with a diagram (Figure 1).

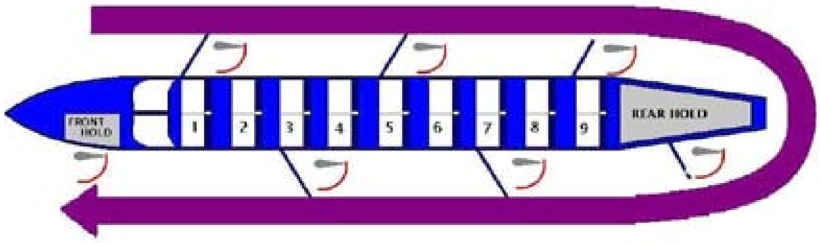


Figure 1

Trislander walk-round route for ground staff

The tail trestle must be in position at all times when the aircraft is parked on stand.

Once all baggage is loaded, call the passengers to the aircraft, with the approval of the Captain.

When all passengers are on board

- *a. Remove steps from the vicinity of the aircraft.*
- *b. Walk down the starboard side of the aircraft, checking each door is secured.*
- *c. Remove the pogo-stick[1] (if being used) and secure in the hold.*
- *d. Walk up port side of the aircraft, checking all the doors.*
- *e. Ensure that the Captain has a copy of the load sheet, and no door warning lights are showing in the cockpit.*

When ready for start-up and the aircraft is secure, seek the Captain's permission to remove the trestle.

In this revised procedure, baggage is loaded before passengers. The pilot remains seated in order to counterbalance the weight of baggage and thereby reduce the load on the tail trestle which impinges upon an area of the fuselage which is not reinforced.

Although the 'pogo-stick' will contact the ground if the loading results in an excessively rearward centre of gravity, it will not always prevent the aircraft from tipping on its tail. Consequently, a tail trestle is used for support during loading. However, because the pogo-stick forms part of the aircraft's standard equipment, the operator has retained reference to it in the ground handling procedure to ensure that it is removed before flight. The operator also intends to paint the inboard surfaces of all baggage doors on its Trislander aircraft with red and white stripes to attract further attention when a door is open.

The organisation which holds the type design authority for Trislander aircraft is considering restarting production of the type. It has stated that it would equip all Trislanders produced in the future with a baggage door warning system including a light in the cockpit that would illuminate if the door was not properly closed. Attempts to retrofit such a system to existing airframes have proved complex and uneconomic.

Conclusion

The baggage door was probably serviceable prior to the flight but it was not secured prior to departure. During the short flight, aerodynamic forces shut the door with sufficient violence to push it into the fuselage aperture.

Footnote

1 The pogo-stick is a pole which attaches to a point beneath the fuselage tail.

ACCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-JEDM
No & type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2003
Date & Time (UTC):	8 June 2006 at 1157 hrs
Location:	30 miles north of Exeter Airport, Devon
Type of Flight:	Public Transport
Persons on Board:	Crew - 5 Passengers - 45
Injuries:	Crew - 1 (Serious) Passengers - None
Nature of Damage:	None
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	8,000 hours (of which 471 were on type) Last 90 days - 101 hours Last 28 days - 16 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by AAIB

Synopsis

The aircraft encountered severe turbulence whilst descending through cloud: the turbulence had not been forecast. The passengers were strapped into their seats in preparation for landing; however, the two cabin crew were still on their feet. During the turbulence, one of the cabin crew was lifted off his feet and landed heavily, breaking his right ankle.

History of the flight

The aircraft was inbound to Exeter Airport on a passenger service from Newcastle. About ten minutes prior to landing the aircraft was descending close to a small area of cumulus cloud when it experienced sudden and severe turbulence: the weather radar was selected to OFF. Recorded data indicates that the event occurred at 9,338 ft when the aircraft's speed was 260 kt. The autopilot disconnected automatically due to the severity of the turbulence. The commander, who was the handling pilot, ensured that the wings remained level and reduced power, he then re-engaged the autopilot once the aircraft was clear of the turbulence. The event lasted 15 seconds during which the aircraft's speed reduced to 240 kt. The maximum recorded vertical acceleration was 2.285g.

The cabin crew had just completed preparing the cabin for landing, which included ensuring that the passengers were correctly strapped into their seats. At the onset of the turbulence one of the cabin crew was walking along the cabin aisle and managed to seat herself in a spare passenger seat. The other cabin crew member was standing in the galley at the rear of the cabin and was unable to get to a seat. He was twice lifted off his feet, and on the second occasion fell very heavily on his right ankle; he came to rest lying across the aircraft between the rear passenger exit and a service door on the other side.

Once clear of the turbulence other members of the crew rendered first aid to their injured colleague. Because the injured crew member could not be moved to a seat, he was immobilised as much as possible. The aircraft landed without further incident and the emergency services attended to the injured crew member before transporting him to hospital. The cabin crew member's right ankle was later diagnosed as broken.

Subsequent engineering checks revealed no damage to the aircraft.

Meteorology

The Low Level forecast below 10,000 ft for the period 0800 hrs to 1700 hrs, in an area that included the location of the severe turbulence experienced by G-JEDM, predicted isolated scattered cumulus and strato-cumulus cloud, with moderate turbulence, between 3,000 and 4,000 ft.

The actual weather reports (METARs) at Exeter Airport close to the time of the accident were:

> At 1150 hrs - surface wind from 160º at 9 kt, visibility in excess of 10 km, few clouds at 2,800 ft, temperature 22ºC, dew point 15ºC.
>
> At 1220 hrs - surface wind from 160º at 7 kt, visibility in excess of 10 km, few clouds at 3,000 ft, temperature 23ºC, dew point 14ºC.

Procedures

The operator's procedures reflect those provided by the manufacturer. The standard operating procedure (SOP) for flight in severe turbulence, as stipulated in their operations manual, states:

> *On entering severe turbulence disengage the autopilot, maintain the desired pitch attitude and maintain wings level if possible…. If severe turbulence is encountered unexpectedly, a slow acceleration/deceleration should be made to achieve the rough air speed.*

The aircraft's maximum permitted operating speed (V_{MO}) below 10,000 ft, as detailed in the Operation's Manual, is 282 kt; below 8,000 ft the V_{MO} is 245 kt. The recommended speed for flight in turbulence is V_{MO} - 10 kt, and 210 kt if the turbulence is severe. The SOPs also required that the seat belt sign should be switched on, and the passengers strapped into their seats, ten minutes prior to landing.

Discussion

The aircraft encountered severe turbulence, which had not been forecast. In the prevailing conditions the commander had decided not to use the weather radar. When the aircraft first encountered the turbulence its airspeed was 50 kt faster than that recommended for flight in severe turbulence, but the encounter was entirely unexpected. The autopilot disengaged automatically due to the severity of the turbulence and, as recommended, the airspeed was reduced during the period of turbulence.

In accordance with the SOPs, the passenger seat belt signs had already been switched on, and the passengers were strapped into their seats in preparation for landing.

The only people in the cabin who were not strapped into a seat when the turbulence was encountered were the two cabin crew. One of them managed to locate a seat immediately, but the other did not and broke his right ankle when he was lifted off his feet and fell heavily.

It is likely that the aircraft would have been subjected to significant movement in the severe turbulence, even at the rough air speed. However, the increased speed would have exacerbated the effects of the turbulence in the cabin.

ACCIDENT

Aircraft Type and Registration:	Agusta A109C, G-HBEK
No & type of Engines:	2 Allison 250-C20R/1 turboshaft engines
Year of Manufacture:	1996
Date & Time (UTC):	21 June 2006 at 1852 hrs
Location:	Private helicopter landing site at High Legh, Cheshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Extensive damage to main rotor head assembly and rotor blades
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	3,900 hours (of which 440 were on type) Last 90 days - 75 hours Last 28 days - 35 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The helicopter was landing at a private landing site where it was to remain for the night. As the pilot approached the site, he noticed that another A109 helicopter was parked "in an obstructive position" on the adjacent taxiway. Knowing that the hoses on the refuelling bowser were short and being aware of the position of the other A109, he wanted to land as close as possible to the bowser, to facilitate refuelling, and as far away as practicable from the other helicopter. After touchdown the engines were shut down. As the main rotor speed decreased, the rotor blades began to droop and strike the side of the bowser. The pilot immediately applied the rotor brake but the blades continued to strike the bowser and more violently. One blade then became lodged in the bowser; this caused the rotors to stop suddenly. As a result the main rotor blades were extensively damaged, one main rotor damper sheared off the rotor head and both engines required an inspection. The fuel bowser suffered only minor damage.

Background information

The helicopter landing site is located in the middle of a three acre field. It has a 19.8 m square concrete landing pad and a hangar to the east. They are connected by a 24 m long taxiway.

Normal operating procedures usually involve one helicopter on the pad at a time. A helicopter usually lands on the pad facing west towards the bowser. Upon shutdown it would be pushed back, with the aid of a tractor, into the hangar (the A109 helicopter has tricycle landing gear). The helicopter would then be refuelled, if required, in the hangar using the mobile fuel bowser that normally stays in the hangar.

Due to a large number of planned movements that week, it was agreed amongst the pilots, for the mobile bowser to be positioned on the western edge of the pad. The pilot of G-HBEK thought the fuel bowser was unable to park on the ground surrounding the pad as it would sink into the ground; for the same reason helicopters could not land there either. Helicopters would land on the taxiway, facing west, and taxi forward towards the bowser. They would then be refuelled before being pushed back into the hangar or onto the taxiway to make room for another helicopter. This procedure had been used successfully on the preceding day.

An Agusta A109C (A109) is refuelled using two refuelling connectors. These are positioned on both sides of the fuselage, one metre above the ground, just aft of the main landing gear. Due to the short hoses on the bowser, the helicopter should be parked with its nose facing the bowser to ease access to the refuelling points.

Prior to this accident another A109 had landed on the pad before G-HBEK arrived. Because it did not need refuelling it had landed on the taxiway. It was, however, parked across the taxiway and parallel to the bowser instead of facing it. It had parked on the taxiway because it was known that G-HBEK would need refuelling and it would be the first helicopter to depart the following day.

History of the flight

The short flight from Knutsford to High Legh proceeded uneventfully. The purpose of the flight was to park the helicopter overnight until it was required the next day. The pilot reported that the weather was light rain, with good visibility and there was scattered cloud at 2,600 agl. The surface wind was from 260º at 25 kt gusting 32 kt.

As G-HBEK approached the landing site the pilot noticed that another A109 was parked "in an obstructive position" on the taxiway. Knowing that the hoses on the bowser were short and being aware of the position of the other A109, he wanted to land as close as possible to the fuel bowser, to facilitate the refuelling, and as far away as practicable from the other helicopter. He added that it is easy to judge the position of the rotor disk, with reference to obstacles, when looking out to the front; however, it is difficult when looking out to the side.

The pilot described the landing as "not easy" due to the strong and gusty crosswind. After touchdown the normal two-minute run down period was observed before the engines were shut down. As the rotor speed decreased through 50% rpm the main rotor blades began to droop. As they did so they began to strike the side of the bowser. The pilot immediately applied the rotor brake but the blades continued to strike the bowser and more violently. One blade then became lodged in the bowser; this caused the rotors to stop suddenly.

Damage assessment

The helicopter repair agency reported that the following damage was sustained as a result of this accident. Two main rotor blades were extensively damaged and beyond repair. The other two were damaged on the tip areas and had possible high inertia loading of the root end bushings. Additionally, one main rotor damper was sheared off at its attachment mountings resulting in mechanical damage to parts of the main rotor head and drive assembly components. Also both engines required an inspection in accordance with the Rolls Royce Operation and Maintenance Manual.

The fuel bowser suffered only minor damage.

Discussion

The owner of the landing site commented that since the weather had been very dry during the preceding months, the area around the pad was very firm. He felt that it would not have caused a problem if the bowser was parked on the grass, or if the pilot had landed on the grass.

In an open and frank report the pilot attributes the many, previously mentioned, factors that contributed to an avoidable accident. These led him to make a rushed and bad decision. He also stated that he did not believe the marshy ground beneath the dry surface layer surrounding the pad would have supported either the laden weight of the bowser or the parked helicopter's wheels.

ACCIDENT

Aircraft Type and Registration:	Eurocopter AS332L2 Super Puma, G-CHCG
No & Type of Engines:	2 Turbomeca Makila 1A2 turboshaft engines
Year of Manufacture:	2003
Date & Time (UTC):	3 March 2006 at 1503 hrs
Location:	104 nm north-east of Aberdeen VOR/DME
Type of Flight:	Commercial Air Transport
Persons on Board:	Crew - 2 Passengers -18
Injuries:	Crew - None Passengers - None
Nature of Damage:	Lightning strike damage to one main rotor blade, one tail rotor blade and other components including all three main rotor servo-actuators
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	Approximately 15,000 hours (of which about 2,500 hrs were on type) Last 90 days - 91 hours Last 28 days - 29 hours
Information Source:	AAIB Field Investigation

Synopsis

The helicopter was ferrying oil company personnel from an oil production platform to Aberdeen Airport when it suffered a lightning strike. There was no vibration or damage visible to the pilots but there was a temporary disruption of the flight instrument screens and navigation system, and indications of failures in the flight data recorders. Whilst approaching Aberdeen Airport in deteriorating weather conditions, the helicopter suffered a hydraulic system failure due to loss of fluid but it was landed safely.

The exterior damage to the helicopter visible on the ground was typical but a further safety hazard was the hidden damage to the interior portions of the main rotor hydraulic actuators which had caused an hydraulic leak, depleting one system. Some of this damage may have been inflicted by an earlier lightning strike and this damage was not detected although the appropriate post-lightning strike checks had been carried out.

New post lightning-strike inspection procedures to be issued by the helicopter's manufacturer and amendments to the operating company's QRH and Operations Manual have been devised.

History of the flight

The helicopter was ferrying oil company personnel between the Beryl 'B' oil production platform and Aberdeen Airport. The outbound flight from Aberdeen had landed on the Beryl 'A' platform, after which the aircraft operated a shuttle flight to the Beryl 'B' platform.

The commander and co-pilot had reported for duty at 1100 hrs for a scheduled departure at 1200 hrs, though this was subsequently revised to 1300 hrs. Pre-flight preparations were routine, with full weather information available to the crew via a computerised self-briefing facility. The weather forecast for Aberdeen was for scattered cumulo-nimbus cloud with snow showers and thunderstorms for the afternoon period, with associated reductions in visibility to as low as 500 m. The Beryl Field weather report for 1215 hrs indicated that shower activity was relatively light and that no lightning activity had been observed. As part of their pre-flight preparation, the crew had access to a Meteorological Information Self Briefing Terminal (MIST) and were able to view information about lightning strikes detected within the current hour and the previous hour. There was no significant lightning activity recorded over the North Sea generally, and none at all in the planned area of operation.

