Air Accidents Investigation Branch

AAIB Bulletin 4/2014

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AAIB Special Bulletins and Interim Reports

This section contains Special Bulletins and Interim Reports that have been published since the last AAIB monthly bulletin.

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AAIB
Air Accidents Investigation Branch

AAIB Bulletin S2/2014
SPECIAL

ACCIDENT

Aircraft Type and Registration:	Eurocopter EC135 T2+, G-SPAO	
No & Type of Engines:	2 Turbomeca Arrius 2B2 turboshaft engines	
Year of Manufacture:	2007 (Serial No: 0546)	
Location:	Glasgow City Centre, Scotland	
Date & Time (UTC):	29 November 2013 at 2222 hrs	
Type of Flight:	Commercial Air Transport	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - 1 (Fatal)	Passengers - 2 (Fatal) Other - 7 (Fatal) 11 (Serious)
Nature of Damage:	Helicopter destroyed	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	51 years	
Commander's Flying Experience	5,592 hours (of which 646[1] were on type) Last 90 days - 38 hours Last 28 days - 19[2] hours	
Information Source:	AAIB Field Investigation	

Footnote

1 646 hrs are the hours on type the pilot had accumulated since 2010.
2 Hours up to and including 26 November 2013.

This Special Bulletin contains facts which have been determined up to the time of issue. It is published to inform the aviation industry and the public of the general circumstances of accidents and serious incidents and should be regarded as tentative and subject to alteration or correction if additional evidence becomes available.

Introduction

At 2222 hrs on 29 November 2013 a Eurocopter EC135 T2+ helicopter, operating in support of police operations, descended onto the roof of The Clutha Vaults bar, on Stockwell Street in central Glasgow. The roof collapsed and the helicopter came to rest embedded in the single storey building. The three occupants of the helicopter and six people in or adjacent to the bar were fatally injured. Thirty-two other people suffered injuries, twelve seriously. One of those seriously injured subsequently died of his injuries on 12 December 2013.

A team of AAIB Inspectors and support staff arrived in Glasgow at 0915 hrs the following morning to commence an investigation. The emergency services and the AAIB were presented with a very complex task, requiring a highly co-ordinated process to successfully meet the aims of the emergency response operation.

In accordance with established international arrangements, the Bundesstelle für Flugunfalluntersuchung (BFU) of Germany, representing the State of Design and Manufacture of the helicopter, the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) of France, representing the State of Design and Manufacture of the engines, and the National Transportation Safety Board (NTSB), representing the State of Design and Manufacture of the Full-Authority-Digital-Engine-Controls (FADECs) on the engines, appointed Accredited Representatives to participate in the investigation. They are supported by advisors from the BEA, the helicopter manufacturer and the engine manufacturer. The European Aviation Safety Agency (EASA), the UK Civil Aviation Authority (CAA) and the helicopter operator are also assisting the AAIB.

AAIB Special Bulletin S9/2013 was published on 9 December 2013 to provide initial information on the AAIB's investigation and the circumstances of the accident. This Special Bulletin is published to provide more factual information and an update on the progress of the investigation. No analysis of the facts is attempted.

History of the flight

At 2045 hrs on 29 November 2013, the helicopter departed Glasgow City Heliport (GCH), to support police operations. On board were the pilot and two police observers, each of whom was in possession of a set of Night Vision Goggles (NVGs). The helicopter had 400 kg of fuel on board, giving an endurance of approximately 1 hour and 35 minutes[1].

Initially, the helicopter tracked towards the Oatlands district of Glasgow, about 2 nm south-east of GCH. This was to assist in the search for a person believed to have been struck by a train. The helicopter remained in that area, at an altitude of approximately 1,000 ft amsl, for about 35 minutes. It then flew to Dalkeith, Midlothian, about 38 nm east of GCH, where it carried out a non-urgent task. It remained there for about four minutes, at various altitudes, before flying back towards Glasgow via Bothwell, South Lanarkshire, where it briefly carried out an observation task. It then flew to Uddington, South Lanarkshire

Footnote

1 Using an average fuel consumption of 200 kg/hr and the operator's Final Reserve Fuel of 85 kg - Final Reserve Fuel being the minimum amount of fuel with which pilots should plan to land.

and Bargeddie, North Lanarkshire, where it carried out non-urgent tasks, orbiting in each location for less than five minutes (see Figure 1). At 2218 hrs, the pilot requested clearance from ATC to re-enter the Glasgow Control Zone, to return to GCH. This was approved. No further radio transmissions were received from the pilot.

Recorded data indicates that, in the latter stages of the flight, the right engine flamed out, and shortly after the left engine flamed out. The helicopter descended and struck the roof of The Clutha Vaults bar at a high rate of descent, in an upright attitude. Evidence indicates that the rotor blades and Fenestron tail rotor were not rotating at the moment of impact. The force of the impact caused the roof to collapse and the helicopter entered the building.

The last recorded radar position for the helicopter was at 2222:19 hrs, showing it at an altitude of approximately 400 ft amsl.

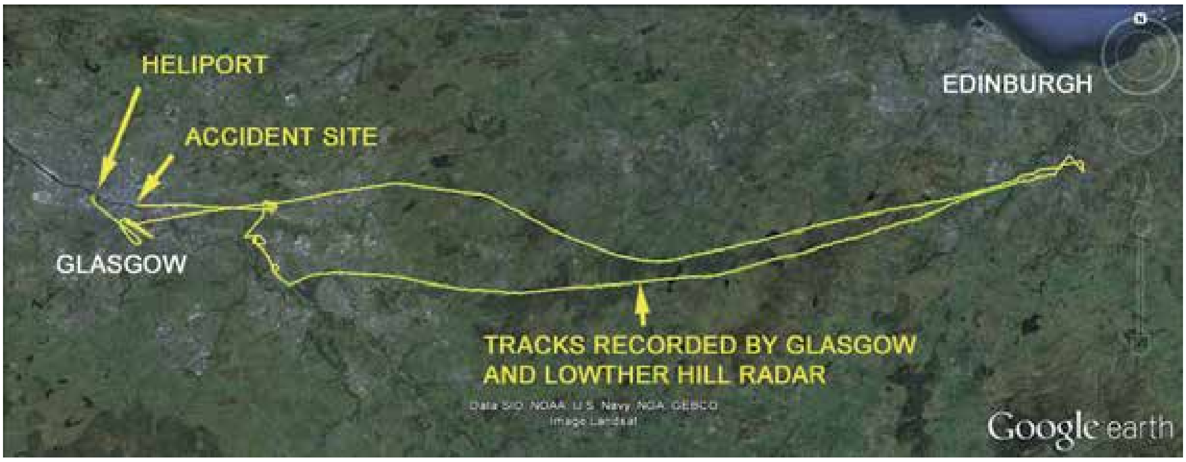

Figure 1
The helicopter's track, as recorded by radar

Weather and celestial information

The weather at 2220 hrs on 29 November 2013 at Glasgow International Airport, 4.5 nm west of GCH, was: CAVOK, surface wind from 300º at 7 kt, temperature 5ºC, dew point 2ºC and QNH 1025 hPa.

The moon set at 1402 hrs on 29 November 2013 and rose at 0449 hrs on 30 November 2013.

Engineering investigation

General

The helicopter was removed from the building in a co-ordinated and complex process to primarily meet the aims of the emergency response operation, while preserving the evidence. The subsequent engineering investigation has been following a methodical process examining the helicopter's systems in detail, as far as practically possible.

Fuel System

The helicopter's fuel tank group was drained and the contents were measured immediately after it was extracted from the building. It was found that the main fuel tank contained 76 kg of fuel, whilst the No 1 supply tank (left) contained 0.4 kg of fuel and the No 2 supply tank (right) was empty. It has also been confirmed, by examination and measurement of the internal design features, that this was the fuel disposition at the time of the accident. That is; fuel had not moved within the tank group whilst the helicopter was at rest in the building. Also, there was no evidence that fuel leaked from the helicopter before or during the impact with the building.

Since the helicopter's recovery to the AAIB facility, a very close examination of the fuel system has continued. It has been determined that the fuel tank group suffered sudden elastic compression during the impact, whilst retaining its basic shape. The compression was sufficiently severe to collapse all four internal fuel quantity transmitters, as they are designed to do, and the tank group bladders remained fuel-tight. Examination of all internal pipe work and transfer passages has not revealed any pre- or post-impact failure and all paths still permit uninterrupted fuel flow. It has been established that unrestricted flow was also available from each supply tank to the corresponding engine fuel control unit, through the relevant fuel shut-off valves which were found set to the OPEN position.

The fuel pump switches were examined at the accident site and it was found that the No 1 and No 2 prime pump switches (PRIME I and II) were set to the ON position and the fore and aft transfer pump (XFER F and A) switches were set to the OFF position.

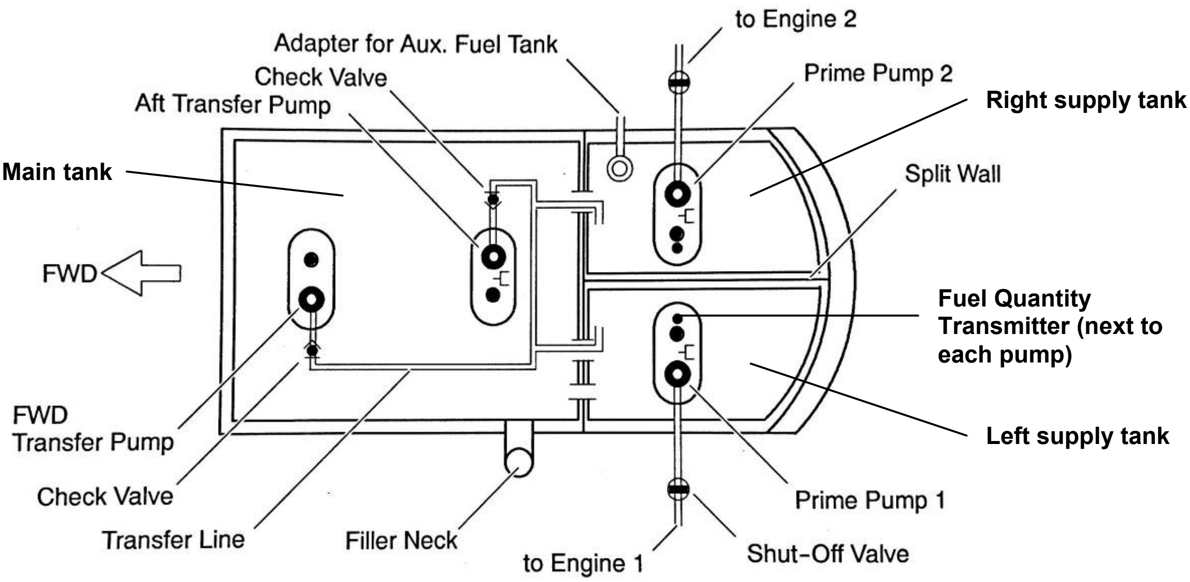

Figure 2

Fuel Tank Group Schematic

The forward and aft transfer pumps, situated in the main fuel tank, and the prime pumps in the No 1 and No 2 supply tanks were tested and found to operate correctly in accordance with their factory specification. The pump inlets and outlets were free from blockage or contamination. The No 2 prime pump and aft transfer pump housings had suffered minor damage, attributable to the tank compression during impact, but this had no effect on their operation under test.

Engines

Both engines were examined in the helicopter and later disassembled and examined at the engine manufacturer's facility. This was carried out under the direct supervision of AAIB investigators, representatives from the BEA and the helicopter manufacturer.

The engines were found to have suffered minor external damage as a result of the impact. Both engine gas generator cores, compressors and turbines, were free to rotate, as were the free power turbines, reduction gearboxes and output shafts. There was no evidence of foreign object damage or intake or exhaust blockage in either engine. Also, there were no signs of bearing or lubrication system failure, and the oil system chip detectors were clean and free from metallic particles. The No 1 (left) engine fuel filter was found to contain a small amount of fuel whilst the No 2 (right) engine was found to be empty of fuel. Both engine fuel control units were bench tested and found to be serviceable in all respects, producing fuel control, pressure and flow outputs within acceptable tolerance deviations, in accordance with the factory test protocol.

Both of the engine fuel valve assemblies were also tested on the bench, confirming that the engine electro-stop valves were fully open. These valves receive an electrical signal, to shut off the fuel to the engine, when selected by the pilot via the ENG I and II switches.