Due to the late arrival of the inbound aircraft a 'rotors running' crew change was made. The aircraft took off at 1330 hrs for an uneventful flight to the Beryl 'A' platform. The aircraft flew at 3,000 ft and, although showers were encountered, weather radar returns were weak and no deviations from track were necessary. The helicopter landed on the Beryl 'A' platform, refuelled and operated the shuttle to the Beryl 'B' as planned. With the co-pilot as handling pilot, the aircraft lifted off again at 1527 hrs with 18 passengers on board.

The initial part of the flight to Aberdeen was flown at 2,000 ft. Although the crew reported a noticeable increase in weather radar returns, there were no high intensity returns and again no track deviations were considered necessary. Thirty six minutes into the flight, the helicopter was flying near to the base of cloud and encountering light hail when a lightning strike occurred. The commander was aware only of a loud bang or crack, whilst the co-pilot, who was looking across the flight deck, was also aware of a flash forward of the aircraft. The passengers generally reported both a flash and a bang.

There were no obvious signs of damage, and no vibration. The helicopter's four Electronic Flight Instrumentation System (EFIS) screens went blank, but recovered automatically within seconds. All flight data indications on the screens appeared normal, with the exception of the route steering information. The navigation system had suffered a power interrupt and all sensors were showing invalid information, including the GPS which was the primary navigation sensor at that stage. Within about a minute, GPS signals became valid again and the system automatically re-entered its navigation mode, with all pilot-entered route data being retained in memory. The crew also noticed that discrete FDR and DFDAU[1] caution lights were illuminated on the Health and Usage Monitoring System (HUMS) control panel, and that the ELEC caution on the Central Warning Panel (CWP) was illuminated, though at a much lower intensity than normal. The ELEC caption could not be cancelled in the normal manner and so it remained illuminated at the reduced intensity for the remainder of the flight (the caption normally indicated that a discrete caution light had illuminated on the electrical panel, though none had in this case).

Footnote

[1] FDR – Flight Data Recorder. DFDAU – Digital Flight Data Acquisition Unit.

The helicopter was descended to 1,000 ft in order to remain clear of cloud and Aberdeen ATC was notified of the lightning strike and change of altitude. The crew did not declare an emergency. There were no QRH actions for a lightning strike, so the crew continued the route with the intention of assessing their landing options as they neared the coast.

The crew were using VHF 2 for ATC communications as was normal practice, and attempted to establish contact with their company on a discrete frequency on VHF 1 but were unsuccessful. The crew tried to contact other company aircraft with a view to having their message relayed (due to their low altitude), but were answered by Scottish Military who indicated that G-CHCG was transmitting on the 'guard' emergency frequency, 121.5 MHz. This was contrary to indications on the radio control panel. Further attempts to use VHF 1 had the same result so the crew regarded the radio as inoperative and ceased trying.

As the helicopter neared the coast, an increasing intensity and quantity of weather radar returns was received and some weather avoidance became necessary, with a line of snow showers stretching from Peterhead in the north towards Aberdeen Harbour. Runway 34 was in use at Aberdeen, but in view of the extra time it would take to fly an instrument approach to that runway, the crew elected to fly visually inbound to the Airport, along the coast at a reduced altitude if necessary. Consideration had been given to landing at Peterhead (Longside) heliport, 22 nm from Aberdeen Airport, but this option was rejected after ATC informed the crew that it was being affected by snow showers. The crew also rejected the possibility of an 'off site' landing due to the hazard that would be created by the recently fallen loose snow.

As the helicopter neared Aberdeen the crew carried out the initial approach checklist, which included lowering the landing gear. Although the gear lowering sequence was normal, and 'down and locked' indications were achieved, it was followed soon afterwards by abnormal hydraulic system indications. The HYD caption on the CWP illuminated, together with SERVO, AP HYD and LVL captions on the hydraulic panel, although the three panel lights appeared to be flashing at random. The co-pilot noticed the hydraulic pressure gauge fluctuate up to three times, each time dropping to near zero before recovering to normal system pressure. The crew discussed the possibility that the indications may be due to an electrical problem, but as they did so the caution lights illuminated steady, the pressure gauge dropped to zero, and the co-pilot felt 'pulses' through the cyclic control as the controls became stiffer, confirming that it was indeed an hydraulic problem.

At about this time the aircraft entered worsening weather conditions, forcing the crew to ask ATC for a climb and radar assistance for an instrument approach to Runway 34. However, as the aircraft was climbing towards 2,000 ft, it emerged from cloud and a clear area was seen to the right, in the direction of the airport. The commander instructed the co-pilot to fly towards the gap, and made a 'PAN' call to ATC stating his intention to revert to a visual approach, which was immediately approved.

The aircraft landed without further problem on Runway 34. Once the helicopter was on the ground, some vibration could be felt through the airframe. After taxi-in and shutdown it became evident that the helicopter had suffered significant lightning strike damage to the main and tail rotor assemblies, and that a major hydraulic leak had occurred, with fluid draining down the helicopter's right side from a region to the rear of the main gearbox.

Examination of the aircraft

The helicopter (Manufacturer's serial no 2592) was examined by AAIB Inspectors at Aberdeen on the day after the incident. By then, the main and tail rotor blades had been removed as had the three main rotor hydraulic actuators. Engineering personnel were checking the transmission and flying control components for the presence of residual magnetism caused by the lightning strike.

There was obvious lightning damage to one main and one tail rotor blade, the main blade exhibiting surface scorching at the tip and root, including an area where the sub-surface bonding braid near the leading edge root had evidently been melted or blasted out and was missing a section about 23 cm long. The bonding strap from the blade to the rotor head had also melted. Other surface effects on the carbon fibre skin were observed at several points along the span.

The tail rotor blade had lost two sections of the metal leading edge erosion strip which also serves as a conductive path for electrical current. The missing sections were at the point where the parallel section of the blade joins the tip and the junction of the erosion strip and the sub-surface conducting strip. The bonding strap from the blade to the rotor hub had also melted.

Other areas of localised overheat damage were found, principally on the pitch link spherical bearings but also on a bearing associated with the flying control circuit within the fuselage. Similar damage had also been found on the spherical bearings of the three main rotor hydraulic actuators and, significantly, on the external 'Fescolized'[2] portion of the ram of two of them (see Figure 1).

Figure 1

Outer rod showing externally visible arcing damage

This damage had the appearance of localised melting and erosion of the chromium plating and the surface of the steel underneath and was clearly the origin of the hydraulic leak from No 1 system. All three actuators were despatched for testing and laboratory examination by their manufacturer under AAIB supervision.

Residual magnetism checks on the main, intermediate and tail rotor gearboxes led to their rejection and removal for examination but it is understood that this did not reveal any internal damage. Signs of arcing on the tail rotor driveshafts and some tail rotor control components also led to their removal. The unserviceable VHF transceiver and DFDAU units were replaced.

Description and examination of the main rotor hydraulic actuators

The AS322 has dual hydraulic systems and, to achieve the necessary redundancy in the primary flying controls, the main rotor servo actuators have a tandem arrangement (see Figure 2) in which each hydraulic system supplies power to separate pistons, although the pistons are on a common shaft forming part of a single actuator. Either system can control the helicopter on

Footnote

2 Patented process for electroplating with cadmium, chromium or nickel.

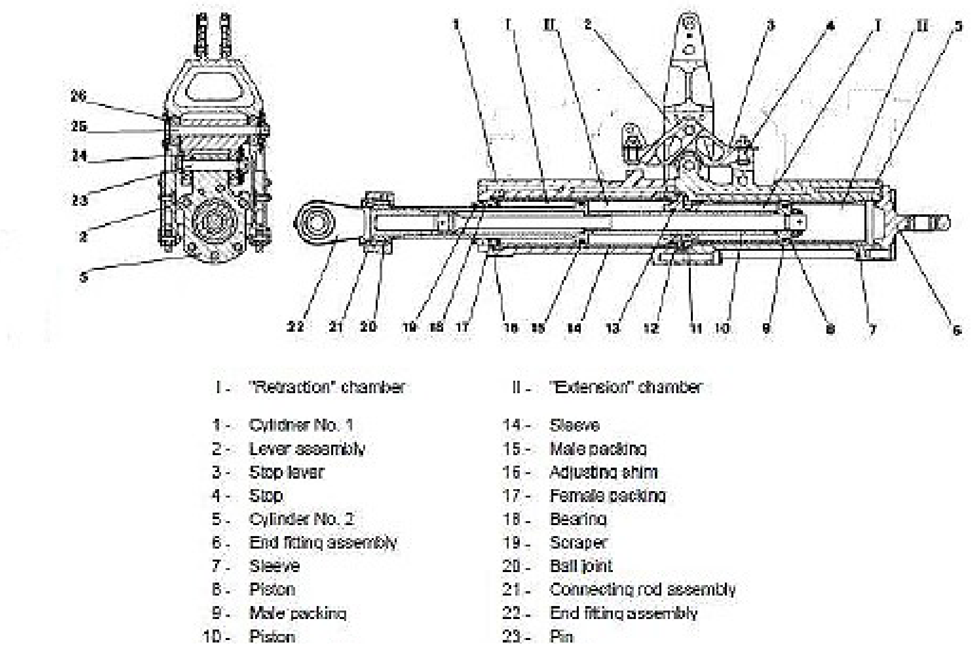


Figure 2

AS332L main rotor servo actuator

its own but, of course, they normally work together. It can be seen that the Fescolized portion of one piston extends out of the body of the actuator (No 1, or Left system) and is therefore visible externally, but the piston of the other system (No 2, or Right) remains completely hidden internally. A drain hole between the intermediate bearings of No 2 system should provide witness of any internal leakage past the Fescolized rod.

The examination commenced with a bench test of all three actuators. They were checked first at about 25 to 30 bar before full system working pressure of 175 bar was applied. The first actuator tested had visible evidence of metal erosion on the external portion of the Fescolized rod and, when tested at low pressure, a significant external leak was obvious such that it was decided not to continue to high pressure. Strip examination of this unit showed that the upper bearing seal had been perforated and it was concluded that this was responsible for the leak which had depleted No 1 system. Some erosion damage was noted on one of the spherical bearings but the internal rod was not marked and there was no leakage from System 2.

The next actuator tested showed some leakage from the centre bearing drain which disappeared at working pressure. There was slight leakage from System 1 at low pressure which again disappeared at the higher value but no leakage from System 2. The external portion of the rod also had visible erosion damage to the Fescolized portion and, when stripped, was found to have similar internal metal erosion damage. This would not have been visible without dismantling. Again, one spherical bearing had erosion damage and both the upper and central bearing seals were slightly damaged, accounting for the leak at low pressure.

The third actuator had no visible damage to the external Fescolized rod. It exhibited a slight leak from System 2 at the centre bearing which disappeared at high pressure but no leakage from System 1. However, when dismantled there was significant erosion damage to the internal rod and it was noted that the damage appeared to have two distinct areas, (see Figure 3), suggesting two separate events occurring with the piston in slightly different extensions; this possibility is discussed below. There was also evidence of electrical tracking on one of the spherical bearings.

Engineering analysis and conclusions

The hydraulic caution lights reported by the crew were to be expected from complete depletion of the No 1 system. The 'LH HYD LVL light illuminates when the reservoir level drops below 4 litres. At this point, a solenoid valve also closes to shut off the landing gear, tail rotor control actuator and autopilot from the main system, generating SERVO and AP HYD captions.

For the most part, the damage to the aircraft was typical of such events and, in particular, the damage to the rotor blades was not as severe as other recorded incidents which resulted in noticeable or severe vibration. Careful visual inspection revealed damaged components such as bearings and residual magnetism checks led to the rejection of otherwise apparently undamaged components. Although this operator was apparently unaware of previous instances of lightning damage to main rotor servo actuators, such damage has been experienced before and has been reproduced in testing for certification of later helicopter designs using similar actuators. When the AS332 was certified, there was no such testing required for these components.

Although there was no loss of hydraulic fluid from System 2, despite the damage to the pistons of two actuators which was revealed on strip examination, the damage to the actuators represented the most serious threat to airworthiness in this incident. The reason for the leak which led to depletion of the No 1 system appears to have been damage to the seal, either from the strike itself or from rubbing against the rough, eroded area of the rod. It is conceivable that, in the absence of seal damage, there will be no leakage when the actuator is moved such that the eroded area no longer impinges on the seal, but when the seal is damaged, leakage could occur at all actuator extensions. It was noted that any slight leakage, indicating seal damage, tended to be evident at low pressure only, suggesting that checking for leaks would be more rigorous at these pressures. However, low pressure testing is not normally required because the seals are optimised for a working pressure of 175 bars. According to the helicopter manufacturer, leakage at low pressure should not necessarily be considered as a malfunction because it would be difficult to define leakage criteria appropriate to low-pressure testing.

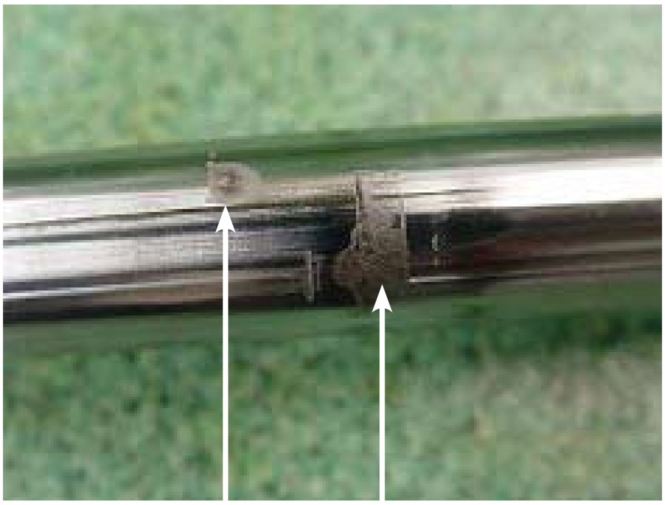


Figure 3
Damage to Fescolized portion of inner rod showing two distinct areas of arcing damage

The fact that lightning damage to the actuators does not appear to be common is perhaps surprising given that any hydraulic component such as this, where there is no direct metal-metal contact between the cylinder and the ram, will have a propensity for a spark to jump across the non-metallic seals and cause localised melting of the steel. Of particular concern is the observation on the internal rod of one actuator that it had experienced two separate strikes. G-CHCG had suffered a lightning strike three days prior to this incident which resulted in a main rotor blade replacement. It is likely that one of the internal damage indications occurred as a result of this strike but it was not detected at the time.

Manufacturer's post lightning-strike check requirements

The Eurocopter Aircraft Maintenance Manual chapter 05-53-00-225 contains guidance on check requirements after a lightning strike**.** Paragraph 3.1.3.3 contained the only specific reference to checking the actuators as part of the main rotor head inspection. It stated:

> *………..perform a detailed check of all junction areas showing electrical discontinuity:*
>
> - *servocontrols (oscillating bearings, power rods and cylinders).*

The safety issue is that it is not possible to check visually for internal damage affecting No 2 system unless a leak is detected from the centre bearing. It is reassuring to note that all three actuators would have been removed even without the obvious damage to the Fescolized rods because of the damage to the spherical bearings (called 'oscillating bearings' in the manual extract quoted above). However, if it is accepted that this had caused one of the marks on the actuator which had apparent evidence of two separate strike events, such damage was not detected after the previous lightning strike.

Eurocopter have stated that they will be producing a Service Letter to operators which will include the following:

> *'To ensure that servo-controls damaged by a lightning strike do not remain in service, the EUROCOPTER documentation will be modified in order to specify the type of checks to be carried out following a lightning strike.*
>
> ***For main rotor servo control:***
>
> *a) Research of arcing mark on ball joint, power rod and body.*
> *b) Research any evidence of leakage.*
>
> *If any of these anomalies will lead (sic), the servo control must be sent to a repair station for detailed inspection and repair.*
>
> ***For tail rotor head servo control:***
>
> *If arcing mark on tail rotor blade or tail rotor head, remove the tail rotor servo control and send this equipment to a repair station for detailed inspections.*
>
> ***For main rotor and tail rotor head:***
>
> *a) Check the flight controls devices on servo control vicinity.*
>
> *b) Following a lightning strike revealed on a helicopter, a particular attention of the two hydraulic circuit's fluid level is to be performed during the next ten daily inspections.'*

Although this Service Letter will apply specifically to the AS332L, it is understood that similar instructions will be issued for other helicopter types manufactured by Eurocopter that have similar servo controls.

Meteorological information

General situation

An aftercast was obtained from the Met Office. At 1200 hrs on 3 March 2006 there was a slack area of low pressure in the North Sea with a line of instability lying just east of the coast of Scotland. The weather was cloudy or overcast with showers of rain and snow at the lower levels. Thunder was likely in some of the showers. The surface visibility would have been 15 to 25 km but reducing to about 2,000 m in snow showers. The base of the cumulus cloud would have been 2,000 to 2,500 ft, with stratus cloud beginning at 3,000 ft. The cloud base would have deteriorated in showers to between 1,000 and 1,500 ft beneath cumulo-nimbus clouds.

Lightning strike information

Information on the lightning strike was obtained from EA Technology, a UK company which has specialised in the monitoring of cloud-to-surface lightning strikes in the area of the British Isles for a number of years (see *Lightning detection systems* below for the method of strike detection). The strike was recorded as a single, isolated cloud-to-surface discharge at 1602:37 hrs, at position N58º 42’ 24” W000º 12’ 47”, with a probable position tolerance of 1,500 m. The recorded position was within 2.5 nm of the estimated position of the strike. The strike had a strength of less than 40 kilo-amps and its polarity was positive. On the same day, between 0700 hrs and 1900 hrs, there were only two other lightning strikes in the North Sea area, each of which was in excess of 70 nm from the helicopter’s position at the time of the strike.

Recorded information

Flight recorders

The aircraft was fitted with a combined Flight Data Recorder and Cockpit Voice Recorder (CVFDR) capable of recording a range of flight data parameters for a period of 8 hours and three audio tracks, each of 90-minutes duration, onto magnetic tape. The CVFDR was downloaded at the AAIB where data and audio recordings were recovered for the accident flight. Unfortunately, flight data from the CVFDR following the lightning strike was corrupted and unreliable, probably as a result of lightning damage to either the DFDAU or the data recording portion of the CVFDR, both of which sustained damage.

HUMS

Vibration data for the accident flight recorded for the operator’s HUMS programme showed that there were no significant differences in vibration levels for the tail rotor and the main rotor before and after the lightning strike. However, these data were recorded at intervals of just under one hour and therefore do not give an immediate comparison pre- and post-strike.

Lightning physics

Lightning is essentially an electric discharge that occurs between one region of the atmosphere and another, or between one region of the atmosphere and the earth’s surface. It occurs when the electric field exceeds a critical value, known as the ‘breakdown potential’. The breakdown potential is high because air is a poor electrical conductor, so there needs to be a significant voltage potential if lightning is to occur. Such voltage potentials often occur in cumulo-nimbus clouds although the exact mechanism which causes them is not fully understood.

There are two types of lightning strike that can affect an aircraft in flight. The first is an ‘intercepted’ strike whereby the aircraft intercepts a naturally occurring lightning strike. The second is a ‘triggered’ strike which occurs when the conducting aircraft itself causes an intensification of the electric field in its vicinity. This intensification is sufficiently large to overcome the breakdown potential of the air and a lightning strike is triggered. It is thought that approximately 90% of all lightning strikes to aircraft are triggered by the aircraft itself, making it very difficult to forecast the strike.

Lightning detection systems

A number of ground-based 'Arrival Time Difference (ATD) systems world-wide are capable of detecting and recording lightning strikes. Such systems use a network of antennae, capable of detecting the extra low frequency radio signals (referred to as 'sferics') emitted by lightning. The time and location of a lightning strike can be calculated from the different times taken for the signals to reach the various receiver stations. The systems are able to discriminate between cloud-to-cloud strikes and cloud-to-surface strikes by the difference in the signals' polarisation, and normally only cloud-to-surface strikes are recorded and displayed, often within seconds of the discharge. The UK Met Office's own system provided the lightning strike data which was viewed by the flight crew on the MIST system as part of their pre-flight preparation.

The North Sea operators had jointly funded a system to display positions of lightning strikes on radar screens at Aberdeen ATC, using data supplied by the Met Office. However, the system used earlier technology and there was a delay of several minutes between a strike occurring and it being displayed, so its operational value was limited. At the time of writing this report, an updated system was being evaluated by National Air Traffic Services for possible future use at Aberdeen.

Airborne equipment is currently limited to weather radar and specialist systems which detect lighting sferics. Weather radar is able to detect areas of storm activity by means of radar returns from water droplets, but is unable to detect lightning itself. Systems which detect the electric signals from lightning are capable of displaying lightning strike data to the pilot on a dedicated display or as an integrated display with weather radar returns. Such systems can detect and display the early cloud-to-cloud discharges which often precede the more powerful cloud-to-surface discharges.

Neither of the two systems above is able to detect or warn of an increased risk of a lightning strike before it actually occurs, as they cannot detect the increase in atmospheric voltage potentials which precede an electrical discharge. Equipment is available which can measure such electrical energy fields, though whilst such devices (known as E-field meters) have been used in electrical field research, they have not been developed for operational airborne use.

Previous accident

On 19 January 1995 an AS332L Super Puma, registration G-TIGK, was lost over the North Sea after suffering a lightning strike which caused severe vibration and loss of tail rotor control. Whilst recognising that lightning discharge detection systems could not warn of the increased electrical fields that precede a discharge, the investigation decided that their required use could still afford helicopters a measure of protection from the lightning strike risk. The investigation made the following recommendation to the Civil Aviation Authority (CAA) on 7 December 1996:

> *"In order to provide helicopter commanders with the necessary 'real time' information to enable them to avoid flight into areas of actual thunderstorms or lightning activity in Public Transport helicopters which have composite rotor blades, the CAA and affected operators should jointly agree the fitment of lightning discharge mapping systems to such aircraft. The Authority should also inform other airworthiness authorities of the action taken in response to this recommendation." (Safety Recommendation 95-45)*

The recommendation addressees responded by insisting that further equipment trials were necessary before a decision could be made, and that the e-field sensing approach should be pursued as this potentially offered the most benefits. Earlier, and in response to the accident, initial development work on an e-field meter system for helicopters had been started by Lightning Technologies Inc. (LTI) of the USA, with the active support of the North Sea companies and the CAA. However, in November 1996 support for the e-field sensor development project was withdrawn, because the North Sea companies felt it to be too expensive. They took the view that, because the project was pure research only, it should be funded solely by LTI. Consequently, the e-field sensor approach was effectively terminated at this time, at least in terms of active support from the North Sea companies and the CAA.

In April 1997 the CAA issued the following response to the safety recommendation:

> *"Although the Authority would agree that an airborne lightning sensor mapping system may provide some benefit as a supplemental aid for North Sea helicopter operations and may lower the chances of a lightning strike attachment, there can never be any guarantee of this and it remains the case that adequate lightning protection provisions must be installed on the helicopter. The Authority would therefore have difficulty in justifying mandating the installation of lightning mapping systems for airworthiness certification purposes."*

Operational guidance

Part A of the operator's Operations Manual contained crew actions to be carried out after a known or suspected lightning strike. It had recently been revised to highlight the fact that there would likely be considerable damage to rotor blades, rotor heads and associated components. The manual stressed that damage may not be visible or detectable through vibration, and that the helicopter should be diverted and landed at the nearest suitable land base. Furthermore, in case of secondary indications of damage such as severe and increasing vibration, the aircraft should be landed immediately.

The pilots were aware that the aircraft's Quick Reference Handbook (QRH) contained no actions or advice in respect of a lightning strike, though with hindsight they both thought it should have done so. The QRH in use at the time was introduced by the operator's Norwegian sister company and had been adopted for use for reasons of commonality. A revised Operations Manual Part B and QRH were in preparation at the time of the accident, which addressed the lack of lightning strike guidance in the QRH. The new QRH contained the following text under the title "LIGHTNING STRIKE":

> *1. LAND AS SOON AS POSSIBLE (Nearest land base recommended)*
>
> *If vibration increases significantly*
>
> *2. LAND IMMEDIATELY*

The new Part B and QRH have been issued to training captains and to the AS332L2 simulator. Line pilots are being trained but printing difficulties have resulted in an effective date of January 2007 for widespread distribution of printed copies to line pilots and into helicopters.

Analysis

The lightning discharge which attached to the helicopter was the only cloud-to-surface strike recorded over a wide area of the North Sea during a 12 hour period. Although the ATD systems do not record inter or intra-cloud strikes, which could therefore have been present in the area, there was no other lightning activity reported by the helicopter's crew. Considering the proximity of the recorded strike to the helicopter's actual position, it is probable that the recorded discharge was the actual strike in question. The absence of other recorded or observed lightning activity would indicate that this was a triggered strike, induced by the presence of the helicopter itself.

The crew were aware that a general risk of lightning had been forecast for the day which, as usual, was associated with thunderstorms. However, the crew had not encountered a thunderstorm and weather radar returns did not suggest any active cloud formations, despite the forecast instability in the atmosphere. Nevertheless, given that the crew reported hail shortly before the lightning strike, it is probable that the helicopter was flying beneath an area of significant convective activity. There was no reliable forecasting of increases in atmospheric voltage potentials, and without the benefit of airborne e-sensing equipment, the crew had no way of knowing that they were entering an area of increased risk.

The crew were concerned by the absence of information in the QRH concerning lightning strikes, although they were aware of relevant advice in respect of the likelihood of damage to rotors blades and associated components within Part A of the Operations Manual. Given that the advice in the Part A that the helicopter should be landed "*as soon as possible*" or "*immediately*" depending on whether there were indications of damage, it is unusual that the QRH did not reflect what is clearly and rightly considered to be a serious situation. However, the operator had by that time taken steps to introduce lightning strike actions into the QRH as part of a full review of the Operations Manual.

Despite the absence of specific instructions in the QRH, the crew's actions were in accordance with their company's Operations Manual. Aberdeen Airport, although further away than alternative landing sites, was the closest suitable location for a safe landing in the prevailing weather conditions.

Conclusions and safety action

The flight crew took appropriate steps to manage the risk of a lightning strike but the very presence of their helicopter in the vicinity of a cumulonimbus cloud induced a lightning strike. They were unaware of any secondary damage to the helicopter's hydraulics until the landing gear was lowered and thereafter, they took measures to manage the attendant risk.

The visible exterior damage to the helicopter was typical and so were the associated electro-magnetic symptoms of the passage of high electrical currents through otherwise visibly undamaged components, leading to their replacement. What was less typical and a further safety hazard was the hidden damage to the interior portions of the main rotor hydraulic actuators. Some of this damage may have been inflicted by an earlier lightning strike and this damage was not detected although the appropriate post-lightning strike checks had been carried out.

New post lightning-strike inspection procedures to be issued by the helicopter's manufacturer have been devised and will be issued to prevent a similar recurrence of undetected lightning damage leading to a hydraulic failure. Also, amendments to the operating company's recurrent training and to its Operations Manual should ensure that appropriate action is considered by flight crews when consulting the QRH immediately after a lightning strike. Consequently, the AAIB did not make any formal safety recommendations.

ACCIDENT

Aircraft Type and Registration:	Beech B58 Baron, N80HC
No & type of Engines:	2 Continental IO-520C piston engines
Year of Manufacture:	1975
Date & Time (UTC):	4 July 2006 at 1154 hrs
Location:	Guernsey Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Strikes to both propellers, engines shock loaded, damage to underside of forward fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	1,658 hours (of which 120 were on type) Last 90 days - 29 hours Last 28 days - 13 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, AAIB telephone enquiries and examination of photographs of damaged components

Synopsis

The pilot heard a loud bang during landing and carried out a go-around. He determined that the nose leg was unlocked and could not be correctly locked down. Considerable damage was inflicted during the subsequent landing. Examination revealed that a bolt in the operating mechanism had failed, causing a change of geometry which allowed excessive loads to be applied to the system, leading to further failure.

History of the flight

The pilot reported that during a visual approach to Runway 27, all landing checks were completed and a normal touchdown was made. As the nosewheel was lowered on to the runway, a loud bang was heard, followed by the landing gear warning horn sounding, the nose gear green light being seen to have extinguished and the gear unsafe light illuminating. Up elevator and go-around power were both applied and during the subsequent go-around it could be seen in the mirror on the left engine cowling that the nose leg was swinging free and unlocked. A flyby of the tower was carried out which did not reveal any further information.

A hold was carried out to the south of the airport where a partial retraction, followed by gear extension using the manual emergency system, was carried out. The nose leg remained in the same position throughout this procedure. An approach and landing was then carried out on Runway 27. As the main gear contacted the runway, the engine mixture levers were selected to CUT OFF and the magnetos were selected to OFF. As elevator authority reduced, both propellers contacted the ground. The aircraft came to rest in a nose down attitude; the pilot selected the fuel and master switches OFF before evacuating via the main door.