The engine control panel switches for the FADECs (Full-Authority-Digital-Engine-Control) were found set to ON and the ENG I and ENG II switches were guarded in the FLIGHT position. The engine mode select panel switches, ENG I and II were set to NORM and guarded and the ENG I and II VENT switches were set to OFF. This was the correct configuration for flight.

Transmission system, main rotor and Fenestron tail rotor

Examination at the accident site and further more detailed examinations at the AAIB facility in Farnborough have shown no evidence that the transmission system, main rotor, Fenestron tail rotor and associated drive shafts were rotating when the aircraft struck the roof of the building. The main rotor and Fenestron gearboxes had superficial external damage but were free from leaks. The main rotor gearbox lubricating oil filter was clean and the magnetic chip detector was free from metallic debris. All of the damage to the main rotor and Fenestron blades was attributable to impact with the building and supports the evidence that they were not rotating just before or at the point of impact. From the overall examination and assessment of the system no faults have been found with the transmission or rotor system.

Sub-systems

There is no evidence of hydraulic system or flying control failure in flight prior to the impact. The electrical power generation and distribution system appears to have been operating correctly prior to the accident. At the accident site the battery master (BAT MSTR) switch was found set to ON and the GEN I and GEN II switches found set to NORM. None of the helicopter circuit breakers, situated on the overhead panel, indicated pre-accident electrical overload failure of any of the vital electrical system devices. In summary, all of the damage and disruption to these systems was consistent with an impact sequence involving a very high energy deceleration.

The SHED BUS switch at the rear of the overhead panel was found guarded in the NORM position. The purpose of this switch is to give the pilot the ability to recover non-essential electrical services should both generators trip off line, such as in a double engine failure. Battery power is recovered to those systems when the guard is lifted and the switch set to EMERG. In this case, with the switch set to NORM, the radio altimeter and the steerable landing light would not have been available to the pilot. These two items are optional equipment and are not standard on the EC135 helicopter. However, a radio altimeter is required for UK police night flying operations, in accordance with Civil Aviation Publication (CAP) 612, *Police Air Operations Manual, Part One*.

Other evidence

There was no evidence of structural failure or in-flight fire and no evidence of damage caused by birdstrike or a foreign object hitting the aircraft whilst in flight.

Recorded data

Data from the helicopter

The helicopter was not required to have, and was not fitted with, flight recorders, nor did its systems provide a continuous recording of helicopter parameters. However, some of the installed helicopter systems recorded snapshots of limited sets of data, under specific circumstances, for engineering purposes.

The contents of the non-volatile memory (NVM) from the equipment known to record data have been successfully recovered and are being analysed. The majority of the recorded data have no form of time stamp. So, whilst the order of some of the snapshots can be determined, their relative timing is unknown. Other systems use time references but ones that are not directly linked to UTC.

The Warning Unit has provided information on the order in which warnings were triggered during the flight but not when they occurred. The unit recorded the normal warnings associated with starting the helicopter, followed by a warning free status. It subsequently recorded intermittent LOW FUEL 1 warnings for the left fuel supply tank, then a permanent LOW FUEL 2 warning for the right fuel supply tank. This was followed by a further temporary LOW FUEL 1 warning, before it became permanent for the remainder of the flight. These LOW FUEL warnings are triggered by thermal sensors in the supply tanks.

For this helicopter build configuration, they indicate when there is approximately 32 kg and 28 kg of fuel remaining in the left and right supply tanks, respectively. On receipt of these warnings, the manufacturer's flight manual for the helicopter instructs the pilot to '*LAND WITHIN 10 MINUTES*'.

An alarm gong was also recorded followed by intermittent warnings relating to low rotor rpm. The penultimate warning recorded related to the battery discharging, which occurs when there is insufficient engine-driven generator power. The last warning related to an autopilot system failure. Investigation into the possible causes for the individual warnings is continuing.

The Central Panel Display System (CPDS) displays cautions and fuel status information to the pilot. It also records internal display system faults but no information relating to its indications. The displays did record flight duration and work is being carried out to link this duration, and the conditions required to start and stop this recorded duration, to the flight path of the helicopter. A fault relating to one of the display systems was recorded and further work is being undertaken to establish the meaning and possible causes of the fault.

Each engine had a FADEC. The FADECs can record a limited number of maintenance reports relating to problems with the control and operation of the engines and instances when one engine is inoperative. Preliminary analysis of the FADEC data indicates that the right engine flamed out, followed, a short time later, by the left engine also flaming out. Since the maintenance reports only give timings relative to the moment the FADECs were turned on (which is not recorded), the exact times at which these flameouts occurred is unknown.

Externally recorded data

The continuous (timed) recordings identified so far are all external to the helicopter and are in the form of radar returns, radio transmissions and closed circuit television (CCTV) footage. No single source has provided a reliable link to all the on-aircraft sources of snapshot data.

The recorded radar track started just after the helicopter departed the heliport. The helicopter's altitude as it approached the area of the accident was approximately 1,000 ft amsl and its average groundspeed was approximately 105 kt. The last radar return reported an altitude of approximately 400 ft amsl, when corrected for ambient air-pressure.

CCTV recordings of the start of the flight are providing a means of linking some of the snapshot data from the helicopter's systems with the radar recorded flight path. However, no CCTV recordings have been obtained that capture the end of the flight.

The recorded radio transmissions do not contain any reference by the crew to difficulties with the aircraft.

Work on the recorded data continues.

Procedures

Fuel policy

The operator's operations manuals contained the following policy on fuel for the EC135 helicopter:

> *'Company Fuel Policy*
>
> *Company helicopters are operated under a principal of Minimum Land on Allowance (MLA), this figure is the minimum amount of total fuel at the point of landing.*
>
> *It is calculated as fuel remaining, not more than 10 minutes after the … FUEL caption (EC135) has illuminated….. and is included in the Final Reserve Fuel amount.'*

Final Reserve Fuel at night/in IFR was 85 kg. The operator advised its pilots that an emergency condition could be considered to exist if the commander believed that the helicopter would land below the MLA.

Emergency procedures

The operations manual provides pilots with guidance and procedures for use following a double engine failure. It states:

> *'Immediate Actions following total power loss in cruise or accelerative flight*
>
> - *Lower collective immediately and flare aircraft to conserve and/or recover NR*
> - *Select attitude for 75kt*
>
> *Selection of speed and RRPM* [Rotor RPM] *in Autorotative flight*
>
> - *Normal Autorotation 100% RRPM, 75kts*
> - *Range Autorotation 85% RRPM, 90kts*
> - *Min RoD* [Rate of Descent]*100% RRPM, 65kts*
>
> *EOL [engine off landing] over Land*
>
> - *At approximately 100' AGL (higher if heavy) initiate flare*
> - *Reduce groundspeed as much as possible*
> - *Level the aircraft and use collective lever to cushion landing*
>
> *EOL at Night or in IMC*
>
> - *Select and maintain 10° Nose Up until speed reaches 75kts and then re-adjust*
> - *Turn shortest arc into wind using ≤ 20° AoB* [Angle of Bank]
> - *Use RADALT* [Radio Altimeter] *to establish flare height*
> - Progressively reduce flare until level at 10' RADALT height
> - Use collective to cushion landing'

The operator teaches its pilots that, once a stable autorotation is established, the SHED BUS switch, in the overhead panel, should be switched from NORM to EMERG, if time is available, to power the steerable landing light and the radio altimeter during an autorotation.

Safety action

On 20 December 2013, the operator issued an amendment to its operations manual, replacing MLA with Final Reserve Fuel. It stated:

> *'An Emergency condition can be considered to exist if the Commander believes that the helicopter will land below Final Reserve Fuel (FRF).'*

The operator also issued the following safety notice to all its pilots on the same date.

> *'… we have conducted detailed examinations and tests on our fleet of EC135s. ……. As a result of these test it was deemed necessary to replace the sender units [fuel quantity transmitters] from the supply tanks on a number of our aircraft.*
>
> *Until such a time as we have an approved maintenance program [from the manufacturer] in place to perform functional checks of these units we have deemed it necessary to maintain a* ***Final Reserve Fuel (FRF) 90Kgs.*** *When completing fuel calculations ……… please use 90kgs as the FRF for all flights (VFR & IFR) until further notice.'*

Ongoing investigation

The AAIB investigation continues to examine all the operational aspects of this accident and to conduct a detailed engineering investigation.

In particular, the investigation will seek to determine why a situation arose that led to both the helicopter's engines flaming out when 76 kg of fuel remained in the fuel tank group, why no emergency radio transmission was received from the pilot and why, following the double engine failure, an autorotative descent and flare recovery was not achieved.

The AAIB will report any significant developments as the investigation progresses.

Published 14 February 2014

AAIB Field Investigation reports

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 747-4H6, 9M-MPL
No & Type of Engines:	4 Pratt & Whitney PW4056-3
Year of Manufacture:	1998
Date & Time (UTC):	17 August 2012 at 2320 hrs
Location:	On approach to Runway 09R at London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 22 Passengers - 340
Injuries:	Crew - None Passengers - None
Nature of Damage:	Electrical failures, hard landing and component failure to No 2 engine
Commander's Licence:	ATPL
Commander's Age:	40 years
Commander's Flying Experience:	10,753 hours (of which 393 were on type) Last 90 days - 80 hours Last 28 days - 11 hours
Information Source:	AAIB Field Investigation

Synopsis

Significant vibration was noted on the No 2 engine during departure from London Heathrow Airport. The engine subsequently failed and was shut down by the crew who elected to jettison fuel and return to Heathrow Airport. During the approach for a planned autoland, all three autopilots disengaged, the cockpit displays and lights flickered and a series of fault messages were displayed. The resulting electrical failures culminated in a loss of power to one of the electrical AC buses, and many of the systems powered by this bus were lost or degraded. The commander continued the approach, manually flying the aircraft to a safe landing.

The investigation determined the flickering cockpit displays and lights resulted from a series of failures within the aircraft electrical system, primarily caused by a latent mechanical failure in a Bus Tie Breaker. The effect of this latent failure only became apparent when the aircraft electrical system automatically reconfigured for the planned autoland. One Safety Recommendation has been made.

History of the flight

9M-MPL was operating a commercial air transport flight from London Heathrow Airport to Kuala Lumpur International Airport with 4 flight crew, 18 cabin crew and 340 passengers. Following normal pre-flight preparation the aircraft took off at 2129 hrs and departed towards the north-east.

As the aircraft climbed through FL150 the crew felt the aircraft vibrate. All cockpit indications were normal but the engine No 2 vibration indicator was indicating 2.3, slightly higher than the 0.9 indicating on the other three engines. The commander disconnected the autopilot, checked the flying controls then re-engaged the autopilot. The vibration increased as the aircraft climbed through FL170 and the pilots noticed that fuel flow on engine No 2 was fluctuating at around 0.3 tonnes per hour compared with approximately 5 tonnes per hour for the other engines. The commander selected idle thrust on engine No 2, which reduced the vibration, but the pilots noticed that the engine oil pressure had exceeded the limit. They then heard a bang and the ENG FAIL EICAS[1] message was displayed in respect of engine No 2. The crew shut down the engine in accordance with the *'ENGINE LIMIT OR SURGE OR STALL'* checklist, asked ATC for permission to level off at FL190 and stated that the aircraft would be returning to Heathrow Airport. The aircraft was sent to LOGAN[2] to hold while it jettisoned fuel.

After jettisoning fuel, which took approximately 45 min, 9M-MPL began its initial approach towards Runway 09R at London Heathrow Airport with the left autopilot in command. The crew briefed for an autoland because the aircraft was heavy, it was night and one engine had been shut down. Apart from the fact that the aircraft was operating on three engines, all other systems were operating normally. The aircraft intercepted the localiser while descending through 3,200 ft amsl and the crew engaged the two remaining autopilots in preparation for the autoland. Shortly after the aircraft levelled at 3,000 feet amsl, the master warning was triggered, the three autopilots disengaged, all the displays and cockpit lights began to flicker and a large number of failure messages appeared on the EICAS displays. The commander began to fly the aircraft manually and approximately thirty seconds later, as the aircraft intercepted the glideslope, the autothrust disengaged.

The pilots decided that, with the runway in sight, the safest course of action was to continue the approach rather than manage the failures. The commander was concerned that all the displays might fail and it would therefore be better to land as soon as possible. He attempted to re-engage autothrust without success but he did not try to re-engage an autopilot. All of the screens flickered "one at a time and continuously" until touchdown. The standby instruments were unaffected.

As the aircraft approached the runway, the commander was expecting the radio altimeter automatic callout of heights above touchdown to begin at 100 ft but the only automatic call he heard was at 20 ft. He therefore did not have sufficient warning to flare the aircraft into the correct landing attitude prior to touchdown. The co-pilot stated subsequently that the radio altimeter indication and "rising runway[3]" indication were missing from his Primary Flight Display (PFD) during the landing. While taxiing to stand after landing the displays stopped flickering and, after shutdown, the commander reported a "hard landing" in the aircraft technical log.

Footnote

1 EICAS: Engine Information and Crew Alerting System.
2 LOGAN: an ATC reporting point in the North Sea at N51 44.9, E001 36.7.
3 A virtual representation of the runway on the PFD designed to give the pilot an impression of the aircraft's closure to the runway.

Comments by the commander

The commander commented later that it had been unnecessary to declare an emergency because he had sufficient information available to maintain a safe flight path. He stated that had he been forced to fly the aircraft solely on standby instruments due to a complete failure of his primary flight display he would have declared an emergency.

Flight recorders

The aircraft was fitted with a two-hour solid-state CVR and a solid-state DFDR. In addition, a solid-state Quick Access Recorder, which recorded essentially the same parameter set as the DFDR, had been fitted to support the operator's flight data monitoring programme. Upon replay, the CVR was found to have recorded over the incident flight and subsequent landing, and the information that it contained did not assist the investigation.

The DFDR data showed that the departure from London Heathrow at 2129 hrs was uneventful and all engine parameters appeared normal. The recordings showed that takeoff gross weight was 377,000 kg and the aircraft was carrying 149,000 kg of fuel. A ground track of the entire flight derived from the DFDR recording is shown in Figure 1.

Engine failure

At 2140 hrs, as the aircraft was climbing through FL130, the No 2 engine oil temperature started to increase markedly. At the same time there was a step increase recorded in the level of broadband vibration and the vibration levels associated with the N_2 stage of the same engine; no change in engine thrust was evident with all engines indicating an engine pressure ratio (EPR) of about 1.4. The status of the left autopilot, which had been the only one engaged, changed to disengaged but was re-engaged 26 seconds later.

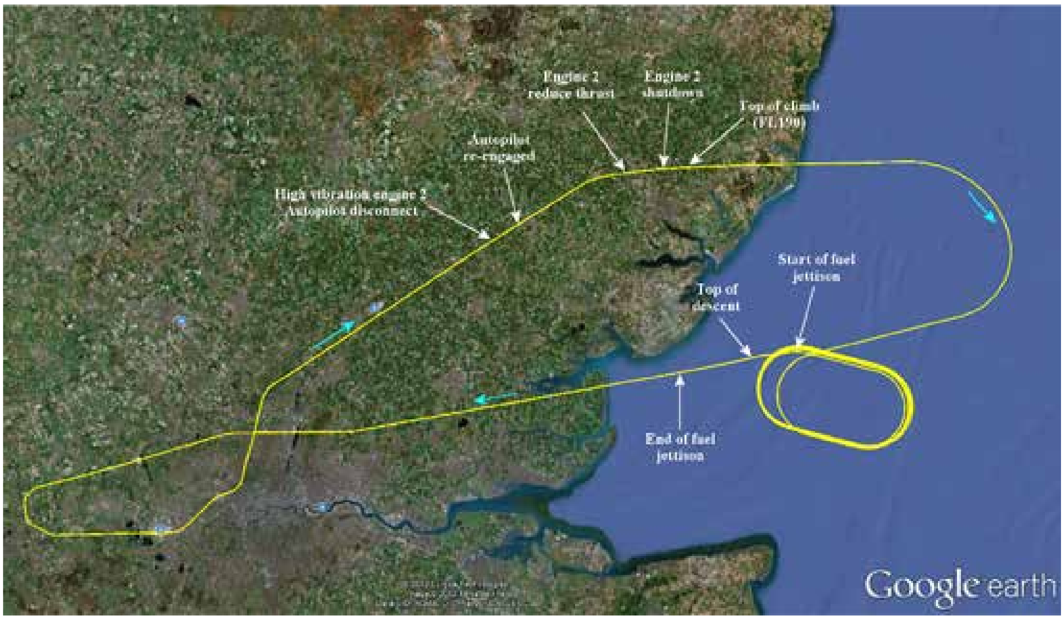

Figure 1
9M-MPL Ground radar track

As the aircraft levelled at FL190, the pilots reduced thrust on engine No 2, initially to an EPR of 1.17 and then to idle before shutting it down. The DFDR recorded engine No 2 peak values of 159.5ºC for oil temperature, 4.06 units for broadband vibration and 2.14 units for the vibration associated with N_2.

A DFDR parameter associated with each of the four AC electrical busses indicated whether the bus was powered. Prior to and after the shutdown of engine No 2, the DFDR data indicated that all four AC busses remained powered. No parameters were available to show the state of APU operation.

Fuel jettison

Between 2201 hrs and 2243 hrs, whilst in a holding pattern at FL190 over the North Sea, the crew jettisoned about 75,000 kg of fuel to reduce the aircraft's gross weight to approximately 285,000 kg. As the fuel jettison was concluding, the crew started a descent towards Heathrow.

Approach

The initial approach for the ILS on Runway 09R was uneventful. Flap 1, 5 and 10 were selected in succession and the localiser was captured at 2301:43 hrs whilst descending in a left turn through 3,160 ft amsl.

At 2301:56 hrs, at 3,080 ft amsl on the extended centreline and just before rolling wings level, all three autopilots were engaged. Eleven seconds later, having levelled at about 3,000 ft amsl, AC Bus 2 indicated a momentary[4] loss of power together with, in the subsequent second, a master warning and the disengagement of all three autopilots. All autopilots remained disengaged for the remainder of the flight.

At 2302:36 hrs, the aircraft intercepted the glideslope and started a final descent. The crew lowered the landing gear and selected Flap 20; autothrust disconnected about 24 seconds later. Flap 25 was selected at about 2,420 ft amsl and Flap 30 at 1,840 ft amsl with the aircraft stable on the ILS and with an airspeed of about 164 kt.

At 426 ft agl, 35 seconds before touchdown, AC Bus 2 lost power and remained in that state until after the landing. Following the loss of AC Bus 2, some other parameters showed anomalies: hydraulic system 2 indicated low pressure and the recorded positions of the left inner and left outer trailing edge flaps changed instantaneously to zero. Seventeen seconds later the lower yaw damper also reported a fault. The approach ground track is shown in Figure 2.

Footnote

[4] The status of an AC electrical bus is sampled once every four seconds. Only one sample of an 'unpowered' status was recorded so the maximum time that the bus could have been unpowered was just less than eight seconds.

Figure 2

9M-MPL Ground radar track

Landing

Aft movement of the control column and the start of the aircraft pitching up indicate that the flare commenced between 34 ft agl and 12 ft agl. Touchdown occurred at 2306:03 hrs at 155 kt, 1.5° right wing down and with a drift angle of +2.4°. A peak normal acceleration of 1.41g and a peak lateral acceleration of 0.167g were recorded at the point of ground contact. From the change in successive samples of radio altitude, the rate of descent at touchdown was between 6 ft/sec and 8 ft/sec. Gross weight at touchdown was 282,700 kg.

The remainder of the rollout was uneventful; thrust reversers were deployed on engine Nos 1, 3, and 4 only. The aircraft vacated Runway 09R, taxied onto Stand 431 and stopped. After the aircraft had come to a halt, AC Bus 2 status returned to the powered state at 2314:34 hrs; the DFDR stopped recording at 2314:59 hrs.

Preliminary examination of the aircraft

General

The aircraft was examined the morning after the incident. There was no visible external damage to the No 2 engine, fan or fan casing, but particles of metallic debris were found in the engine tail pipe. There was also considerable metallic debris on the master magnetic chip detector (MCD) and the No 3 bearing MCD. The aircraft had also sustained damage to the keel beam during the hard landing.

Centralised Maintenance Computer data

The aircraft *Centralised Maintenance Computer (*CMC) Present Legs Faults (PLF) report for the incident flight contained a number of faults relating to the No 2 engine failure and subsequent shutdown, between 2141 hrs and 2144 hrs.

In addition, the PLF contained a series of faults associated with the aircraft electrical system and faults relating to aircraft systems which had been lost or degraded when AC Bus 2 became permanently unpowered at 2305 hrs. These are shown in the following table.

Time	CMC Faults	Nature of Fault
2302	BUS CONTROL UNIT/ FCC-C FAIL	INTERMITTENT
	BUS CONTROL UNIT/ FCC-L FAIL	INTERMITTENT
	ELEC BUS ISLN 4 - BUS TIE BREAKER 4 TRIPPED 'DIFFERENCE CURRENT' (GCU-4)	HARD
	AC BUS 2 NOT POWERED	INTERMITTENT
	FIRST OFFICERS AC BUS NOT POWERED	INTERMITTENT
	FO XFR BUS – FO TRANSFER RELAY FAIL (BCU)	INTERMITTENT
	AC BUS 2>IRU-R INTERFACE FAIL	INTERMITTENT
	WINDOW HEAT-1R AC POWER INPUT FAIL	INTERMITTENT
2303	WINDSHEAR SYS - WXR-R TRANSCEIVER FAIL	INTERMITTENT
	WINDSHEAR PRED - WXR PREDICITIVE WINDSHEAR SYSTEM FAIL	INTERMITTENT
2305	ELEC BUS ISLN 1 – ADVISORY, BUS TIE BREAKER-1 TRIP 'DIFFERENCE CURRENT' (GCU-1)	HARD
	WXR WAVEGUIDE SWITCH FAIL	INTERMITTENT
2306	DATALINK SYS - SCID-1 CARD FAIL OR ACARS/ ACARS-R > SCID-1 CARD BUS FAIL	INTERMITTENT
	ACARS MU - SCID-1 CARD FAIL OR ACARS/ACARS-R > SCID-1 CARD BUS FAIL	INTERMITTENT

The PLF also contained some non-specific status messages relating to the window heat, APU bleed isolation, weather radar system, fuel override pumps and the flight director bar bias.

The CMC Fault History Summary Report, which records details of faults from the previous 60 sectors, also showed an 'ELEC BUS ISLSN 4 - BUS TIE BREAKER 4 TRIPPED 'DIFFERENCE CURRENT (GCU-4)' fault on 14 June 2012.

Engine exceedance reports

The Aircraft Centralised Maintenance System (ACMS) generated a number of Engine Exceedance Reports between 2144:05 hrs and 2144:31 hrs, which were printed after the aircraft landed. The exceedence reports were triggered by high oil temperatures on the No 2 engine. Peak values of 165°C for oil temperature and 2.9 units for No 2 engine vibration were recorded.

Aircraft Electrical Power Generation System (EPGS)

Electrical power

There are four electrical networks on the B747-400. A separate 'Standby Power' network provides power to the most critical aircraft systems when the primary source is lost. A simplified schematic of the electrical system architecture is shown in Figure 3.

Each network has 115 V Alternating Current (AC) and 28 V Direct Current (DC) portions. Four Integrated Drive Generators (IDG), one mounted on each engine gear box, normally provide power for the electrical system. The IDGs convert mechanical power from the engines into an AC electrical supply (3-phase, 115 V, at a frequency of 400 Hz). The 115 V AC power from the IDGs is provided to four main AC buses[5] (AC Bus 1, 2, 3 and 4), through Generator Circuit Breakers (GCB).