Engineering investigation

Subsequent examination of the aircraft by the repair company revealed that a bolt locating a drive rod operating the drag brace had sheared, thus affecting the geometry. As a result the normal over-centring action could not take place during the gear extension phase and the nose leg could not be locked down.

The landing gear assembly was returned to a company in the USA for repair and overhaul. No details of the failure mode of the bolt have so far been received. If any significant new information is received by the AAIB, this will be published in a further AAIB Bulletin.

ACCIDENT

Aircraft Type and Registration:	Cessna F172L, G-AZXD
No & type of Engines:	1 Lycoming O-320-E2D piston engine
Year of Manufacture:	1972
Date & Time (UTC):	21 July 2006 at 1700 hrs
Location:	Shobdon, Herefordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Impact damage to outboard rib; wing bent back; rear spar buckled
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	308 hours (of which 26 were on type) Last 90 days - 22 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft struck a parked trailer whilst taxiing.

History of the flight

The pilot reported that he landed on Runway 27. He then taxied back using Taxiway 'B' which runs from the western end of the runway, very close to the northern boundary, towards the parking area mid way along the field. Two large agricultural trailers were parked close to the taxiway, on a narrow grass strip separating it from the neighbouring potato field. One of the trailers was positioned at a slight angle to the taxiway axis, and one corner of it was thus very close to or slightly overlapping the paved taxiway surface. Although the pilot manoeuvred the aircraft to avoid the obstruction, its left wing struck the corner of the trailer about 6 to 8 inches in from the tip.

Pilot's comment

In his report the pilot accepted that he had misjudged the available wing tip clearance.

ACCIDENT

Aircraft Type and Registration:	Glasair III Turbine, G-ICBM	
No & type of Engines:	1 Allison 250-B17B turboprop engine	
Year of Manufacture:	2000	
Date & Time (UTC):	20 October 2006 at 1400 hrs	
Location:	Peterborough (Conington) Airfield, Cambridgeshire	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Nosewheel detached, nose leg fork abraded and propeller blades broken	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	55 years	
Commander's Flying Experience:	9,486 hours (of which 2 were on type) Last 90 days - 100 hours Last 28 days - 50 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The handling pilot was undergoing a Licensing Skills Test. After the landing a pilot-induced oscillation in pitch occurred; the nose landing gear failed and the examiner took control bringing the aircraft to a stop on the runway. There were no injuries or fire.

History of the flight

The handling pilot, who had also built the aircraft, was undergoing a Licensing Skills Test. The examiner reported that, after landing at the correct speed on Runway 28, the pilot was slow to retard the power and, shortly after touchdown, a pilot-induced oscillation (PIO) in pitch occurred. On the second cycle of the PIO the nose pitched down heavily, the nose landing gear failed and the examiner took control. The aircraft was brought to a stop on the runway and shut down. There was no fire and the crew were uninjured. The aircraft also suffered damage to its five-bladed propeller and the engine was potentially shock loaded; further inspection of the damage to the engine is being conducted. The weather conditions were good, with scattered cloud at 2,500 ft agl, a surface wind from 260° at 6 kt and 50 km visibility.

Another flying instructor at the airfield observed the accident from outside the airfield's hangar. He had seen the aircraft making a number of approaches during the previous week. On this occasion the approach seemed to be fast, which caught his attention. He reported that the aircraft landed firmly, the nose pitched forward and, as it continued down the runway, he saw what appeared to be flames coming from the aircraft. The airfield rescue and fire fighting vehicle attended the aircraft without delay but there was no fire. It was surmised that the 'flames' had, in fact, been sparks from the remaining nose landing gear fork, which had been abraded and had left scrape marks on the runway.

ACCIDENT

Aircraft Type and Registration:	Piper PA-23-160 Apache, G-MOLY
No & type of Engines:	2 Lycoming O-320-B3B piston engines
Year of Manufacture:	1959
Date & Time (UTC):	17 July 2006 at 1645 hrs
Location:	Little Shelford, Cambridge
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to left wing tip, pitot mounting, left flap and left landing gear drag link
Commander's Licence:	Private Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	2,242 hours (of which 134 were on type) Last 90 days - 29 hours Last 28 days - 15 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and aircraft examination by the repair agency

Synopsis

While on the ground, the pilot inadvertently operated the landing gear retraction lever resulting in the collapse of the left gear and causing damage to the aircraft. The aircraft anti-retraction system was found to have been in the 'FLIGHT' position, thus allowing the gear to retract while on the ground.

History of the flight

The aircraft had completed an uneventful flight from White Waltham to Little Shelford in Cambridgeshire. Having landed on the easterly runway, the aircraft was taxied off the runway and, while stationary, the pilot inadvertently operated the landing gear retraction lever. Both left and right landing gear 'UNLOCKED' lights illuminated. Realising his mistake, the pilot stopped both engines in order to limit the damage and attempted to manually pump the landing gear into the down position. The right landing gear 'DOWN AND LOCKED' indication did illuminate, however the left landing gear collapsed causing damage to the left wing tip, left flap and its operating mechanism. The single occupant exited the aircraft without difficulty.

The aircraft was jacked, the left landing gear lowered and all three landing gear 'DOWN AND LOCKED' indications then illuminated.

System description

The aircraft has a hydraulically actuated retractable tricycle landing gear system; each landing gear leg is individually actuated by a hydraulic actuator. When the landing gear is selected DOWN, hydraulic pressure causes each actuator to extend a drag link on the respective gear leg until the link reaches an over-centre position. The final movement of the actuator causes a mechanical lock to lock the drag link in the over-centre position. Once the landing gear has locked down, microswitches for each gear leg trigger their respective green lights in the cockpit and the gear selector returns to the neutral position. When the gear is selected UP, the actuators retract causing the downlocks to unlock and the drag links to collapse. Once the gear is locked up, microswitches cause an amber light in the cockpit to illuminate and the gear selector returns to the neutral position. When no lights are illuminated the landing gear is in an intermediate position.

If the engine-driven hydraulic pump fails, an emergency hand pump can be used in its place. In the event of a hydraulic system failure caused by a line rupturing, an emergency CO_2 bottle can be activated to blow the landing gear down.

The aircraft is fitted with an anti-retraction system to prevent the landing gear from retracting when the aircraft is on the ground. A landing gear anti-retraction valve is located on the left main gear strut housing. This restricts hydraulic fluid pressure from building up in the retraction system until the landing gear strut is fully extended, ie the aircraft weight is no longer on the wheels.

Aircraft examination

Figures 1 and 2 respectively show the anti-retraction valve in the closed position, ie aircraft in flight, and the open position, ie aircraft on the ground. The actuating rod is attached to the left main landing gear; when the oleo is in the compressed position, the rod is pushed

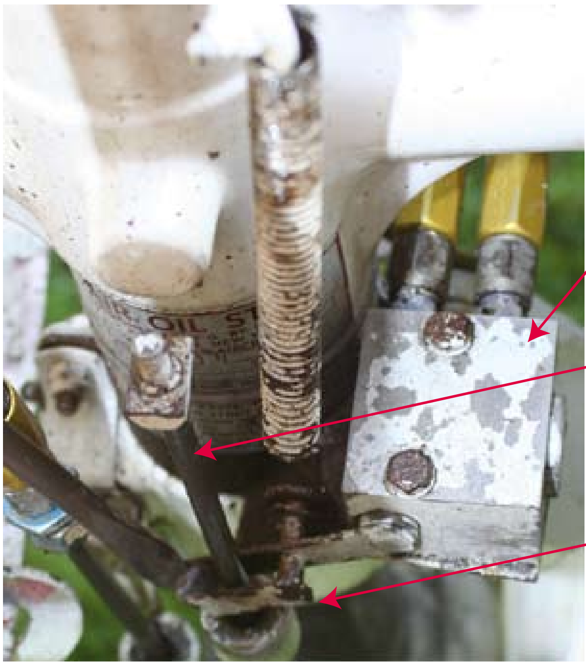


Figure 1

Anti-retraction valve in closed position - aircraft in flight

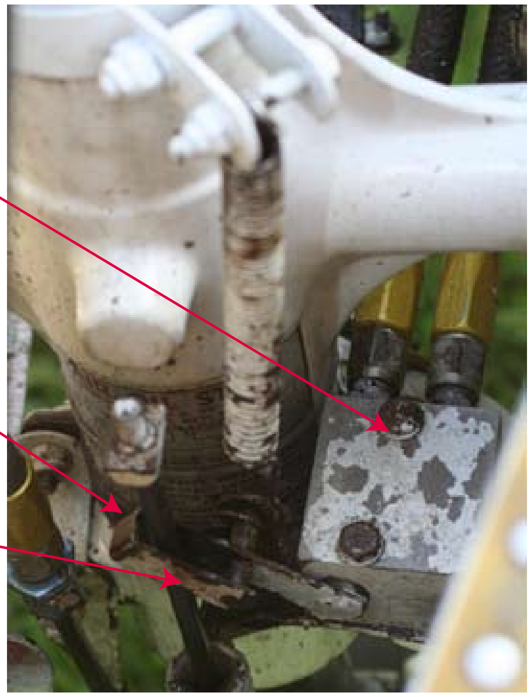


Figure 2

Anti-retraction valve in open position - aircraft on ground up which in turn pushes the valve operating arm up. Examination of the anti-retraction valve showed that the operating arm had been stuck in the closed position. Debris and corrosion in this area had built up causing the operating arm to become stuck. In the opinion of the repair agency it had been in this condition for some time and thus represented a dormant failure. With the anti-retraction valve in the 'FLIGHT' position it was possible for the landing gear to retract when the aircraft was on the ground.

The operating arm was manually freed, the spring pulled the operating arm into the ground position, and the valve then operated correctly.

The Piper Apache service manual requires a check of the anti-retraction system at every 50 hour inspection. The last check on G-MOLY was an annual inspection carried out on the 17 February 2006.

INCIDENT

Aircraft Type and Registration:	Piper PA-23-250, G-BBHF
No & type of Engines:	2 Lycoming IO-540-C4B5 piston engines
Year of Manufacture:	1973
Date & Time (UTC):	4 July 2006 at 1440 hrs
Location:	Between Lands End and St Mawgan
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage limited to left engine
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	1,980 hours (of which 27 were on type) Last 90 days - 208 hours Last 28 days - 68 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, engine strip examination in the presence of the AAIB and further detailed metallurgical examination

Synopsis

The aircraft suffered an engine failure during the cruise, diverted and subsequently landed safely at St Mawgan.

History of the flight

The aircraft had taken off from Lands End Airfield and was cruising at about 2,000 ft when the left engine failed. The pilot feathered the propeller and carried out the engine failure checks. He secured the engine and decided to divert to St Mawgan. The aircraft hydraulic system, which operates both the landing gear and flaps, was by now inoperative; consequently the pilot performed an orbit on final approach in order to manually lower the landing gear. He then carried out a successful flapless landing without further damage or injury.

Initial examination of the left engine revealed that a connecting rod had been ejected through the crankcase but had been retained within the engine cowling.

Aircraft description

G-BBHF was fitted with two Lycoming IO-540-C4B5 fuel injected six cylinder, direct drive, horizontally opposed, air cooled engines. This aircraft type has a hydraulically actuated retractable tricycle landing gear system; each landing gear leg is individually actuated by a hydraulic actuator powered by a pump driven by the left engine. If the engine driven hydraulic pump fails, an emergency hand pump can be used in its place. In the event of a hydraulic system failure caused by a line rupturing, an emergency CO_2 bottle can be activated to blow the landing gear down. The flaps are also hydraulically actuated.

Aircraft and maintenance history

Both engines had been subject to an overhaul to zero hours in January 2002 and were refitted to G-BBHF in July 2002. In November 2002 the aircraft was grounded awaiting the embodiment of an Airworthiness Directive (AD 2004-05-24) which required the replacement of the crankshaft gear retaining bolt on both engines. This work was completed in January 2003 and carried out 'in-situ' by hoisting the engines without complete removal. However, following this work there were pilot reports that the aircraft 'would not fly straight' and in May 2003 it was found that the left engine mounts had been incorrectly fitted. Rectification work was carried out as a result.

Since the overhaul both the left engine (serial number L11064-48) and the right engine (serial no L-1545-40) had completed around 130 hours. The most recent maintenance was a 50-hour check carried out on 23 January 2003, 30 hours prior to the engine failure. At that time a note in the left engine log book stated: 'very small amount of alloy particles found in oil filter, considered fit to continue and to be re-inspected at next 50-hour inspection'.

Engine strip examination

The left engine was removed from the aircraft and stripped in the presence of the AAIB. There was a hole in the crankcase which had been caused by the No 4 cylinder connecting rod being forced through it. The connecting rod and remains of the bolts were found retained within the engine cowling. Pieces comprising the complete connecting rod assembly and bolts were found but not the No 4 crankshaft bearing shell. All the fractures of the recovered components were consistent with overload failure and there was no evidence of fatigue.

The oil filter was removed, disassembled and was found to contain a large amount of metallic debris. The oil pump had seized due to the presence of additional metallic debris; once this had been cleared the oil pump was free to rotate. The engine oil sump was removed and the sump filter found almost full of similar debris.

The crankshaft and its main bearings exhibited some wear consistent with the amount of debris which had been circulating in the oil. The connecting rods from all the other five cylinders were undamaged and the bolts found to be correctly torque tightened. The piston crowns exhibited a normal amount of combustion deposits although the piston skirts did show some scoring, again consistent with circulating debris. The piston rings were intact, free in their grooves and exhibited normal operating wear. The piston pin and plug assemblies were intact and undamaged and showed only a small amount of wear, consistent with the low number of engine hours. The crankshaft bolt, which had been the subject of the AD, was found to be correctly torque tightened.

The debris from the oil was examined using a Scanning Electron Microscope and found to be consistent with crankshaft bearing shell material. The oil filter from the right engine was removed for examination and found to be clean.

Both magnetos were tested satisfactorily. The spark plugs were in serviceable condition; the electrodes were clean and had only light deposits.

Discussion

The final uncontained failure of the connecting rod could be attributed to the break-up of the No 4 crankshaft bearing. The other connecting rods had been correctly torqued and although the torque on No 4 could not be checked all the fracture surfaces were consistent with overload failure so it was unlikely that the bolts had been loose. The wear in the other bearings was consistent with the debris circulating in the oil and so it is possible that some debris was already circulating, which led to the break up of the No 4 bearing. At the last 50-hour check the presence of some particles had been noted. It was not possible to identify the source of the initial contamination from the large amount of debris now present in the oil.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-161 Cherokee Warrior II, G-BODR
No & type of Engines:	1 Lycoming O-320-D3G piston engine
Year of Manufacture:	1979
Date & Time (UTC):	2 August 2006 at 1330 hrs
Location:	A field south of Wycombe Air Park, Buckinghamshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to the landing gear and left wing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	19,840 hours (of which 175 were on type) Last 90 days - 227 hours Last 28 days - 93 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and a report by a locally-based licensed engineer

Synopsis

During the climb out following a touch-and-go landing, after a cross-country flight, the engine rapidly lost power and subsequently stopped. A forced landing in a field was carried out during which the landing gear and left wing were damaged. Subsequent examination revealed that there were 50 litres of fuel in the left fuel tank but only 150 millilitres in the right tank.