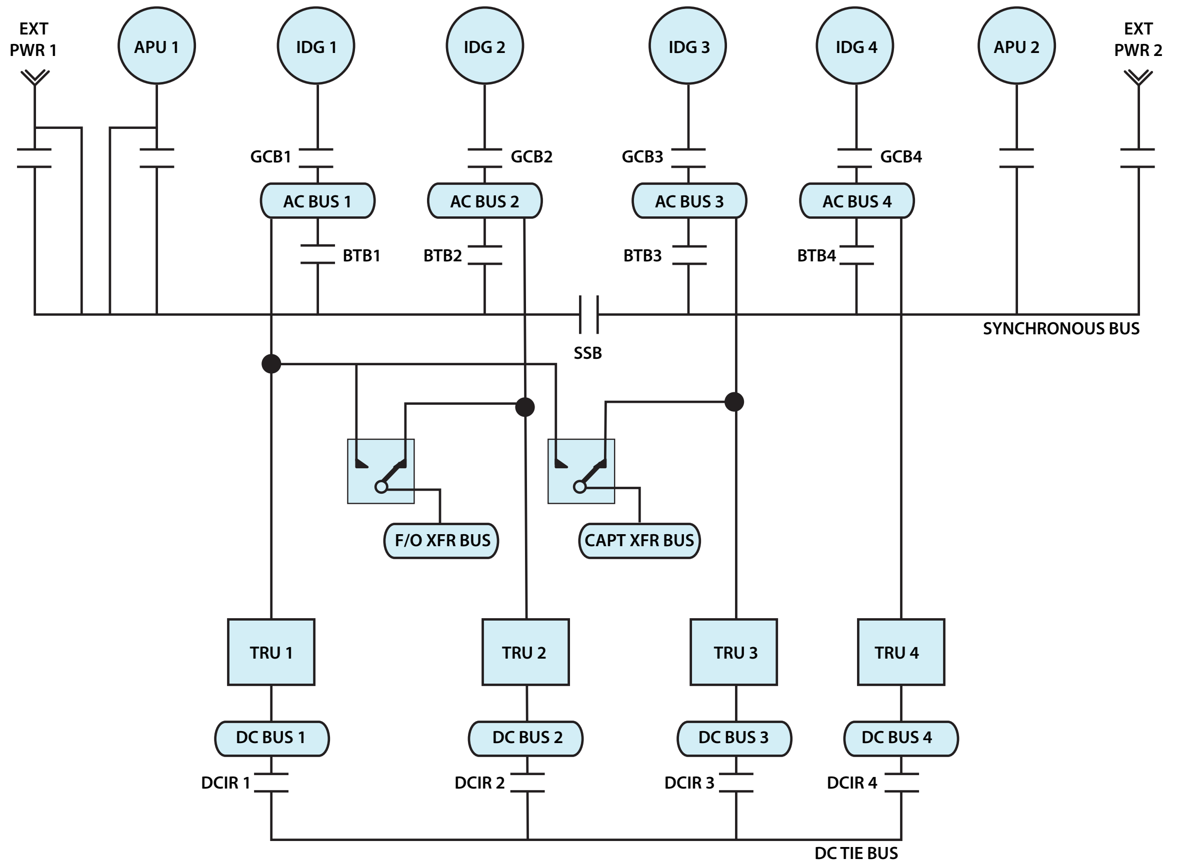

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Figure 3

Simplified schematic of B747-400 Electrical System Architecture

Footnote

[5] A bus or busbar is an electrical conductor with a high current-carrying capacity from which multiple circuits can be fed.

The electrical system can also be supplied by external power from a ground power unit (GPU) when parked, or by the Auxiliary Power Unit (APU) generator. In this case AC power is provided to the main AC buses via the synchronous bus and the Bus Tie Breakers (BTB).

The main AC buses supply other AC buses, which distribute power to the aircraft's AC systems and Transformer Rectifier Units (TRUs), which convert the AC supply into 28 V DC. AC Bus 1 supplies TRU 1 which provides power to DC Bus 1, and so on. DC Isolation Relays (DCIR) tie the DC buses to a common DC Tie Bus.

System configuration

The aircraft electrical system can operate in several split or parallel configurations. The IDGs are automatically synchronized so they can be connected to a common synchronous bus ("sync bus") to distribute load and provide backup power for all AC buses.

In normal flight operations all four electrical channels operate in parallel (Figure 4). In this configuration each AC bus is 'tied' to the sync bus by a closed BTB. If the Split System Breaker (SSB) on the sync bus is also closed, then the aircraft electrical loads will be shared equally by all four IDGs. This is known as parallel operation. If the SSB is open, the electrical system can be operated as two separate parallel systems (left and right).

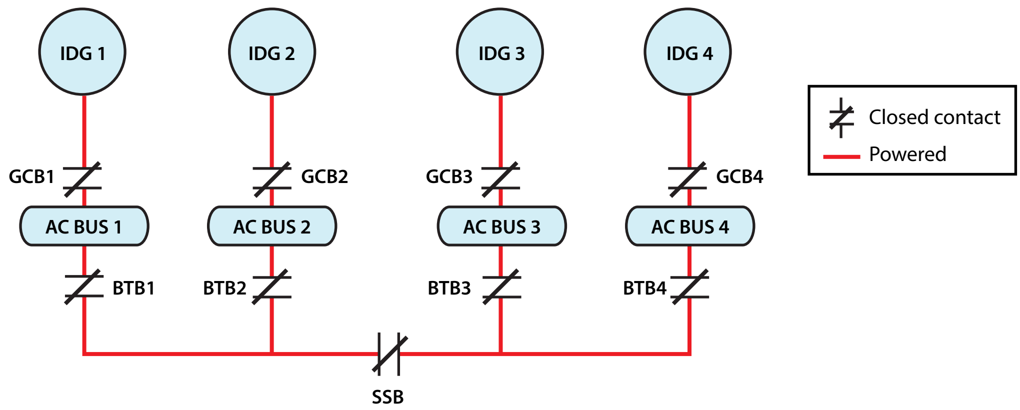

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Figure 4

EPGS configuration in normal parallel operation

When the system operates as a fully split system, all BTBs are open (Figure 5). Each main AC bus is powered only by its own IDG, via the GCB. The AC buses are said to be isolated from the sync bus.

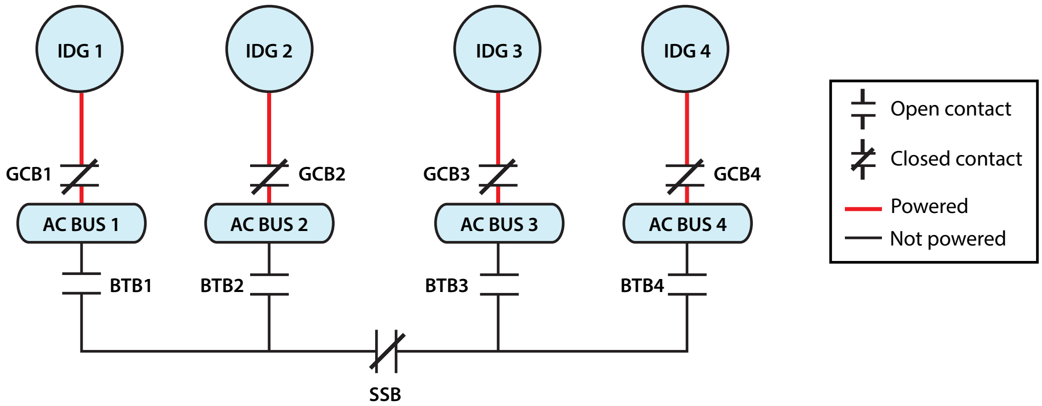

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Figure 5

EPGS configuration in split operation

Electrical load shedding

The IDGs and APU generator each have a maximum output rating of 90 kVA (kilovolt-amperes). Each generator is individually capable of supplying the aircraft's electrical requirements. If the electrical demand on an IDG exceeds its output capability, progressive automatic load shedding of non-essential loads takes place. Load shedding will occur if the load on an IDG exceeds 83.8 kVA for 4 minutes, or exceeds 105.2 kVA for 5 seconds.

EGPS control

The EGPS is designed for automatic operation to minimise flight crew workload. Two Bus Control Units (BCU 1 and 2) and four Generator Control Units (GCU 1 - 4) control, protect and regulate the EPGS in automatic and manual modes. Each GCU provides system protection and control for its IDG and operates in conjunction with the BCUs. The GCUs will also isolate IDG faults and open the appropriate GCB to protect the EGPS.

The electrical power control panel on the flight deck overhead panel annunciates the status of the electrical system and also allows for manual operation of the electrical system. A synoptic display showing the status of the electrical power system can also be displayed on the lower EICAS screen.

Circuit breakers

Circuit breakers, or contactors, are used extensively throughout the B747-400 electrical system and include the BTBs, GCBs and SSB. These identical components, Part Number B-430Z, are also used on the B747-8 aircraft. The contactors have three main contacts: T1 L1 for Phase A current; T2/L2 for Phase B; and T3/L3 for Phase C. There are also 26 pairs of auxiliary contacts (1/2, 3/4 …..51/52) which fulfil a variety of functions within the electrical system (Figure 6).

The contactor can be in one of two states, 'closed' or 'tripped' (open). In normal parallel operation of the electrical system, the main contacts of the BTBs, GCBs and SSB are closed. They are said to be 'normally closed'. When the main contacts are closed, half of the auxiliary contacts are 'normally open' and the other half are 'normally closed', depending on their specific function within the electrical system. All of the main and auxiliary contacts are mechanically attached to a single armature, which moves in response to the magnetic field created by energising an electrical coil within the contactor. When the contactor is energised the armature moves and magnetic forces hold it in the closed position. When the contactor is de-energised, the armature returns to the tripped position and is held in position by spring force.

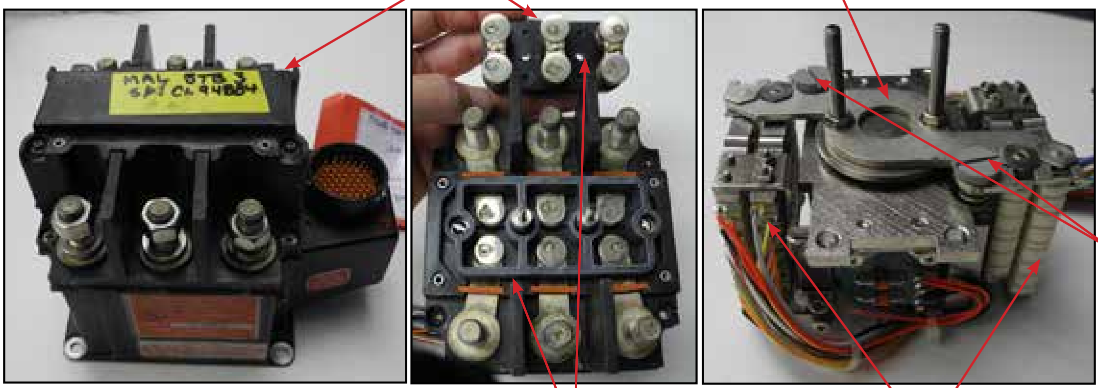

Figure 6

B430Z Contactor

Auxiliary contacts 51/52 on the BTBs, GCBs and SSB are used for the Difference Current Protection circuit. They are 'normally open'; that is, when the main contacts are closed, this set of auxiliary contacts will be open, and vice versa. BTB auxiliary contacts 15 /16 provide status information to BCU 1 and auxiliary contacts 31/32 provide status to BCU 2.

Difference Current Protection

Difference Current Protection (DCP) is one of the electrical system protections provided by the GCU. It provides a means to detect and correct imbalances in electrical load division between the IDGs when they are operating in parallel. A dedicated sensing loop uses current transformers[6] (CTs) to measure the Phase C current flow from each IDG and compares it with the average current flow from all the paralleled IDGs.

Footnote

[6] A current transformer is a device used to measure current when the current in a circuit is too high to apply measuring instruments directly in the circuit. It produces a reduced current accurately proportional to the current in the primary circuit which can then be measured. The primary circuit is largely unaffected by the insertion of the CT.

The output current from each IDG flows through a Generator Control Current Transformer (GCCT) which produces a current signal proportional in magnitude and phase angle to Phase C of the IDG output current. The CT signal current has two possible paths: out of the CT and through a GCU sensing circuit, and back to the CT; or out of the CT and around an equalizing loop. The actual current signal flow path may be a combination of both and depends on the IDG loading while operating in parallel.

If all the IDG load currents are equal and perfectly balanced, the CT signals will be equal in magnitude and phase angle and will flow entirely through the equalizing loop and the CT. No CT signal current will flow through the GCU sensing circuit, indicating that the system is in perfect balance.

When imbalances are present, a signal will flow around the equalizing loop that is equal to the average output of the un-shorted CTs connected in the loop. If a particular CT generates a signal different from the average CT output, the portion representing the difference from average will flow through the associated GCU sensing circuit. The current flow in the GCU sensing circuit indicates the direction and magnitude by which that IDG load differs from the average load current of the paralleled generators.

If the current output of an IDG differs from this average by more than 37.5 +/- 2.5 amps, corrective signals will be generated to maintain stable system operation. These include tripping the BTB on the affected channel, to isolate the respective AC Bus and therefore protect the IDG from a load imbalance. As the difference from average increases, the time between the fault occurrence and the protective BTB trip decreases, according to an inverse time delay logic.