History of the flight

On the day of the accident the pilot planned to fly from Wycombe to the Isle of Wight and return without landing. The expected flight time was to be approximately 1 hour and 20 minutes. During the initial internal checks the pilot noted that the fuel gauge for the left tank was registering approximately 17 gall US (64.6 litres) and the gauge for the right tank between ¾ and full (67 to 90 litres). He completed the pre-flight aircraft checks, including a visual check of the contents of both fuel tanks. The left tank contained fuel to the tab indicator. The right tank contained fuel to a level very slightly below the tab indicator. The technical log/authorisation sheet indicated that the aircraft held a total of 97 litres of fuel. The Pilot's Operating Handbook states that the aircraft's total usable fuel capacity is 180 litres divided equally between the left and right tanks.

The pilot started up using the right tank, which appeared to contain the lesser amount of fuel. Prior to changing to the left tank he had to return to the aircraft dispersal to change a defective headset, entailing some delay. For engine power checks, takeoff and departure the pilot had the left tank selected in accordance with the checklist. The aircraft departed Wycombe at 1205 hrs, airborne time. When approximately abeam Farnborough, about 10 to 15 minutes after takeoff, he changed from the left to the right tank, which he intended to use until the approach check when returning to Wycombe. During the flight the pilot deviated from his planned track around Lasham to avoid gliding activity in that area, climbed to 4,000 ft to transit over the Solent and carried out an orbit around Hurst Castle. The aircraft performed normally except that, towards the end of the return leg to Wycombe, the pilot noticed a tendency for it to roll slightly to the left. He adjusted the rudder trim and checked the fuel gauges for a possible reason, but both tanks showed roughly equal quantities, around 15 gall US (57 litres).

Shortly afterwards, and just prior to entering the Wycombe ATZ, the pilot carried out a fuel, radio, engine, direction indicator, altimeter (FREDA) check and noted that both fuel tanks were indicating approximately 15 gall US (57 litres). The flight time prior to this point was approximately 1 hour and 10 minutes. The pilot joined the circuit directly onto the downwind leg for Runway 24 and completed the 'downwind' checks. The fuel gauge readings appeared similar to those observed in the FREDA check. At the end of the downwind leg he elected to carry out a touch-and-go instead of a full-stop landing. The extra circuit and landing were to be for handling practice. The touch-and-go landing was uneventful and the aircraft was climbed towards circuit height following the noise abatement procedure.

At approximately 100 to 200 feet (just after retraction of 'drag' flap) the engine rapidly lost power, at which point the pilot lowered the aircraft's nose and altered course by approximately 60º to the left and headed towards a field. During the brief approach to this field he carried out visual engine failure checks which did not determine a cause for the failure. He notified the control tower that the aircraft had suffered an 'engine failure' and positioned the aircraft for a landing. At about 100 ft agl the engine power was momentarily restored but then failed again. This power surge provided the pilot with the opportunity to reselect a slightly better landing area beyond the original aiming point. There was insufficient height or time for further trouble-shooting so he committed to a landing, closed the throttle and touched down in the selected field on a heading of about 070º. During the landing roll, despite maximum braking, it appeared that the aircraft was not going to stop before contacting the far hedge and tree-line, so rudder and differential braking were used to yaw the aircraft to the left. The aircraft came to a halt at approximately 1320 hrs, about 15 to 20 m from the hedge and on a heading of around 360º. The time from when the right tank was selected until the accident was approximately 1 hour and 15 minutes.

Engineering examination

A locally-based licensed aircraft engineer attended the aircraft some 30 minutes after the event. On inspection there was no fuel visible in the right tank but the left tank was showing slightly below the tab (the tab indicates approximately 64 litres out of a total usable capacity of 90 litres). There were no signs of any fuel leakages from either tank or their drain valves. On checking the engine, there were no signs of any leaks and the engine turned over freely.

On entering the aircraft, the fuel, magneto and battery master switches were all found switched off although all the other electrical services switches were selected on. On selecting the battery master switch ON there was no indicated fuel pressure (normally on this aircraft type there is fuel pressure indicated on the gauge for a considerable time after the engine is switched off). The left fuel gauge indicated approximately half full (12 gall US/45.6 litres), whilst the right fuel gauge indicated about 2 gall US/7.6 litres. With the fuel selected to the right tank and the electric fuel pump switched on the fuel failed to prime (rapid 'clicking' heard) and the fuel pressure gauge needle did not move. On selecting the left tank the fuel pump primed ('clicking' slowed) and the fuel pressure gauge indicated 4 psi, which is normal.

Having ascertained that the undercarriage was not in danger of collapsing, the engine was started with the left fuel tank selected and it started and ran normally. A full-power engine run was carried out and all indications were normal. The results of magneto and carburettor heat checks were found to be normal. The right fuel tank was then selected with the engine speed set at 1,500 rpm. After 65 seconds the fuel pressure smoothly dropped to zero and 15 seconds later the engine stopped and would not restart. On selecting the left fuel tank the electric fuel pump was used to reprime the fuel system and the engine started and ran normally again.

Prior to recovery of the aircraft from the accident site, approximately 50 litres of Avgas was drained from the left tank and 150 millilitres drained from the right tank (both through their respective drain valves). The Pilot's Operating Handbook states that the unusable fuel in critical flight attitudes is 1 gall US (3.8 litres); the Maintenance Manual gives an unusable quantity of 0.125 gall US (0.47 litres) per tank.

Analysis

The pilot gave a very full and frank account of the circumstances of this accident and made the following assessment of why it occurred:.

"The primary cause was my failure to select to the left tank during the FREDA and the downwind checks when returning to the Wycombe airfield.

The secondary causes were:-

1. *Possible visual overestimation of fuel quantity in right tank.*
2. *Optimistic right fuel gauge.*
3. *Increased fuel burn due to:*
   a. *Long taxi time due to change of a defective headset,*
   b. *Diversion around Lasham due to gliders,*
   c. *Climb to 4000 ft over the Solent,*
   d. *An orbit over Hurst Castle*

I had estimated that there should have been 15 minutes endurance remaining in the right tank when I returned to Wycombe airfield. The above factors had reduced this to just a few minutes.

I have tried to understand why I failed to change back to the left tank, as I had planned to do so, on the return leg. After leaving the Farnborough MATZ there were a number of distracting factors:

Radio frequency change from Farnborough to Wycombe, with associated RT calls.
Descent due to LHR TMA ahead.
Moderate turbulence.
The attempted diagnosis of increasing roll tendency.

I believe that my observation of equal (and sufficient) fuel quantities, at this point, persuaded me to leave the fuel selection as it was for the remaining 10 minutes of the flight.

I believe now that I should have been more pessimistic in my fuel calculation in view of the factors in (3) above and certainly not have attempted an extra unplanned circuit, without reconfiguring the fuel system."

ACCIDENT

Aircraft Type and Registration:	Piper PA-32R-300 Lance, G-DTCP
No & type of Engines:	1 Lycoming IO-540-K1G5D piston engine
Year of Manufacture:	1977
Date & Time (UTC):	25 August 2006 at 1411 hrs
Location:	Cranfield Airport, Bedfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passenger(s) - None
Injuries:	Crew - None Passenger(s) - N/A
Nature of Damage:	Nosewheel collapse, propeller damaged, engine shockloaded and engine exhaust stubs crushed
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	26,000 hours (of which 160 were on type) Last 90 days - 250 hours Last 28 days - 80 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During taxi the GPS assembly fell from the right instrument panel. The commander attempted to catch the unit, with the aircraft still in motion. Whilst the commander was distracted the aircraft departed the taxiway, causing the aircraft to sink into a 'french' drain, leading to the collapse of the nosewheel.

History of the flight

The commander's intention was to fly a private flight from Cranfield to Farnborough. The commander taxied the aircraft toward holding point A1 for Runway 21. As he passed the crossing for Runway 18, the GPS assembly fell from the right instrument panel, pulling its wiring with it. As it appeared that the falling unit might cause damage, the commander attempted to catch it, requiring him to stretch across the right seat. At this point the aircraft was still in motion and was approaching a series of bends in the taxiway, firstly to the right followed by a turn left. The aircraft drifted to the left of the centre line and departed the hard surface of the taxiway. The commander attempted to regain the taxiway using the rudder pedals, but the nosewheel sank into a 'french' drain that ran along the side of the taxiway. The nosewheel subsequently collapsed causing damage to the propeller and engine. The commander did not suffer any injuries and was able to exit the aircraft in the normal manner.

The GPS assembly had been held in place on the instrument panel by the use of double-sided sticky tape. The commander suggested that the ambient heat had allowed the tape to soften, reducing its adhesive properties and allowing the unit to fall.

The commander has admitted, in hindsight, that he should not have been distracted by the falling GPS assembly and, instead of trying to catch the unit with the aircraft still in motion, he should have stopped the aircraft and then dealt with the situation. As a result of this accident, the commander now makes a point of checking the security of all 'temporary' instruments.

ACCIDENT

Aircraft Type and Registration:	Pitts S-2A, G-TIII
No & type of Engines:	1 Lycoming AE10-360-A1A piston engine
Year of Manufacture:	1979
Date & Time (UTC):	25 June 2006 at 1115 hrs
Location:	Redhill Aerodrome, Surrey
Type of Flight:	Private
Persons on Board:	Crew -1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller and underside of fuselage; engine shockloaded; damage to the G3 aerodrome marker board
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	3,506 hours (of which 131 were on type) Last 90 days - 136 hours Last 28 days - 56 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

While being taxied to the parking area after landing, the aircraft collided with a marker board.

History of the flight

After landing on Runway 08L, the pilot of G-TIII was cleared to vacate to the left and follow the taxiway to the 'A3' hold. Then, as the aircraft was taxiing in a northerly direction, the pilot was cleared to cross the grass to the west towards his parking area. He subsequently commented that he was weaving the aircraft as he crossed Runway 18 to ensure that he avoided the runway markers which were small frangible posts about 12 inches high. However, once clear of the runway, the aircraft struck the 'G3' marker board; this board indicated the hold position for Runway 18.

The weather was good and the pilot acknowledged that he was familiar with the position of the 'G3' board. He also accepted that he had responsibility for ensuring that his taxi route was clear. However, he commented that the board was 'end-on' and therefore least visible from the direction from which he was approaching. Additionally, the background to the board included hangars, parked aircraft and helicopters, which made it more difficult to see.

Background information

This was the third accident involving tailwheel aircraft colliding with the 'G3' board since November 2005.

The first accident, involving G-BWEF on 19 November 2005, was reported in AAIBBulletin 6/2006 together with the following recommendation:

> *'Redhill Aerodrome Limited establishes a programme of regular formal meetings with flying organisations based at the aerodrome to discuss and monitor operating procedures.'*

In response to that recommendation, the aerodrome authority stated:

> *'Redhill Aerodrome Limited will consult with the based flying training organisations as the benefits of re-establishing the User's Committee in addition to the consultation/notification presently undertaken by e-mail and the Redhill Aerodrome web site'.*

After the second accident, involving G-BMKB on 6 April 2006 and reported in AAIB Bulletin 8/2006, the Aerodrome Operator stated on 27 June 2006 that a User's Meeting was planned for 20 September 2006 but that there appeared to be "little enthusiasm for the meeting". The operator also stated that the taxi routes for fixed wing aircraft had been amended and promulgated in the Aerodrome Operator's Circular. This amendment became effective on 27 June 2006, one day after the accident involving G-TIII. The amendment would be reviewed at the end of the summer period.

Conclusion

Three separate accidents involving different aircraft colliding with the same marker board indicates a problem with the position and conspicuity of the marker board. If the board is required and cannot be made more visible, the sensible solution would be to restrict the movement of aircraft within the vicinity of the board. The aerodrome operator has amended the taxi procedures and the User's Meeting on 20 September 2006 was an appropriate time to review the situation.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna F152, G-BHDR
No & type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1980
Date & Time (UTC):	1 August 2006 at 0905 hrs
Location:	1.7 nm north of Tillicoultry, Clackmannanshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller hub separated, nose leg bent aft, wings bent, tail section separated from fuselage
Commander's Licence:	Commercial Pilot's Licence with Instructor Rating
Commander's Age:	35 years
Commander's Flying Experience:	1,625 hours (of which 1,050 were on type) Last 90 days - 97 hours Last 28 days - 40 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

During a cross-country flight below cloud level the engine began to run rough and then lost all power. A forced landing was carried out on a hillside, which resulted in the aircraft turning upside down. Carburettor ice formation was considered a potential cause of the engine failure.

History of the flight

The pilot was carrying out a cross-country flight from Cumbernauld Airport to Perth. He had been cruising at 1,700 feet just below the cloud base while approaching the Ochil Hills, when he decided to initiate a climb as the clouds over the hills were higher than over the valley. While climbing through 2,400 feet the engine began to run rough and lose power. The pilot applied carburettor heat, confirmed that the fuel cock was ON, the mixture was set to RICH and that the master switch was ON. However, very shortly afterwards the engine lost all power. He attempted to restart the engine, without success, so he prepared for a forced landing on the ridge of a hill. While manoeuvring for the landing he continued to try to restart the engine. Eventually the engine started but it ran rough and produced insufficient power for the aircraft to climb. The pilot extended full flap, shut off the fuel, turned off the master switch and then reduced the aircraft's speed towards the stall; he then successfully 'stalled' the aircraft onto the upward slope of the valley. The left wheel touched down first, followed by the nosewheel, and then the aircraft flipped upside down within 5 to 8 metres of the touchdown point. The pilot was able to exit the aircraft through the window unassisted.

Weather

An aftercast issued by the Meteorological Office estimated that the temperature and dewpoint in the area at the time of the accident were 14ºC and 12ºC respectively (relative humidity of 87%) at ground level. At 1,700 to 2,400 feet the temperature would have been slightly lower and the humidity slightly higher. The chart of carburettor induction system icing probability in Safety Sense Leaflet 14 of LASORS[1] indicated that, in these conditions, there was a serious risk of icing at any power setting for a typical light aircraft piston engine without carburettor hot air selected.

Aircraft examination

Before the aircraft was recovered from the hill side the aircraft was heavily vandalised. The propeller and wheels were taken and all the flight instruments were stripped. No examination of the engine, induction system or fuel system was carried out by the operator.

Pilot's assessment of the cause

The pilot reported that he had applied carburettor heat as part of his cruise checks approximately 5 minutes before the engine started to run rough, but he believes that carburettor ice could still be the cause. He reported that his application of carburettor heat after the engine started to run rough might have dislodged a build-up of ice, causing the engine to ingest water, resulting in the sudden engine failure.

Analysis

A problem with the engine, induction system, fuel system or fuel could not be ruled out as potential factors in the engine failure because no examination was carried out. However, the atmospheric conditions at the time and the symptoms experienced by the pilot indicated that carburettor ice could have been a factor. In AAIB Bulletin 5/2004, the AAIB published Safety Recommendation 2004-01 recommending that the CAA sponsor or conduct research on the effects of carburettor ice. Since then the CAA has carried out carburettor ice research and a report on the results is pending. The CAA Safety Regulation Group Safety Plan 2006 stated the following with regards to carburettor icing:

> *'Since 1976 Carburettor Icing has been a contributory factor in 14 fatal accidents and in over 250 other occurrences in the UK with numerous AAIB recommendations to SRG. Progress has repeatedly been hampered by the lack of data on where ice forms, how quickly and how much heat is effective in removing it. There has also been some doubt that the level of carburettor heat required by the Airworthiness Requirements (e.g. EASA CS-23) is adequate to mitigate the risk. CAA has conducted research using a specially designed carburettor test rig in conjunction with Loughborough University and an industry partner for systematic data collection. The CAA will publish a report on carburettor icing, including potential mitigation.'*

Footnote

[1] LASORS (Licensing Administration Standardisation Operating Requirements Safety) is an annual publication by the CAA containing '*essential licensing requirements and safety information for pilots of all aircraft*'.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna F172M Skyhawk, G-BAEY
No & type of Engines:	1 Lycoming O-320-E2D piston engine
Year of Manufacture:	1972
Date & Time (UTC):	18 April 2006 at 1053 hrs
Location:	Conington Airfield, Peterborough
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller tips and nosewheel, buckling of fuselage skin and cockpit floor
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	485 hours (of which 90 were on type) Last 90 days - 22 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The pilot reported that shortly before touchdown the aircraft pitched up unexpectedly. He responded by pushing forward on the control yoke. The aircraft landed on its nosewheel, causing the nose landing gear to collapse, bucking of the fuselage skin and cockpit floor, and damage to the propeller. There was no evidence of a pre-existing mechanical defect that would have resulted in the unexpected manoeuvre or of any weather conditions that might have affected the flight adversely.

History of the flight

The pilot intended to conduct a flight for the purpose of aerial photography, for which he would carry a photographer as passenger. Because he had not flown a single piston-engine aircraft since September 2005, he was required beforehand to carry out three takeoffs and landings in order to meet the requirement to have recent experience before carrying a passenger[1]. Accordingly, he planned to fly, on his own, a series of circuits and landings on the tarmac Runway 28 at Conington, where the aircraft was based.

Footnote

[1] A pilot shall not operate an aeroplane or helicopter carrying passengers as pilot-in-command or co-pilot unless that pilot has carried out at least three takeoffs and three landings as sole manipulator of the controls in an aeroplane or helicopter of the same type or class to be used in the preceding 90 days. In order to meet these experience criteria a pilot may fly with a flight instructor, providing that the instructor does not influence the controls at any time.

The flight was observed from the ground by another pilot who flew regularly for the aerial photography organisation, which referred to him as the "Senior Pilot". He and other witnesses on the ground reported that the first circuit was uneventful until the landing, during which the aircraft bounced several times before going around into another circuit. The aircraft pilot recalled that at the end of this circuit, following a stable final approach, he flared the aircraft for landing. During this manoeuvre the nose pitched up unexpectedly to above the normal landing attitude and in order to prevent the aircraft from stalling he pushed forward on the control yoke to lower the nose. Shortly afterwards the aircraft touched down heavily on its nosewheel, causing the nose landing gear to collapse partially and allowing the tips of the propeller blades to make contact with the runway. Despite this damage the uninjured pilot was able to taxi the aircraft to a parking position at the eastern end of the airfield.

The Senior Pilot reported that, immediately after the accident, the pilot of G-BAEY had expressed concern that there may have been a control restriction which resulted in his being unable to manoeuvre the aircraft satisfactorily. He appeared re-assured, however, when told that the aircraft had flown without incident since its most recent scheduled maintenance. In his statement to the AAIB the pilot commented that a sudden and unexpected change of wind direction and strength may have caused the nose of the aircraft to pitch up suddenly.

Pilot's recency

The accident pilot had not flown a single-engined piston aircraft within the previous 90 days. His recent flying experience had been accrued in a jet transport aircraft simulator.

Damage to aircraft

The nose landing gear was displaced laterally and vertically in a manner consistent with a high rate of descent on touchdown. Upward displacement of the instrument panel had trapped the shafts of both control yokes, the position of which corresponded to a nose-down elevator input[2]. Ripples in the skin of the fuselage and upward displacement of the cabin floor indicated a very heavy landing.

Aircraft information

The Cessna 172 is a high wing single engine aircraft with a tricycle landing gear. In common with most aeroplanes it is designed to touch down on its main wheels. The nose landing gear provides steering and stability but is not designed to absorb the first impact of landing. The maximum crosswind for takeoff or landing demonstrated by the manufacturer was 15 kt.

The organisation responsible for maintaining G-BAEY had no record of any pre-existing mechanical defects that would have contributed to the accident. Following an annual inspection the aircraft had returned to service on 12 April 2006, six days before the accident, and had flown uneventfully until the accident.

Meteorological information

The surface wind reported by the AFIS at the time of the accident was from 260º at 15 kt with visibility of 10 km or greater and scattered cloud at 4,000 ft. The pilot reported that the actual wind was varying between 260º and 290º at 15 kt. This would have resulted in a maximum crosswind component of approximately 5 kt.

Footnote

2 The control yokes are mounted on horizontal shafts which run through the instrument panel ahead of each pilot. The shafts rotate to transmit aileron inputs and move fore and aft to transmit elevator inputs.

The local topography is not noted to produce unusual surface winds or turbulence and no weather conditions were reported which would have adversely affected the safe operation of this type of aircraft. The runway surface was dry.

Previous occurrences

A review of previous AAIB bulletins revealed several similar occurrences, in which approaches became unstable shortly before landing and attempts to lower the nose abruptly resulted in damage to the nose landing gear and propellers. These occurrences were not confined to a particular design of aircraft.

Conclusion

The available evidence indicates that the aircraft was serviceable prior to the accident. It is unlikely that the reported weather conditions affected the flight adversely. The aircraft touched down on its nosewheel, subjecting the nose landing gear to loads in excess of those for which it was designed and causing it to fail. The shafts of both control yokes were trapped when transmission of these loads through the firewall caused deformation of the cockpit floor and instrument panel.

Discussion

Safety Sense Leaflet 1e – *Good Airmanship*, published by the CAA, contains the following advice under the heading *Landing*:

> *a. A good landing is a result of a good approach. If your approach is bad, make an early decision and go-around. Don't try to scrape in.*
>
> *b. Plan to touch down at the right speed, close to the runway threshold, unless the field length allows otherwise. Use any approach guidance (PAPI/ VASI) to cross-check your descent.*
>
> *c. Go-around if not solidly 'on' in the first third of the runway, or the first quarter if the runway is wet grass.*

If an approach or landing appears to be unstable, a go-around reduces the immediate danger of flight near to the ground and provides an opportunity to reassess the conditions before making another attempt. A pilot who is experiencing consistently unsatisfactory approaches and landings should seek the assistance of a qualified flying instructor who is familiar with the particular type to be flown.

ACCIDENT

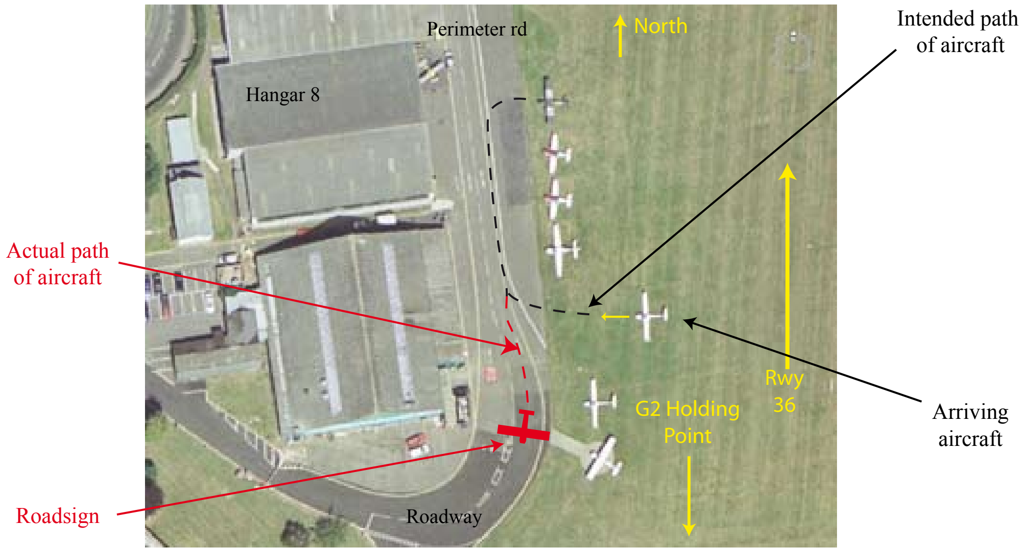
Aircraft Type and Registration:	Stampe SV4A (Modified), G-AZNK
No & type of Engines:	1 Gipsy Major 10 MK1 piston engine
Year of Manufacture:	1946
Date & Time (UTC):	4 August 2006 at 1015 hrs
Location:	Redhill Aerodrome, Surrey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - Nil Passengers - N/A
Nature of Damage:	Damage to propeller and landing gear
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	372 hours (of which 16 were on type) Last 90 days - 4 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB enquiries

Synopsis

After taxiing in front of a hangar for a short distance, the pilot found that the point at which he intended to turn onto the grass surface had been obstructed by an arriving aircraft. The pilot continued to taxi the aircraft in an attempt to find another suitable point and, in doing so, entered an area not intended for aircraft movements. In searching for a new turning point, he looked solely out of the left side of the cockpit and did not see a road sign and traffic island positioned to his right. The aircraft struck the road sign at slow speed, damaging the propeller and landing gear.

History of the flight

The aircraft had been parked amongst a line of light aircraft, on the apron area facing Hangar 8. After start up, the pilot was given clearance to taxi on the grass west of Runway 18/36, to Holding Point G2 for an intersection departure on Runway 36. The pilot moved the aircraft forward and turned left to follow the line of parked aircraft, with the intention of turning onto the grass at a gap between aircraft, Figure 1. As he approached the gap, an arriving aircraft pulled into it, preventing him from making the turn. The pilot continued to taxi and, because he was looking down the left side of the aircraft for another point to cross onto the grass, he allowed the aircraft to enter an area not intended for aircraft movements. The aircraft hit a



Aerial photograph from Google Earth

Figure 1

road sign mounted on a small traffic island, Figure 2, at very low speed, sustaining damage to the right landing gear and propeller.

The airfield

The airfield surface at Redhill Aerodrome is predominantly grass but, outside Hangar 8, there is a paved surface with markings for both a roadway and a small 'apron', large enough to allow aircraft to be parked facing the hangars without infringing the road. Aircraft facing the hangar must taxi onto the road for a short distance and find a suitable point at which to turn back onto the grass surface before entering the area clearly marked as a road. The road sign and traffic island had been in position for several years and the pilot confirmed that he was aware of their presence.

When in the ground attitude, the pilot's field of vision ahead in a tail wheeled aircraft such as the Stampe, is extremely limited. When taxiing, a pilot must frequently look out of both sides of the cockpit, weaving from side to side, to ensure that the aircraft's path is free from obstructions.

Figure 2

Accident

Aircraft Type and Registration:	Tecnam P2002-EA Sierra, G-TESI
No & type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2006
Date & Time (UTC):	17 September 2006 at 1300 hrs
Location:	Draycott Farm, Swindon, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Fuselage, engine frame, nosewheel, left wing and propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	63 years
Commander's Flying Experience:	196 hours (of which 55 were on type) Last 90 days - 30 hours Last 28 days - 13 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Immediately after lifting off from an undulating grass airstrip, the aircraft rolled to the left and landed heavily some 25 m to the left of the runway.

History of the flight

The aircraft departed Hinton-in-the-Hedges with a total fuel load of around 75 litres, giving an endurance of approximately three and a half hours. The aircraft was equipped with a fuel tank in each wing, each placarded at 50 litres, but which the pilot stated actually held 55 litres. After an uneventful fight and landing at Draycott Farm, Swindon, the pilot and his passenger spent a couple of hours socialising, after which the pilot offered one of their company a flight.

Having boarded the aircraft with his new passenger, the pilot carried out his usual checks in preparation for the flight, during which everything appeared normal, including an engine magneto check at 4,000 rpm. The fuel selector was set to allow the engine to draw fuel from both wing tanks. The runway in use comprised a recently cut grass strip, aligned 180º/360º, some 700 m long by 25 m wide, and with what the pilot described as two pronounced "rises and falls" some 3 to 4 m in height, spaced at even intervals along its length. The temperature was 21ºC to 22ºC and the wind was reported by RAF Lyneham, some 10 miles distant, as 222º at 10 kt. This was well within the aircraft's crosswind limit.

The acceleration during the takeoff roll felt normal and, as the indicated airspeed passed 55 kt, the pilot eased back the stick. The aircraft lifted off normally at the top of the first rise in the runway but, once airborne, it banked steeply left and stopped accelerating. The pilot confirmed that the throttle was fully open, but realising that he was not going to climb away, he initiated a landing. By this stage, the aircraft was some 10 m to the left of the strip, and approximately 6 ft above the ground. Just before contacting the ground, the pilot reported that he remembered the engine was still running and shutting the throttle.

The aircraft subsequently touched down heavily, with little flare, approximately 25 m to the left of the strip, in the area of the first hollow in the ground, approximately 100 m from the point of lift off. The nose landing gear dug into the soft ground and collapsed, but the aircraft came to rest with neither occupant having suffered injury. After shutting off the fuel and all electrical systems, both occupants vacated the aircraft without difficulty.