When a generator is removed from parallel operation, such as when engine No 2 was shut down, the GCB main contacts open to isolate the IDG from the rest of the channels. The total system load is redistributed among the remaining IDGs operating in parallel. With the GCB main contacts open, the GCB difference current auxiliary contacts 51/52 close to provide a short circuit across the GCU sensing circuit; any GCCT signal current will then flow around the equalising loop. The short circuit prevents any current flow from the equalising loop or the CT from reaching the GCU sensing circuit, effectively disabling difference current protection for that channel.

A similar short circuit will occur through the difference current auxiliary contacts when any GCB or BTB is tripped open. Thus difference current sensing and protection remains active only on the generators operating in parallel. Therefore in theory, a DCP BTB trip can only occur for an IDG which is operating in parallel with other IDGs.

The DCP design allows for a maximum of 1 ohm contact resistance in the auxiliary contacts of the BTBs and GCBs. A resistance of more than 1 ohm will give the GCU false current measurements on the GCU sensing circuit, and may cause the BTB on that channel to trip.

Autoland isolation

When an aircraft performs a triple channel autoland[7], the aircraft electrical system is divided into three separate power sources, in order to provide the three Flight Control Computers (FCCs) with three independent AC and DC power sources. This process is known as autoland isolation and is managed by the BCUs. In normal operations the right FCC is powered from IDG 2; the left from IDG 1 and the centre from IDG 3. IDG 4 provides backup power during the autoland operation if any other IDG is inoperative.

When the approach is armed, the three Flight Control Computers (FCCs) send an autoland isolation request to BCU 1. BCU 1 determines the number of IDGs and TRUs that are operating and the status of the BTBs, GCBs, SSB and DCIRs. Based on this information BCU 1 decides how to divide the electrical system and directs the GCUs to operate the BTBs and DCIRs to isolate the electrical buses to the FCCs.

There are five possible system configurations determined by which, if any, IDG or TRU is inoperative. Each IDG and TRU is considered as an individual power generator (PG) by the autoland logic. If an IDG and TRU on the same channel are inoperative, they are considered as a single PG. If more than one PG is inoperative, BCU 1 ignores the autoland request as three independent power supplies cannot be assured.

BCU 2 monitors BCU 1 to see that power is isolated for each autopilot channel and then sends a bus isolated signal to the FCCs to confirm that the buses are isolated. If the bus isolation does not occur within 4 seconds of the autoland request, the request is cancelled and the autopilot goes to a 'NO LAND 3'[8] condition.

If an IDG or TRU fails while in autoland configuration, BCU 1 reconfigures the system to re-power the lost AC and DC buses. If more than one IDG or TRU becomes inoperative during autoland, the confirmation signal from BCU 2 to the FCCs is removed and the autoland is cancelled. If this occurs at an altitude above 200 ft the BTBs and DCIRs return to their original position before autoland and a 'BUS CONTROL UNIT / FCC FAIL' EICAS message is generated for the affected FCCs.

As IDG 2 was offline during the approach on the incident flight, in order to achieve three separate power sources BCU 1 would have commanded BTBs 1 and 3 to trip to isolate their respective channels. BTB 4 and BTB 2 would have remained closed so that IDG 4 supplied power to AC Bus 2 via the sync bus. Figure 7 shows the configuration of 9M-MPL's electrical system at the commencement of the autoland.

Footnote

[7] A fully automatic landing using three independent autopilot systems.
[8] 'NO LAND 3' is an EICAS message which reflects that a triple channel autoland cannot be performed.

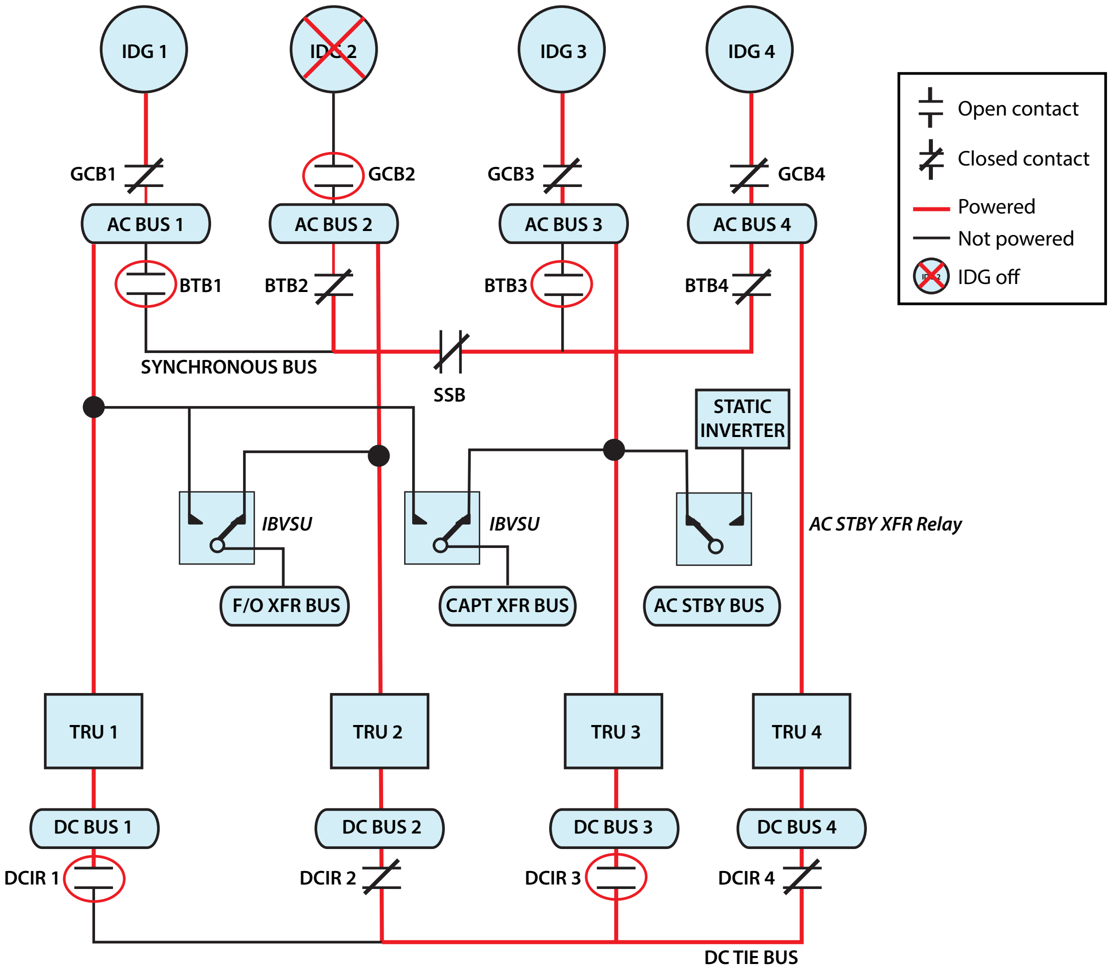

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Figure 7

9M-MPL Electrical System Configuration at commencement of the autoland

The integrated display system

The integrated display system displays information for the flight crew on six liquid crystal Display Units (DUs) in the flight deck and comprises a Primary Flight Display (PFD) and a Navigation Display (ND) in front of each pilot, and two EICAS displays on the central part of the instrument panel (Figure 8).

The PFDs present aircraft attitude, performance, flight path and autopilot mode information. The NDs provide navigation, weather radar and Traffic and Collision Avoidance System (TCAS) information. The upper EICAS screen presents engine primary data, aircraft system configuration information and, following an aircraft system failure, a list of inoperative items and required crew checklist actions. The lower EICAS screen provides synoptic displays showing aircraft system status.

Figure 8
The B747-400 integrated display system

Integrated display system power supplies

Electrical power to the six flight deck displays is provided as follows: the commander's PFD, ND and the upper EICAS screen are powered by the Captain's Transfer Bus, which is normally powered by AC Bus 3 through an Instrument Bus Voltage Sensing Unit (IBVSU). If the primary power source is lost, the IBVSU will automatically switch to AC Bus 1 to power the Captain's Transfer Bus. The first officer's PFD, ND and the lower EICAS screen are powered by the First Officer's Transfer Bus which is normally powered by AC Bus 2 through another IBVSU, with AC Bus 1 as a backup power source (Figure 7).

The IBVSUs continually monitor each phase of primary power. When the voltage of any phase of the primary power drops below 97 +/- 2 V for 187 +/- 12ms, the IBVSU will transfer the associated instrument bus to the alternate power source. The IBVSU will transfer the instrument bus back to the primary power source when all three phases of primary power source voltage recover to above 106 +/- 2 V for 1.2 +/- 0.2 secs. The IBVSU has a 180 ms delay when transferring from a primary to an alternate power source, and not more than 20 ms delay when transferring from an alternate back to the primary source. Auxiliary contacts in each IBVSU are used to provide an indication on EICAS when a flight instrument transfer bus has transferred erroneously, or when ones fails to transfer when required.

Cockpit lighting power supply

Many of the cockpit lights, including the lights on the various instrument panels are powered by AC Bus 3.

Timeline

The following timeline was created from the DFDR data and from the Present Legs Faults (PLF) page in the CMC.

Time	Event	Source of information
2144	Engine 2 Shutdown complete	DFDR/ PLF
2301:43	Aircraft captured localiser at 3,200 ft (press alt)	DFDR
2301:55	Centre and Right A/P engaged at 3,040 ft (Left had already been engaged)	DFDR
2302:06	Descending through 3,000ft, momentary power interrupt to AC Bus 2 lasting 1 sample (this discrete is sampled every 4 secs)	DFDR
2302:06	All A/P and A/T disengaged	DFDR
2302	ELEC BUS ISLN 4 - BUS TIE BREAKER 4 TRIPPED 'DIFFERENCE CURRENT' (GCU4)	PLF
	AC BUS 2 NOT POWERED (INTERMITTENT)	
	FIRST OFFICERS AC BUS NOT POWERED (INTERMITTENT)	
	FO XFR BUS – FO TRANSFER RELAY FAIL (BCU)	
	BUS CONTROL UNIT/ FCC-C FAIL (INTERMITTENT)	
	BUS CONTROL UNIT FCC-R FAIL (INTERMITTENT)	
	AC BUS 2>IRU-R INTERFACE FAIL (INTERMITTENT)	
2302:36	Aircraft Captured glideslope at 2,980 ft	DFDR
2305	ELEC BUS ISLN 1 – ADVISORY, BUS TIE BREAKER-1 TRIP 'DIFFERENCE CURRENT' (GCU-1)	PLF
2305:30	AC Bus 2 unpowered	DFDR
2306:03	Aircraft landed	DFDR
2314:34	AC Bus 2 power came back on	DFDR
2314:56	AC Bus 3 power off	DFDR
2314:57	FDR recording stops	DFDR

Detailed aircraft examination

'Autoland Unique' function tests

An 'Autoland Unique Test' can be conducted on the ground via the aircraft's CMC to verify that the correct signals are sent to the BCUs in response to an autoland request from the FCCs. When this test is conducted with the engines running, the electrical system physically reconfigures to provide the autoland isolation configuration. This test was performed a number of times during post-incident troubleshooting, with GCB 2 open to represent the incident configuration. Following completion of each Autoland Unique Test, when the electrical system should have returned to its previous configuration, BTB 3 was observed (on the EICAS electrical system synoptic and on the P6 electrical power control panel) either to remain open or to take a considerable time to re-close (between 30 secs and 2.5 minutes), resulting in AC Bus 3 remaining isolated.

Component testing

Removed components

The following electrical system components were removed for further investigation and subjected to their manufacturer's Acceptance Test Procedures (ATP): IDG 2, GCB 2, First Officer's IBVSU, BTB 3, BCU 1 and GCUs 1 - 4. No anomalies were noted on any of these components during testing, except for BTB 3.

BTB 3 examination

BTB 3 was tested in accordance with the manufacturer's ATP. When voltage was applied to command the BTB to trip, only some of the main and auxiliary contacts transitioned to the expected positions. This resulted in the contactor being in an intermediate state, which did not correspond to either the tripped or the closed condition. When voltage was then applied to command the BTB to close, it did not change state. However when the BTB was subjected to a light external impact on the outer case, the contacts moved and it returned to the closed state. Repeated testing confirmed that it was not possible to predict which contacts would move to the expected positions when the BTB was commanded to trip or close.

After removal of the BTB outer housing, a nut on one of the armature guide posts was found not properly secured, causing the armature to be misaligned (Figure 9). Loctite[9] was evident on the nut and threads of the guide post, in accordance with the design.

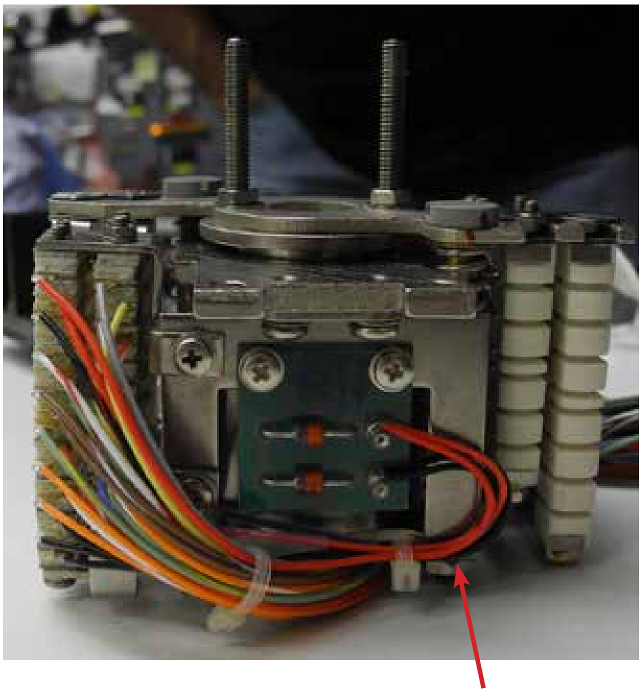
The lock washers on both guide posts had been compressed, as designed, when the nuts were tightened. This suggests either that the nut had backed off over time, perhaps due to airframe vibration, or that the contactor had been disassembled at some point after original assembly. The BTB manufacturer was not aware of any previous cases of the guide post nut loosening in service. The manufacturing drawing did not specify a torque requirement for the nut.

Examination of the main contacts revealed that they exhibited very little wear for a unit of its age (14 years), although there were indications that the contacts had been filed or buffed at some point after manufacture. BTB 3 had been installed on the aircraft since delivery and the component history records indicated that it had never been removed or overhauled.

After tightening the loose nut and replacing the washers, the contactor operated correctly.

Footnote

9 A thread-locking compound intended to prevent threaded nuts coming loose.



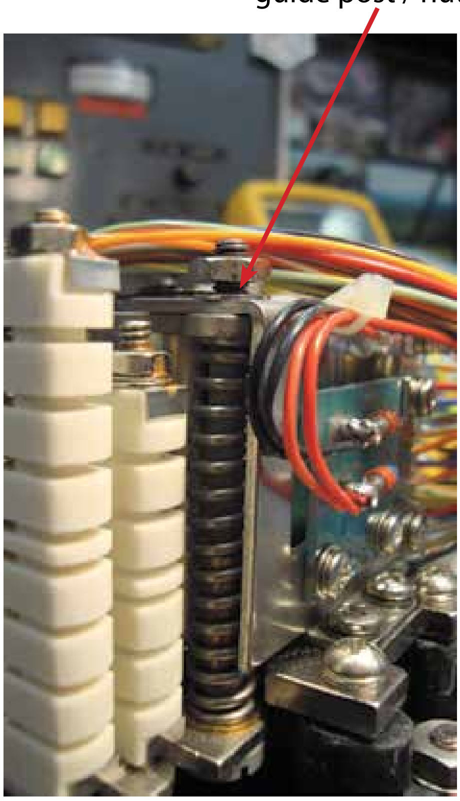


Figure 9

BTB loose guide post nut

B747-400 electrical systems test rig

Preliminary testing

The B747-400 electrical systems test rig at the manufacturer's facility was used to try to recreate the electrical system anomalies observed during the incident. The rig was representative of, but not identical to, the aircraft electrical system. The rig could be instrumented such that voltage and current at various points could be recorded. It was not equipped with flight deck displays.

Testing was initially carried out with shop units installed on the rig, with IDG 2 offline to simulate the No 2 engine shutdown during the incident. Electrical loads typical of the approach phase of flight were applied to each main AC Bus. In this condition, when the electrical system was commanded to reconfigure to the autoland configuration, it configured correctly. However, when the electrical load on either AC Bus 2 or 4 was marginally increased such that the total load on IDG 4 slightly exceeded its nominal 90 kVA capability, BTB 4 tripped after a few seconds due to Difference Current Protection. When the autoland request was removed and BTB 3 was manually tripped to simulate its failure to close during the incident, BTB 1 also tripped due to Difference Current Protection.

A number of other electrical system configurations were trialled to simulate other IDGs being offline. The Difference Current Protection BTB trips were observed to occur any time a single IDG was tied to the sync bus and was carrying the load of more than one AC Bus, even when the electrical system was not in the autoland configuration.

Testing of components from 9M-MPL

Further testing on the electrical system test rig was performed with the following components from the incident aircraft installed in place of the normal shop units: GCU 1, 2, 3 and 4, BCU 1, BTB 3, and the First Officer's IBVSU. GCB 2 from 9M-MPL was not installed due to access difficulties on the test rig.

When first installed on the test rig the incident BTB 3 was noted to be in an intermediate state. The most notable effect of this condition was observed when the test rig was powered by external power, before the IDGs had been brought online, corresponding to an aircraft receiving ground power. In this configuration, all GCBs are usually open and all BTBs are usually closed. The AC Buses receive their power from the sync bus through their BTBs, rather than directly from their respective IDGs. The AC Standby Power Transfer Relay, which is powered directly by AC Bus 3, was observed to energise and de-energise alternately and the AC Standby Bus voltage was observed to fluctuate. In addition a CAPT XFR BUS EICAS message was generated.

The AC Standby Power Transfer Relay is an AC voltage sensing relay that drops out when the Phase C voltage drops to between 88 V and 8 V AC and picks up when the Phase C voltage is greater than 109 +/- 2 V AC. This indicated that the BTB 3 main contact T3 / L3 (Phase C) was neither in the fully closed nor the fully open position, so the voltage across this main contact appeared intermittently and resulted in energising and de-energising the relay.

Repeated testing confirmed that commanding BTB 3 to trip or close could produce random combinations of main and auxiliary contact positions, and thus a variety of effects on the electrical system. When the rig was powered by IDG power, in the incident configuration, Difference Current Protection trips occurred on BTB 4, even when nominal approach electrical loads were applied to AC Bus 2 and 4.

Follow-up testing

Subsequent testing performed by the aircraft manufacturer at a later date, with shop units installed on the test rig, determined that high resistance in the difference current auxiliary contacts 51/52 of the BTBs or GCBs could lead to the GCCT signal on the respective channels not correctly shorting across the auxiliary contacts, and thus cause BTB trips due to difference current. This effect was demonstrated with the test rig in the incident configuration, by artificially increasing the resistance across the difference current auxiliary contacts of GCB 2. Depending on the electrical load on IDG 4, BTB 4 tripped due to Difference Current Protection at resistance values between 2.3 and 5.1 ohms.

This led the aircraft manufacturer and the electrical system supplier to hypothesise that, had there been a build-up of resistance on the auxiliary contacts of the GCB 2 installed on 9M-MPL, they might not have correctly shorted the GCCT 2 current signal. A false indication of the current being carried by IDG 2 could possibly have accounted for the difference current protection trips during the incident. The resistance on the difference current auxiliary contacts 51-52 of the incident GCB 2 was measured at 0.6 ohms, in the days following the incident. A subsequent resistance measurement at a later stage in the investigation was measured at 0.03 ohms.

The aircraft manufacturer advised that the test rig had not been used for a number of years prior to this investigation. They therefore considered it possible that the initial test results, with normal shop units, could have been influenced by high resistance build-up on the difference current auxiliary contacts of the various BTBs and GCBs installed on the test rig, and that repeated cycling of these contacts during the testing had caused the high resistance to dissipate.

Resistance can build up over time on electrical contacts due to lack of use, poor surface contact, contamination or oxidisation. The resulting poor contact can result in poor electrical performance. Repeated exercising of electrical contacts or cleaning can cause contact resistance to dissipate.

Previous Difference Current Protection faults

The aircraft manufacturer conducted a review of the available B747 fault history data for the period December 2000 to August 2012 to search for CMC fault codes associated with DCP BTB trips resulting in AC Bus isolations. This was done for the global B747-400 fleet, for the operator's B747-400 fleet and for 9M-MPL in particular.

There were 4,721 DCP BTB trips resulting in isolation of the associated AC Bus in the database split approximately equally among BTB 1 - 4. For the operator's fleet there were 391 events, 64% (250) of which occurred on BTB 4. 47% (188) of the operator's total events occurred on 9M-MPL, of which 98% were BTB 4 DCP trips.

The electrical system supplier advised that nuisance DCP BTB trips occurred most commonly when a single IDG was paralleled to the sync bus. This configuration could occur during engine start, as IDGs are progressively brought online one at a time; during single-engine taxi operations; or during an autoland, when typically IDG 4 is the only IDG paralleled to the sync bus. Similar behaviour had been observed by the supplier during development of parallel electrical systems on other aircraft.

The data search was further refined to look for BTB DCP trips resulting in AC Bus isolations while the aircraft was in autoland configuration. 26% (1,234) of the 4,721 B747 fleet events occurred during autoland, and 84% (1,036) of these were BTB 4 trips. 44% (175) of the events on the operator's fleet occurred during autoland, almost all of which (99%) were BTB 4 trips and occurred on 9M-MPL.

It was not possible to determine from the data whether any of these combinations of faults occurred with an IDG offline. Data for 9M-MPL indicated that the BTB 4 DCP trips occurred in clusters over periods of a few months at a time and dated back many years.

Aircraft maintenance history

A review of the technical log for 9M-MPL from July 2007 to August 2012 showed many previous occurrences of AC bus isolations. Of particular note was an entry for AC Bus 3 and 4 isolations, during approach on 14 June 2012.

Additionally, there were numerous clusters of AC bus isolation events during approach over periods of a few days in March and April 2011, August 2009, May and June 2009 and October 2007. Some of the events occurred when one IDG was disconnected. Nine of the events involved multiple AC bus isolations. Several of the bus isolations resulted in 'NO LAND 3' EICAS messages, suggesting that planned autolands were cancelled. During some of the periods when these events were prevalent, successful autolands were also recorded in the Technical Log.

No AC bus isolation was recorded, but a defect on 11 December 2011 recorded in the Technical Log stated that when the approach mode was armed the cockpit lights started to flicker until touchdown and a 'F/O XFR BUS' EICAS message was generated. The First Officer's IBVSU was tested and no anomalies were noted.

Detailed engine examination

Engine No 2 was a Pratt & Whitney PW 4056 engine, serial number P729050, with a total operating time of 44,084 hours and 4,775 cycles at the time of the incident. It had accumulated 27,505 hours and 2,857 cycles since the last overhaul.

Preliminary borescope inspections of the engine revealed multiple high pressure turbine (HPT) 2nd stage blade fractures. During disassembly of the engine, it was noted that the HPT 2nd stage Blade Outer Air Seal (BOAS) exhibited significant spalling of the abradable ceramic coating. Additionally two HPT 2nd stage BOAS segments had holes through the gas path surface and the aft corner was missing on another segment. All of the HPT 1st and 2nd stage blades appeared to have encountered heavy blade tip rub, and ten of the HPT 2nd stage blades were fractured. A 145º circumferential arc of the brush seal land on the 1st stage Inner Air Seal (IAS) was also missing.

Further detailed examination of the engine and its components by the engine manufacturer determined that material from the HPT 2nd stage BOAS had liberated and impacted the HPT 2nd stage blades, which initiated the fracture of one of those blades through fatigue. HPT 2nd stage Blade No 33 was identified as the primary blade to have fractured based on the specific features of the fracture surface, which exhibited fatigue in multiple locations, progressing from an impact site on the leading edge of the blade, consistent with a hard body impact. Transferred material on the leading edge was high in zirconium and aluminium, consistent with the composition of the abradable ceramic coating used in the BOAS.

The engine manufacturer advised that spalling of the BOAS was a known issue and that they had introduced a redesigned BOAS for this particular engine installation. The redesign is part of an upgrade package available for PW4000 series engines and includes a thin abradable ceramic, which has been shown to be more spall-resistant than the thick coating on the existing BOAS.