Aircraft examination

The pilot reported the accident to the AAIB and was given permission to move the aircraft. Some three hours later, with the aid of a digger, and some canvas straps secured to the structure in the centre fuselage, the aircraft was recovered. During the lifting process, the pilot noted that, with the aircraft thus suspended, it hung noticeably left wing low. He calculated that the fuel burn on the outbound leg from Hinton-in-the Hedges would have left approximately 55 litres of fuel on board the aircraft at the time of his subsequent takeoff attempt. Having noted the aircraft's lateral imbalance during the recovery, he subsequently checked the fuel tank contents visually through the tank filler apertures. A quantity of fuel had apparently been lost via the tank vents, but the pilot estimated that the left tank contained about 40 litres, whereas no fuel was visible in the right tank. Some time later, when the tanks were drained in preparation for disassembly of the aircraft, 35 litres were recovered from the left tank but the right tank was found to be empty. When he inspected the engine, he found that both carburettors float bowls contained fuel.

The pilot paced out the length of his takeoff run and estimated that it had been of the order of 280 m to 300 m, compared with a normal takeoff distance, on a tarmac runway, of less than 200 m[1]. On reflecting further upon the circumstances of the accident, and the fuel imbalance he found subsequently, the pilot realised that, after landing at Draycott Farm, the aircraft had been parked on a slight side-slope, right wing high, and that both fuel taps had been left in the ON position. The capacity of the left tank alone would have been sufficient to accommodate the estimated total fuel load of 55 litres on board at that time, and he considered that this had allowed the whole of the right tank's contents to transfer into the left tank under gravity, via the open fuel taps. This would have created a lateral imbalance, which the pilot considered could have been sufficient to cause his control problems after lift off.

A photograph taken of the aircraft after the accident, showed damage to the propeller that was consistent with the engine not turning at the time the aircraft struck the ground. This lack of evidence of rotation raised the possibility that the engine might have lost power during the takeoff, albeit unnoticed by the pilot, and then failed, although the pilot reported that he was not aware of any change in the note of the engine. If this were so, then, in the absence of any reported engine defect, the possibility that the engine fuel supply had been affected by the right tank being empty and with both tanks having been selected for the takeoff, could not be dismissed.

Footnote

1 The CAA Safety Sence Leaflet 7c indicates that a takeoff on dry grass may result in a 20% increase in the takeoff distance to 50 ft, when compared with a takeoff from a paved surface, although the effect on the groundroll would be greater.

ACCIDENT

Aircraft Type and Registration:	Flight Design CT2K, G-CBUF
No & type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2002
Date & Time (UTC):	10 June 2006 at 2005 hrs
Location:	High Wych, near Sawbridgeworth, Hertfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to engine firewall and tail
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	386 hours (of which 151 were on type) Last 90 days - 116 hours Last 28 days - 30 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional AAIB enquiries

Synopsis

Whilst in a steep continuous orbit to the left at relatively low level, the engine stopped suddenly, leaving little time for the pilot to plan for a forced landing. After touching down in a field of standing corn, the aircraft flipped over on to its back. The occupants were uninjured and vacated the aircraft through the doors.

Two Safety Recommendations are made relating to the fuel system design.

History of the flight

The CT2K is a high wing, side-by-side two-seater aircraft in the Microlight Category, with the fuel tanks located in the inboard sections of the wings. The fuel selector in the cockpit allows the engine to be supplied from either the left or right tank, but not both simultaneously.

Prior to the flight, the pilot conducted an inspection of the aircraft, noting that the left fuel tank was virtually empty and that the right tank contained around 40 litres. Each tank has a maximum capacity of approximately 65 litres. The pilot stated that, as he normally flew the aircraft solo from the left seat, a fuel imbalance in favour of the right tank helped to equalise the lateral weight distribution and thus prevent a tendency for the aircraft to turn to the left. On this occasion, although he was taking a passenger, he accepted the as-found fuel state on the aircraft as being adequate for the intended flight, which was a photographic sortie over his passenger's house.

After taking off from Hunsdon in Hertfordshire, the pilot established radio communication with Stansted tower and requested clearance to enter Stansted Control Zone. This was granted, subject to the aircraft remaining below 1,000 ft QNH, which allowed a maximum height of approximately 750 ft agl in the area of interest. Some time later, the pilot put the aircraft in a sustained 40º banked turn to the left and, after about three orbits, the engine stopped suddenly. The limited height available allowed the pilot only enough time to level the wings and prepare for a landing in a field ahead. This contained a crop of standing corn and, after touching down, the aircraft pitched over onto its back. However, the occupants were uninjured and left the aircraft via the doors.

Examination of the aircraft

The pilot returned to the field the following day in order to recover his aircraft. He found approximately 10 litres of fuel remaining in the right tank, together with evidence of a slow fuel seepage that had occurred while the aircraft had lain in its inverted attitude. The flight had been approximately one hour in duration and, based on a fuel consumption of around 12 litres/hour, the pilot considered there would have been some 25 litres in the tank at the time of the accident. This was well above the three litres normally considered to be unusable fuel.

The aircraft was subsequently examined by a representative from the manufacturer and, in the absence of any evidence of a mechanical problem with the engine, the most likely cause of the engine stoppage was considered to have been fuel starvation. Whilst the aircraft had been in the sustained left turn, deviation from balanced flight could have resulted in the body of fuel in the right tank moving outboard and away from the fuel outlet. In the CT2K, this is located in the aft, inboard region of the tank. After the accident, the pilot commented that he had put the aircraft in a left turn because he was concerned that the fuel state would be more likely to uncover the fuel outlet in the right tank had he conducted a turn to the right, although this was less convenient for his passenger to take photographs[1].

Fuel system design issues

CT2K aircraft registered in countries other than the UK are equipped with a fuel system that allows fuel to be supplied to the engine from both tanks simultaneously; UK registered examples only allow fuel to be fed from either one tank or the other, but not both. This is because the aircraft type was certificated in the UK against the Civil Aviation Authority's British Civil Airworthiness Requirements (BCARs) Section S. Although the fuel system is, in practice, a 'gravity feed' system, the engine is fitted with a fuel pump and hence is 'technically' regarded a pumped system. As such, the fuel system needed to comply with Fuel System (General) paragraph S951(a) of the BCARs, which states that:

> *'Each fuel system must be constructed and arranged to ensure a flow of fuel at a rate and pressure established for proper engine functioning under any normal operating conditions.*

Footnote

[1] In a perfectly balanced turn, ie, with the slip ball centred, fuel would not flow inboard or outboard in a tank. However, when orbiting with reference to a ground feature, particularly with low fuel level, it is possible that such a turn might not always be in perfect balance, with the attendant risk that the fuel outlet may become uncovered if, in this case, the aircraft was skidding to the right.

Also, section S951(b) states that:

> *'Each fuel system must be arranged so that no fuel pump can draw fuel from more than one tank at a time. Gravity feed systems may not supply fuel to the engine from more than one tank at a time, unless the airspaces are interconnected in a manner to ensure that all interconnected tanks feed equally.'*

In order for the CT2K aircraft to comply with the BCAR requirements for a gravity feed system, the tank vents would need to be connected together. This would complicate the wing construction in a microlight aircraft in which the wings are designed so that they easily can be removed for storage and transportation. Aircraft delivered to the UK were equipped with a left tank/right tank fuel selector and no interconnection of the tank airspaces, which were independently vented to atmosphere, thus complying with the BCAR S951(b) requirement for a pumped system. However, the UK company that represents the aircraft manufacturer has indicated that this arrangement has given rise to a number of incidents of fuel starvation.

The CT2K has been superseded by the CTSW, which has a shorter wingspan but is identical in most other respects. The UK certification basis for the latter aircraft was a hybrid of the European Aviation Safety Agency (EASA) Certification Specifications for Very Light Aircraft, (EASA CS-VLA) Parts C and D (respectively Structure, and Design and Construction), and BCAR Section S for everything else. Approval was granted by the CAA working in conjunction with the British Microlight Aircraft Association (BMAA). It is worth noting that, although the CS-VLA specifications were not used for the fuel system, the relevant Fuel System (General) paragraph is worded identically to that contained in the BCAR quoted above. Despite this, all CTSW aircraft in the UK are fitted with fuel selectors that allow fuel to be supplied simultaneously from the left and right tanks.

Safety Recommendations

Although all CTSW aircraft and all non-UK registered CT2K's have identical non-pressurised fuel systems which can supply fuel from both tanks at the same time, UK registered CT2K aircraft do not have this capability, despite the various (microlight) design requirements in other countries permitting simultaneous supply from both tanks[2]. In the case of UK CTSW aircraft, it would appear that a different interpretation of the S951 requirements to that applied to the CT2K, has not resulted in a common design being adopted. Whilst this might be indicative of a 'common sense' approach, it also demonstrates an inconsistency in the application of the relevant design requirements by the CAA.

BCAR Section S is periodically reviewed by a working group, chaired by the CAA and involving the BMAA, the Popular Flying Association (PFA) and UK manufacturers. The following Safety Recommendation is therefore made to the CAA:

Safety Recommendation 2006-105

It is recommended that the British Civil Airworthiness Requirements Section S Working Group of the Civil Aviation Authority, review the Section S Fuel System design requirements to ensure that any present or future requirements are applied in a consistent manner to UK registered aircraft.

Footnote

2 The CT2K aircraft is a microlight as defined by Annex II of Regulation 1592/2002 and therefore does not fall under the jurisdiction of EASA and is only subject to national approval. Accordingly CAA has no influence on how such types are regulated in other European countries.

In response to the issues raised in this report, the CAA has made the following comments:

> *'Whichever tank had been selected, assuming it contained usable fuel, there should have been uninterrupted flow to the engine, during any normal flight operating condition. A 'both' selection if available may not have helped in this case as one tank was empty. It appears that this particular design, with large flat horizontal surfaces to the base of the tanks, could result in fuel not being available at the single pick-up position. A review of the fuel feed arrangements from the tanks is recommended for this particular aircraft to ensure fuel flow under all likely operating conditions in accordance with BCAR S 951(a). Simply applying a 'non-compliant' tank feed (both selection) arrangement, as recommended by AAIB, is not supported without appropriate review of the whole fuel system, including consideration of S 951(a).*

In the case of the accident to G-CBUF, it is possible that fuel starvation occurred whilst the aircraft was in a sustained, steep, imbalanced turn to the left, in which the fuel in the right tank moved outboard, uncovering the fuel outlet. Fuel in the left tank would have tended to move inboard under these circumstances, which, had a suitable fuel selector been fitted, would have maintained fuel to the engine. Whilst the pilot has indicated that there was little useable fuel in the left tank on this occasion, it is probable, had an alternative selector been fitted, that there would have been a more equal fuel distribution between the tanks prior to the flight. The following Safety Recommendation is therefore made to the manufacturer's UK agent, P&M Aviation:

Safety Recommendation 2006-106

It is recommended that P&M Aviation review the fuel system design of the CT2K aircraft and consider making available to UK owners a modification that makes the fuel system the same as that approved in the CTSW version of the aircraft, ie, the ability to feed fuel to the engine from both fuel tanks simultaneously.

In response to the issues raised in this report, the BMAA have stated:

> *'....the BCAR Section S working group met on 3/8/06 and an amendment to S951 was discussed with a view to clarifying the situation, as per recommendation 2006-105. A draft form of wording has been put together which is likely to go into the next revision paper for Section S, and addresses the issues of tanks effectively interconnected by atmospheric pressure.'*

ACCIDENT

Aircraft Type and Registration:	Mainair Blade, G-BYOW
No & type of Engines:	1 Rotax 582 piston engine
Year of Manufacture:	1999
Date & Time (UTC):	16 September 2006 at 1437 hrs
Location:	Barra, Western Isles, Scotland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Two propeller blades snapped, hang bolt and base bar bent. Trike pod, engine, wing and undercarriage damaged.
Commander's Licence:	Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	143 hours (of which 104 were on type) Last 90 days - 10 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst taxiing the aircraft in a strong and gusty wind, the aircraft was blown over and the pilot sustained minor bruising to his ribs.

History of the flight

The pilot was taking part in his club's annual visit to Plockton during which he decided to fly to Barra and back. However, as the pilot had no access to the internet he was unable to use the Met Office's on-line aviation services and, therefore, obtained a weather forecast from the BBC local news which forecast a southerly wind of 7 kt with visibility of over 10 km. Before he departed Plockton the pilot contacted Barra who informed him that Runway 15 was in use and the wind was 160º/20 kt.

The pilot flew the first part of his journey to North Uist at a height of 9,800 ft and noted that he had a tailwind of 7 kt, which increased to a 35 kt headwind when he turned south towards Barra. On arriving in the circuit at Barra, the pilot experienced difficulty in flying the aircraft due to strong rotors coming off the hills to the south of the runway. Nevertheless, he landed on the sand runway and back-tracked to the parking area. The pilot reported that once on the ground he experienced difficulty in moving the wing due to the strong wind. As he taxied the aircraft into the allocated parking area, a strong gust of wind tipped the wing and trike over, forcing the base bar into the pilot's chest. Ground and fire staff assisted the pilot in vacating and righting the aircraft. The aircraft was badly damaged and the pilot sustained bruising to his ribs.

Meteorological information

The Met Office reported that at the time of the accident there was a fresh to strong southerly flow covering the western Highlands and Western Isles of Scotland. The 2,000 ft wind between Plockton and Barra was estimated to be from 190º at 25 kt and may have been as much as 30 kt over the Barra area. The Met Office also reported that the TAFs and METARs for Benbecula, on the day of the accident, would have been representative of the weather conditions at Barra. The TAF at Benbecula at the time of the accident forecast a wind from 170º at 20 kt gusting to 30 kt and the METAR recorded the wind as from 160º at 21 kt.

Comment

The pilot reported that despite the strong wind, the landing was within the crosswind limit of the aircraft and that it was the unexpected gust that caused the aircraft to tip over whilst he was taxiing to the parking area. He had realised the limitations on relying on the local radio weather forecasts and had thought that this forecast combined with the information provided by Barra would have been sufficient. Unfortunately, the wind information obtained from Barra made no mention of the forecast gusty conditions.

The manufacturer of the aircraft confirmed that they do not publish ground handling limits and that providing the wind is steady the pilot should be able to safely taxi the aircraft in reasonably strong winds. However, gusting winds present more of a problem and the average pilot may experience difficulty in operating his aircraft in gusty winds above 20 mph (18 kt).

ACCIDENT

Aircraft Type and Registration:	Mainair Blade, G-MZIW
No & type of Engines:	1 Rotax 462 piston engine
Year of Manufacture:	1997
Date & Time (UTC):	17 July 2006 at 1950 hrs
Location:	Nightfield Lane, Balderstone, Lancashire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - 1 (Serious)
Nature of Damage:	Severe damage to left wing and trike unit
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	164 hours (of which 147 were on type) Last 90 days - 6 hours Last 28 days - 1.75 hours
Information Source:	Aircraft accident report form submitted by the pilot, report by BMAA official and other AAIB enquiries

Synopsis

The pilot attempted a precautionary landing following an unexpected 'jolt' in flight. The aircraft struck trees and was badly damaged. The cause of the 'jolt' remains undetermined.