Cockpit voice recorder preservation

The Cockpit Voice Recorder (CVR) installation is designed to record audio information when electrical power is selected on the aircraft, and the CVR that was fitted is designed to preserve at least the last 2 hours of audio information. Flight crew communications were considered important to this investigation and the CVR should have provided further insight. However, the CVR continued to run for a considerable time after the aircraft had arrived safely on stand and all of the audio information relating to the event was lost.

ICAO Annex 6, Part I, 11.6 states:

> *'An operator shall ensure, to the extent possible, in the event the aeroplane becomes involved in an accident or incident, the preservation of all related flight recorder records and, if necessary, the associated flight recorders, and their retention in safe custody pending their disposition as determined in accordance with Annex 13.'*

The applicable requirements for this operator regarding the preservation of flight recordings were contained in the Malaysian Civil Aviations Regulations. The operator's Maintenance Management and Organisation Exposition (MMOE) addressed this topic and contained the following policy/procedure:

II. REMOVAL OF FLIGHT RECORDERS FOR AIRCRAFT ACCIDENT/ INCIDENT INVESTIGATION AND PREVENTION

1. Example of incident investigation which may warrant a flight recorder removal :-
   a. Instruction from Department of Civil Aviation.
   b. Instruction from Senior Manager Quality Assurance.
   c. Air traffic accident/incident.
   d. Heavy landing/overweight landing.
   e. Aircraft overrun runway.
   f. Aircraft leaving the runway surface.
2. Flight Recorders shall be removed immediately upon receipt of request and to be quarantined for Quality Assurance Department attention.
3. Quality Assurance Engineer to follow-up on the removal and ensure Flight Recorders are sent for read-out as soon as possible.
4. Quality Assurance Engineer is responsible to obtain the read-out/print-out and analyse data with Flight Safety Department (incident) or present data to the investigation committee (for accident).
5. Quality Assurance Engineer /Flight Safety to recommend for prevention of recurrence (if necessary).

NOTE : The contents of the Flight Recorders in part or in whole are not to be made available to any person external to the investigation except for the purpose in item 4.

Further reference was also made in the operator's Flight Operations Policy Manual (FOPM) which stated the following:

Flight/Cockpit Voice Recorder Recordings

Following an incident that is subject to mandatory reporting or whenever the Authority so directs, the Company shall preserve the relevant original recordings of a flight recorder (if the aircraft involved is so equipped) for a period of 60 days or for another period as directed by the Authority.

Note: The Company shall, within a reasonable time of being requested to do so by the Authority, produce any recording made by a flight recorder which is available or has been preserved.

If the Commander wants to safeguard stored data in case of a serious incident, an entry should be made in the aircraft Technical Log 'Remove Flight Data Recorder for investigation'.

Cockpit voice recorder recordings may not be used for purposes other than for the investigation of an accident or incident subject to mandatory reporting except with the consent of all crewmembers concerned.

Whenever it is intended to safeguard the CVR data, an entry should be made in the aircraft Technical Log 'Remove Cockpit Voice Recorder for investigation'. (If accessible on the flight deck, the circuit breaker may be pulled to stop the CVR from continuous recording with the aircraft power on.)

The CVR/FDR shall not be switched off, unless essential to preserve accident or serious incident.

The MMOE contains examples of events when flight recorders need to be preserved, but the list is brief and does not cover the circumstances encountered by the crew of 9M-MPL. In the FOPM, no mention is made of the requirement to preserve the recordings following an accident and no obligation is placed on the commander to preserve them in the event of a serious incident. The phraseology used indicates that it is at the commander's discretion to do so.

As the recording duration of a CVR is relatively short (30 minutes or 2 hours) it is essential that the recordings are secured before further assessment of the circumstances is carried out. Any procedure that does not require the crew to preserve the recordings pending any maintenance inspection will not be conducive to timely preservation of this evidence. In addition, the procedures should ensure that, even if the flight crew successfully remove power from the CVR in a timely manner, subsequent maintenance activity does not include the re-application of electrical power to the recorder. One effective way of preserving CVR and DFDR data is to pull and collar the relevant circuit breakers, and physically remove the recorders. Once permission has been granted by the investigating authority, they can then be reinstated.

The operator of this aircraft was advised, at an early stage of the investigation, of the need to have robust procedures in place for flight and ground crew to minimise the risk of losing information on flight recorders. The AAIB provided guidance on this issue and drew the operator's attention to related guidance provided to UK operators published by the UK CAA in Airworthiness Communication (AIRCOM) 2010/10. The AIRCOM made the following recommendations:

'Operators and continuing airworthiness management organisations should ensure that robust procedures are in place and prescribed in the relevant Operations Manuals and Expositions to ensure that CVR/FDR recordings that may assist in the investigation of an accident or incident are appropriately preserved. This should include raising awareness of Flight Crew and Maintenance staff to minimise the possibility of loss of any recorded data on both the CVR and FDR.

When appropriate, the relevant circuit breakers should be pulled and collared/ tagged and an entry made in the aircraft technical log to make clear to any airline personnel that an investigation is progressing. Furthermore, confirmation from the investigating authority/operator is required to be obtained before systems are reactivated and power is restored.

Operators who contract their maintenance or ground handling to a third party should ensure that the contracted organisation is made aware of all their relevant procedures.'

Analysis

Failure of engine 2

Examination of the No 2 engine revealed that spalling of the abradable ceramic coating on the HPT 2nd stage BOAS resulted in a portion of the BOAS being released and impacting the HPT 2nd stage blades. This initiated a fatigue fracture in HPT 2nd stage Blade No 33. Subsequent damage from the liberated blade resulted in imbalance of the high speed rotor, leading to the engine vibration and necessitating shutdown of the engine.

Sequence of electrical failures

Following the engine shutdown at 2144 hrs, IDG 2 was no longer able to provide power to the electrical system and GCB 2 was tripped to isolate IDG 2 from the other channels. The electrical system automatically reconfigured to distribute the loads among the remaining three IDGs and continued to operate normally until the aircraft was on approach.

When all three autopilots were engaged to perform an autoland at 2301:55 hrs, the autoland request was sent to the BCUs by the FCCs and the electrical system automatically reconfigured to provide three independent channels for each of the FCCs. This was achieved by BTB 1 and 3 tripping to isolate AC Bus 1 and AC Bus 3; BTB 2 and 4 remained closed so that AC Bus 2 was powered by IDG 4 via the sync bus (Figure 10).

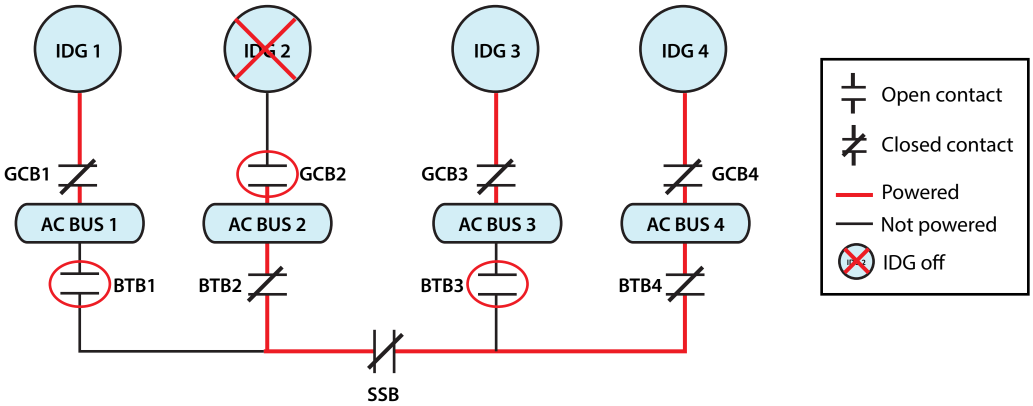


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Figure 10

Configuration of electrical system at time 2301:55 hrs

Eleven seconds later, BTB 4 tripped because Difference Current Protection isolated AC Bus 4 from the sync bus. Momentary power interruptions to AC Bus 2 and the First Officer's Transfer Bus were recorded. As three independent power supplies could no longer be assured the autoland operation was cancelled, indicated by the 'BUS CONTROL UNIT / FCC-C FAIL' and 'BUS CONTROL UNIT / FCC-L FAIL' faults. BTB 1 and 3 were commanded to return to their previous position and AC Bus 2 then became re-powered (Figure 11).

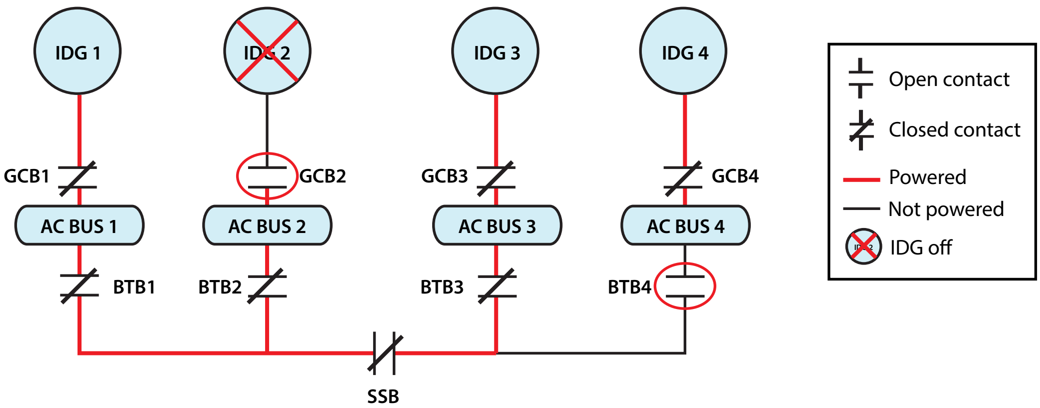

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Figure 11

Configuration of electrical system at time 2302 hrs

This configuration was sustained for a further three minutes until 2305 hrs, when BTB 1 also tripped due to Difference Current Protection, isolating AC Bus 1. DFDR and CMC data showed that power to AC Bus 2 was lost at this point. AC Bus 2 should still have received power from IDG 3 via BTB 3 but the loss of AC Bus 2 indicates that BTB 3 did not successfully close and re-parallel to the sync bus when commanded (Figure 12). It is therefore likely that the mechanical failure of BTB 3 prevented some or all of its main contacts from re-closing, leaving it in an intermediate state.

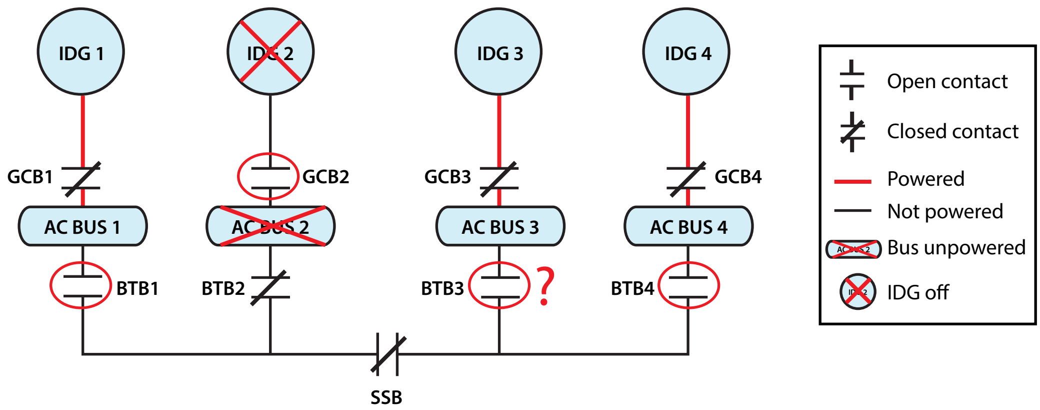

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Figure 12

Configuration of electrical system at time 2305 hrs

BTB 3 mechanical failure

The loose nut on the BTB 3 guide post allowed the armature to tilt as it moved, causing greater travel on one side than the other. As all of the BTB contacts are transitioned by a single movement of the armature, this defect meant that the correct transition of all of the contacts could not be assured. Tests demonstrated that the BTB could fail in a variety of intermediate states, corresponding to neither the closed nor the tripped state. It was not possible to predict reliably which contacts would correctly transition each time the BTB was commanded to change state. The precise effects on the aircraft electrical system might therefore differ each time the BTB was operated.