History of the flight

The pilot reported that 10 minutes into the flight he experienced a 'jolt' through the airframe and controls. He suspected a failure of the rigging or some other component and reduced the engine rpm to tick-over. He initiated a gentle descent into a large field for a precautionary landing. He then became aware that he was too high for the selected field so he opted to continue to another field approximately 1/4 mile to the east.

When the pilot attempted to turn to the left onto his final approach he considered that the aircraft felt very heavy and reluctant to turn. He therefore increased the angle of bank and raised the airspeed. This resulted in a rapid loss of height and it became clear that the aircraft would not complete the turn. The pilot therefore levelled the wings, applied full power and pushed the control bar forward in an attempt to clear the trees. Unfortunately the aircraft hit the tree canopy and fell through into the middle of a coppice. He turned off the ignition switch as the aircraft impacted the tree canopy, or shortly afterwards. The aircraft came to rest in a dry stream bed where the pilot evacuated the machine before checking the passenger and assisting him to evacuate also.

The aircraft was reported to have been moderately heavily loaded and the ambient temperature, at the time of the accident, was high.

Examination of the wreckage

The wrecked aircraft was examined at the scene by an official of the BMAA who found that all the rigging wires were intact and that no pre-impact failure of the airframe was evident. It was his opinion that the aircraft had been fully airworthy up to the time of impact with the trees. The machine was subsequently removed to the premises of its manufacturer where a detailed examination was carried out. Again all the rigging wires were found to be intact and all the failures of other structural parts were examined and found to be consistent with the effects of impact.

Pilot's comments

The pilot considers that he did not allow fully for the weight of the aircraft and the conditions of the evening, resulting in his being too low and slow and without full control authority when the approach was attempted. The 'jolt' which occurred 10 minutes into the flight caused him great concern and precipitated his desire to carry out a precautionary landing. The cause of this 'jolt' could not be determined.

ACCIDENT

Aircraft Type and Registration:	Thruster T600N 450, G-CCCH
No & type of Engines:	1 Jabiru Aircraft Pty 2200A piston engine
Year of Manufacture:	2003
Date & Time (UTC):	15 July 2006 at 1330 hrs
Location:	Cloughan Lane, Ballyclare
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Severe damage to wings, fuselage and vertical fin
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	73 hours (of which 53 were on type) Last 90 days - 11 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst taking off from a grass field, the aircraft struck a hedge and overturned.

History of the flight

The pilot was landing at a private field belonging to a friend, about one mile to the north of Ballyclare. He assessed the wind as 2 to 3 kt from the south and made three practice approaches at lowering heights, during which he noticed some buffeting on approach and climb out, but this did not concern him. The field was roughly square in shape with power cables and trees running along the south-eastern boundary, so the pilot landed on a south-easterly heading without incident, stopping in approximately ¼ of the distance available.

After a stay of about 45 minutes, he and his passenger boarded the aircraft for the return flight. He judged that the wind conditions had not changed, so he elected to taxi the aircraft to the south-eastern corner of the field to commence the takeoff run in a north-westerly direction. His rationale for doing this was to maximise the distance available (ie diagonally across the field) and to avoid the cables, even though it meant there was a slight crosswind at 90° to the aircraft's heading. After briefing his passenger and completing the pre-flight checks, the pilot applied full power and commenced his takeoff roll. From the beginning, he had applied slight back pressure on the control column to protect the nosewheel and, with the aircraft just airborne, he relaxed the pressure to enable it to accelerate. However it became apparent that the aircraft was not going to clear a 5-foot hedge on the field boundary and the pilot tried to coax the aircraft over the hedge and accept a forced touchdown in the next field, which he knew was suitable. Unfortunately the aircraft's wheels hit the top of the hedge, pitching it forward nose-first into the field whereupon it stopped immediately and flipped onto its back.

The pilot and passenger exited the aircraft uninjured and unassisted via the doors: the pilot turned off the master switch and the fuel and alerted the emergency services.

The pilot cited the following factors as causal to the accident:

- The grass had recently been cut for silage but fresh growth had had an adverse effect on the aircraft's performance.
- The ambient temperature was 26 C° - the warmest day of that period – and the effects on engine and climb performance were significant.
- The decision to take off with a cross-wind, although this was somewhat forced upon him by the presence of obstructions.

In summary, although he states that he was aware of the individual effects of the three factors on takeoff performance, the combined effects "were significantly more than the sum of the parts".

BULLETIN CORRECTION

AAIB File:	EW/C2006/02/05
Aircraft Type and Registration:	Socata TB10, G-BNRA
Date & Time (UTC):	16 February 2006 at 1120 hrs
Location:	Nottingham Airport (Tollerton) Nottinghamshire
Information Source:	Aircraft Accident Report Form submitted by the pilot; examination of the failed components by the AAIB

AAIB Bulletin No 12/2006, page 40 refers

The final paragraph of the report included the statement:

> 'The fatigue cracking appears to have been partly a consequence of non-optimum temperature conditions in the hub material during the forging process'.

This comment is in error.

A similar comment had been deleted from the body of the report as, although it had been considered during the investigation, it had not been found to be supported by evidence.

The final paragraph should therefore read:

Conclusions

The engine partly separated from the airframe as a result of propeller imbalance following the release of one blade due to fatigue failure in its hub. Recommendations within an existing Service Bulletin addressed the problem although the absence, at the time, of an Airworthiness Directive rendering such checks mandatory contributed to its non-implementation on this aircraft before the accident. The UK CAA, the EASA and the FAA have all responded positively to contain the hazard by introducing inspections and/or replacement of the hub parts.

AIRCRAFT ACCIDENT REPORT No 1/2007

This report was published on 10 January 2007 and is available on the AAIB Web site www.aaib.gov.uk

REPORT ON THE SERIOUS INCIDENT TO BRITISH AEROSPACE ATP, G-JEMC 10 NM SOUTHEAST OF ISLE OF MAN (RONALDSWAY) AIRPORT ON 23 MAY 2005

Registered Owner and Operator	Emerald Airways
Aircraft Type	British Aerospace ATP
Nationality	British
Registration	G-JEMC
Place of Accident	10 nm southeast of Isle of Man (Ronaldsway) Airport
Date and Time	23 May 2005 at 1740 hrs

Synopsis

This serious incident was notified to the Air Accidents Investigation Branch (AAIB) by ATC at the Isle of Man (Ronaldsway) Airport, at 1855 hrs on 23 May 2005. The following Inspectors participated in the investigation:

Mr P T Claiden	Investigator in Charge
Mr T Atkinson	Operations
Mr A H Robinson	Engineering
Mr P Wivell	Flight Recorders

Under the *Isle of Man Civil Aviation (Subordinate Legislation) (Application) Order 1992*, the *United Kingdom Civil Aviation (Investigation of Air Accidents) Regulations 1989* are applicable in the Isle of Man. Accordingly, Inspectors of Air Accident from the AAIB carried out an investigation into this occurrence.

The aircraft was configured with 64 seats; 33 passengers were on board. Shortly after takeoff, a seal associated with the retraction line for the hydraulically operated integral airstairs at the front left cabin door, failed. This allowed hydraulic fluid to escape in the form of a fine mist, depleting the contents of the main hydraulic system. This misting was perceived by the cabin crew as smoke, and they informed the flight crew accordingly. In flight, this line is normally de-pressurised but, owing to a jammed airstairs UP selection switch and a stuck door safety microswitch, it had remained pressurised.

The intensity of the misting in the forward section of the cabin led the cabin crew to reposition the passengers towards the rear of the cabin. As a result, the aircraft's centre of gravity (CG) position moved beyond the operator's specified aft limit.

An emergency was declared to ATC and the aircraft returned to Ronaldsway. During the approach, the EGPWS system alerted the crew to an incorrect flap setting for landing.

After landing, the aircraft was taxied clear of the runway but difficulties encountered with the nosewheel steering system forced the commander to stop the aircraft short of the terminal buildings. One passenger, who was asthmatic, was taken to a local hospital but later discharged as medical treatment was not considered necessary.

The investigation identified the following causal factors:

1. A combination of a stuck door safety microswitch plunger and a jammed-on airstairs UP switch caused hydraulic pressure to remain applied to the airstairs retraction actuators in-flight.

2. The failure of the hydraulic seal associated with the airstairs operating mechanism occurred in-flight; this resulted in the fluid contents of the main hydraulic system being discharged as a fine mist into the passenger cabin.

3. At the time of the incident, there were no periodic inspection or maintenance checks required on the airstairs operating system.

4. The rearward movement of the aircraft's CG position beyond the aft limit as specified by the operator, was caused by the cabin crew moving passengers towards the rear of the cabin in an attempt to minimise their exposure to the 'smoke'.

5. There was no requirement for cabin crews to obtain agreement from the commander prior to moving passengers towards the rear of the cabin although, on this occasion, the commander was informed of their actions.

6 The flight crew's non-adherence to SOPs[1] and associated checklists put the aircraft and its occupants at unnecessary increased risk from potential handling problems as well as risk of fire and prolonged exposure to hydraulic fluid mist.

One safety recommendation was made.

Findings

1. The crew was properly licensed and qualified to conduct the flight, and the flight crew held valid medical certificates.

2. The crew had rested adequately before commencing duty.

3. The aircraft's documentation was in order and there were no outstanding defects recorded in the log.

4. Shortly after takeoff, a hydraulic connection associated with the forward left door airstairs sprang a leak and caused the forward part of the passenger cabin to fill with hydraulic fluid mist.

5. The cabin crew diagnosed the mist as 'smoke'.

6. The mist mostly affected the forward part of the cabin, but also entered the flight deck.

7. The cabin crew reported the 'smoke' promptly and clearly to the commander via the interphone.

8. Immediately after the report of 'smoke' had been passed to the commander, the aircraft's

Footnote

[1] Standard Operating Procedures.

warning system alerted the flight crew to a HYDRAULIC LOW LEVEL condition.

9. The commander elected to return to Ronaldsway, which was the nearest available airport.

10. The flight crew did not comply with Standard Operating Procedures regarding checklist use and crew co-ordination.

11. The commander did not action the HYDRAULIC LOW LEVEL checklist correctly, and did not comply with its instructions.

12. The commander declared to ATC a state of urgency (PAN) and, later, emergency (MAYDAY), but did not use the standard radiotelephony phrases.

13. Following depletion of the hydraulic system's contents, flight crew did not follow correctly the '*EMERGENCY AND ABNORMAL LOWERING OF LANDING GEAR CHECKLIST*'.

14. The crew did not associate the near-simultaneous low hydraulic fluid quantity warning with reports of smoke from the cabin.

15. No review of available information was carried out by the flight crew, and they did not endeavour to establish whether the hydraulic system problem and the onset of 'smoke' were related.

16. The flight crew did not follow the actions proscribed in the company's Operating Manual with regard to smoke on board the aircraft.

17. The flight crew did not action any checklists referring to smoke on board the aircraft.

18. After the onset of the 'smoke', the cabin crew moved a number of passengers to seats towards the rear of the cabin.

19. At takeoff, the aircraft's loadsheet indicated that the aircraft's CG position was at about 24% MAC; the limits were 21% to 29%.

20. The cabin crew could not recall with precision where the passengers were seated after they had been moved.

21. The best estimate of the new CG position suggested that it had moved to between 30% and 31% MAC, beyond the company's specified aft limit.

22. The cabin crew did not inform the commander that most of the passengers had been re-located in the rear section of the cabin.

23. The commander did not seek amplification of the information regarding the movement of the passengers nor take action to address the implications associated with the rearward movement of the aircraft's CG position.

24. The commander selected the Environmental Conditioning System packs to OFF, without reference to a checklist, and contrary to the instruction contained in the '*FIRE, SMOKE AND FUMES WITHIN FUSELAGE CHECKLIST*'.

25. An alert from the EGPWS drew the flight crew's attention to the incorrect flap setting as the aircraft passed below the

Decision Height; the flaps were then set correctly.

26. Prior to landing, the flight crew were not aware that the nose wheel steering system was inoperative.

27. The flight crew experienced difficulty in controlling the aircraft on the ground whilst manoeuvring the aircraft by using differential thrust and brakes.

28. The commander's decision to continue to taxi the aircraft after landing was not in accordance with the checklist requirement to keep taxiing to a minimum.

29. The commander's decision to attempt to continue to taxi the aircraft to the stand after landing did not minimise the occupants' exposure to the 'smoke' or the risk of a serious fire.

30. The operator had not brought to the attention of their flight crews the information contained within the CAA FODCOMs on the topic of fire and smoke.

31. The cause of the hydraulic leak was not identified by the investigation; the seal appeared to be undamaged but had been installed for a considerable period of time.

32. Prior to this incident, there were no periodic inspections or maintenance requirements covering the forward left door safety microswitch.

Safety Recommendations

Safety Recommendation 2006-069

It is recommended that the Civil Aviation Authority advises all operators of Commercial Air Transport aircraft on the UK register of the need to ensure that the training of cabin crew members includes an awareness that handling problems may result from the movement of the aircraft's CG position, should a significant redistribution of passengers be required in flight. This awareness training should include the necessity to both inform and seek the approval of the flight crew prior to such a redistribution taking place and should be reflected in the appropriate Cabin Crew Safety Manuals.

Safety actions

On 4 May 2006, the CAA suspended the operator's Air Operator's Certificate (AOC). The company has effectively ceased trading and, therefore, no further safety recommendations are made to the Civil Aviation Authority or Emerald Airways.

FORMAL AIRCRAFT ACCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

2005

1/2005 Sikorsky S-76A+, G-BJVX
near the Leman 49/26 Foxtrot Platform
in the North Sea on 16 July 2002.

Published February 2005.

2/2005 Pegasus Quik, G-STYX
at Eastchurch, Isle of Sheppey, Kent
on 21 August 2004.

Published November 2005.

3/2005 Boeing 757-236, G-CPER
on 7 September 2003.

Published December 2005.

2006

1/2006 Fairey Britten Norman BN2A Mk III-2
Trislander, G-BEVT
at Guernsey Airport, Channel Islands
on 23 July 2004.

Published January 2006.

2/2006 Pilatus Britten-Norman BN2B-26
Islander, G-BOMG, West-north-west of
Campbeltown Airport, Scotland
on 15 March 2005.

Published November 2006.

3/2006 Boeing 737-86N, G-XLAG
at Manchester Airport
on 16 July 2003

Published December 2006.

2007

1/2007 British Aerospace ATP, G-JEMC
10 nm southeast of Isle of Man
(Ronaldsway) Airport
on 23 May 2005.

Published January 2007.

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