Safety action

The manufacturing drawings and component maintenance manual for the B430Z contactors did not include any specific torque requirement for the guide post nuts. As a result of the findings of this investigation, the BTB manufacturer introduced a torque requirement of 18 in/lbs for the guide post nut. Additionally, as this component is installed in the B747-8 aircraft, all newly manufactured B430Z contactors are required to meet enhanced vibration requirements.

Difference current protection trips

The Difference Current Protection of the GCU is designed to protect an IDG from load imbalance when it is operating in parallel with other IDGs. During the incident, two separate BTB trips occurred due to DCP. On each occasion only one IDG was paralleled to the sync bus.

When GCB 2 main contacts tripped after the engine shutdown, the GCB 2 auxiliary contacts would have closed simultaneously to short out the GCCT 2 signal current. Subsequently during the approach when BTB 1 and 3 were commanded to open for autoland, the BTB 1 and 3 auxiliary contacts should have closed to short out GCCT 1 and GCCT 3 signal currents. In this configuration, DCP for channels 1, 2 and 3 would have been effectively disabled. IDG 4 would have been the only generator paralleled to the sync bus and no load sharing would have been taking place with the other generators when the BTB 4 protective trip occurred. The average IDG current output would have been equal to the IDG 4 current output.

True DCP trips can only happen when one or more IDGs are operating in parallel, therefore it is concluded that the BTB 4 trip was a nuisance DCP trip. If the GCCT 1, 2 or 3 current signals had not shorted correctly through the BTB 1, GCB 2 or BTB 3 auxiliary contacts 51/52, GCU 4 sensing circuit would have detected a current imbalance and commanded BTB 4 to trip. For this to happen, at least one set of auxiliary contacts would have had to be open, or have had a contact resistance greater than 1 ohm.

Similarly, when the BTB 1 protective trip occurred, IDG 1 was powering AC Bus 1 and AC Bus 2 which were tied together via the sync bus. As AC Bus 2 subsequently became unpowered, it can be assumed that no load sharing was taking place with IDG 3 at this time. GCU 1 would therefore only have commanded BTB 1 to trip if at least one GCCT was not properly shorted by the BTB 1, GCB 2 or BTB 3 auxiliary contacts.

The particular nature of the mechanical failure within BTB 3 meant that it was quite possible that its difference current auxiliary contacts had remained open, or stuck in an intermediate position during the system reconfigurations. In such a case the GCCT 3 signal may not have been correctly shorted, leading GCU 4 and GCU 1 to detect erroneous difference current signals, and commanding protective trips. It is therefore possible that the BTB 3 fault on its own was sufficient to cause the DCP trips and the subsequent loss of power to AC Bus 2.

However, testing on the electrical systems test rig demonstrated that protective DCP BTB trips could also occur under certain load conditions, and in particular at any time that a single IDG was tied to the sync bus and carrying the load of its own and one other bus. If an IDG is genuinely overloaded, the correct system response is automatic load shedding and not DCP, suggesting that these were nuisance DCP trips. This phenomenon was observed on the test rig even when the defective BTB 3 was not installed. These results were in keeping with the experience of the electrical system supplier. They advised that nuisance DCP trips occurred most commonly during normal operations, when only one IDG was paralleled to the sync bus such as during engine start, single-engine taxi operations or autoland.

After follow-up testing on the electrical systems rig, the aircraft manufacturer and the electrical systems supplier concluded that high contact resistance on the difference current auxiliary contacts of GCB 2 could have led to the DCP trips during the incident. This effect was demonstrated on the test rig by artificially increasing the resistance on the GCB difference current auxiliary contacts and observing the resulting DCP trips. However post-incident resistance measurements on the GCB 2 from 9M-MPL indicated that the contact resistance was well below the 1 ohm contact resistance limit of the system. This combined with the fact that GCB 2 from 9M-MPL operated normally during ATP testing, and that no testing of this GCB 2 was conducted on the test rig meant it was not possible to verify this theory. Furthermore, as the GCB 2 auxiliary contacts 51/52 closed when the No 2 engine was shut down, high contact resistance, had it existed, could have led to a nuisance DCP at any time, and not just when the electrical system was subsequently commanded to reconfigure for autoland. There was therefore insufficient evidence to identify high contact resistance on the difference current auxiliary contacts of GCB 2 as a specific contributor to the incident. However the possibility of high contact resistance on the auxiliary contacts throughout the difference current loop could not be ruled out as contributing to the sequence of events.

In summary, it was determined that the DCP trips encountered during the incident were not genuine difference current trips resulting from an IDG load imbalance. They were most likely nuisance difference current trips caused by inadequate shorting of the GCCT currents. These could have resulted from the mechanical failure of BTB 3, high resistance on the auxiliary contacts in the difference current loop, or a combination of both conditions.

Previous Difference Current Protection trips

B747-400 fleet fault history reviewed in the course of the investigation indicated that difference current faults are a relatively common occurrence. It was not possible to ascertain from the data how many of these were events were due to genuine DCP trips, but the aircraft manufacturer suspected that the high numbers were largely being driven by nuisance trips. Ordinarily, in normal operations, nuisance DCP BTB trips would have a limited effect on the performance of the electrical system. In particular a BTB 4 DCP trip when the electrical system was configured for autoland would have had little or no effect on the electrical system. However, the effect in this case was more pronounced due to one IDG being offline, and IDG 4 having to provide backup power to the affected channel for the autoland configuration.

It was largely possible to correlate the high incidence of BTB 4 DCP trips on 9M-MPL with the defects recorded in the aircraft's Technical Log. This data indicated that the mechanical fault with BTB 3 is likely to have been present and undetected for some time, but was intermittent in nature.

Safety action

As a result of the findings of this investigation, the aircraft manufacturer plans to revise the B747-400 and B747-8 Fault Isolation Manuals (FIM) to include checks of the BTBs, when repeated nuisance difference current BTB trips are recorded by the CMC. The new instructions are planned to be included in the February 2014 revision of the FIMs.

Effects of the electrical failures

It was not possible to reproduce or simulate the flickering of the commander's and first officer's display units during testing in the exact manner described by the crew. However two issues were identified which would have contributed to the displays blanking.

The momentary power interruption to AC Bus 2 following the BTB 4 trip, and the ultimate loss of power on AC Bus 2 resulting from the BTB 1 trip, would have contributed to at least three occasions of momentary blanking on the first officer's displays, as the First Officer's IBVSU switched from AC Bus 2 to the AC Bus 1 alternate power source, and back again. This would not, however, have accounted for any blanking or flickering of the commander's display units.

Testing on the electrical systems rig when the incident BTB 3 was in an intermediate state revealed a condition where one phase of AC power from AC Bus 3 was observed to oscillate, causing intermittent cycling of a voltage sensing relay. Although this precise effect was observed while the test rig was receiving ground power rather than IDG power, the defective BTB could have had a similar effect on the AC Bus 3 voltage during the incident.

As AC Bus 3 is the primary source for the commander's displays, it is quite possible that fluctuating voltage on one or more phases may have caused power oscillations on the Captain's Transfer Bus. However there were no CAPT XFR BUS EICAS messages generated during the incident. This aspect is not fully understood, but one explanation could be that the voltage fluctuations were not sufficiently large, or of sufficient duration to trigger the IBVSU to command the Captain's Transfer Bus to its alternate power source. Fluctuating voltage on AC Bus 3 is also the most likely explanation for the flickering of the cockpit lights, many of which are powered by AC Bus 3. The flight crew reported that flickering of the displays and cockpit lights stopped after landing. It is possible that the firm landing caused some of the BTB 3 contacts to be re-seated. However, it is noted that AC Bus 2 did not become repowered until the aircraft was on the parking standing, most likely coinciding with the application of ground power to the aircraft, which suggests that not all of the BTB 3 contacts transitioned to the closed state.

Loss of AC BUS 2 and its dependent sub-busbars resulted in degradation or loss of multiple aircraft systems, including the right flight control computer. The resultant loss of displayed data, in combination with the flickering displays at a critical phase of flight, created an extremely demanding situation for the flight crew to manage and could have adversely affected the safe operation of the flight.

The simultaneous intermittent blanking of the commander and first officer's displays should not have been possible given that they are powered from independent electrical networks, with alternate power sources in the event of a primary power failure. However, the particular nature of the latent mechanical failure in BTB 3, in combination with the specific configuration of the electrical system, created an unanticipated failure mode.

Given the unique nature of both the event and the BTB 3 failure and the prevalence of nuisance DCP trips during normal operations, other B747-400 and B747-8 operators should be informed of the details of this incident. The following Safety Recommendation is therefore made:

Safety Recommendation 2014-012

It is recommended that Boeing Commercial Airplanes notify all B747-400 and B747-8 operators of the characteristics of the bus tie breaker mechanical failure on 9M-MPL and nuisance difference current protection trips, emphasising the maintenance actions required if repetitive difference current protection trips occur.

Preservation of flight recordings

The CVR continued to run for some time after the aircraft landed and as a result all relevant CVR recordings were lost. The investigation determined that the operator's procedures for the preservation of flight recordings were not sufficiently robust to ensure that recordings would be preserved in a timely manner following an incident or accident. The operator expressed willingness to address this issue and has proposed amendments to their FOPM. The revised procedures require the commander to secure the recordings as soon as possible after a flight involving a serious incident by pulling and tagging or collaring the appropriate circuit breakers and, if the means for achieving this is not on the flight deck, the commander is required to ensure that the appropriate maintenance personnel take that action. Additional emphasis is also placed on the need to do this before any other maintenance task is conducted.

The operator has circulated these revised procedures as a temporary amendment to the FOPM and intends to provide the associated continuation training. The revised instructions were included in the update of the FOPM issued in July 2013.

The AAIB are satisfied that, when followed, the updated procedures coupled with the associated training will reduce the risk of losing these important flight recordings and, as a consequence, consider that a Safety Recommendation to address this issue is not required.

Conclusion

The intermittent blanking of the flightdeck displays, the complete loss of power to AC Bus 2 and the resultant degradation of multiple aircraft systems were caused by a latent hardware fault on BTB 3, in combination the following factors:

- the failure of No 2 engine, which lead to IDG 2 being offline
- configuration of the electrical system for an autoland
- nuisance difference current protection BTB trips by GCU 1 and 4

The investigation determined that the nuisance difference current protection trips could have been caused by the mechanical failure of BTB 3, high resistance in the difference current loop or a combination of both conditions.

INCIDENT

Aircraft Type and Registration:	Cessna 525 Citation Jet, D-IPCS	
No & Type of Engines:	2 Williams FJ44 turbofan engines	
Year of Manufacture:	1998 (serial no. 525-0264)	
Date & Time (UTC):	31 October 2013 at 1820 hrs	
Location:	South East England	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 2	Passengers - 4
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	4,900 hours (of which 400 were on type) Last 90 days - 71 hours Last 28 days - 10 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft diverted to London Gatwick Airport after both FUEL FLTR BYPASS warning lights illuminated during the cruise, indicating that the fuel filters were obstructed. The aircraft landed without further incident. The investigation concluded that the obstruction was probably caused by ice forming on the fuel filters due to insufficient anti-icing additive being added to the fuel during the previous refuelling.

History of the flight

The aircraft departed Barcelona at 1555 hrs for a flight to Manchester. On board were the two flight crew and four passengers. The flight proceeded normally until approaching the English Channel, cruising at FL 400, where the ram air temperature (RAT) was reported as -48°C. By this time a fuel imbalance of about 120 lb had developed, which the flight crew dealt with by transferring fuel from the right tank to the left.

About 10 minutes after completing the fuel transfer a RH FUEL FLTR BYPASS caption illuminated, indicating bypass of the right engine fuel filter. The flight crew consulted their Quick Reference Handbook (QRH), which advised that a landing should be made 'AS SOON AS PRACTICAL' and that the crew should consider the possibility of partial or total loss of the thrust from both engines. As the aircraft was nearing its destination, the crew elected to continue the flight to Manchester. However, after a further 10 to 12 minutes, the LH FUEL FLTR BYPASS caption also illuminated, indicating that both engines fuel filters were now affected.

The flight crew informed ATC of the situation and requested diversion to a suitable airport. London Gatwick was offered, which the crew accepted. The aircraft landed at Gatwick at 1841 hrs after an expeditious but uneventful arrival. There were no further abnormal cockpit indications and both engines continued to operate normally. Following an external inspection by the airport fire service, the aircraft was taxied to the parking area and shut down.

Fuel system description

Fuel is contained in two integral wing tanks, one in each wing, and is normally supplied to each engine by a primary ejector pump in each tank. These use fuel pressure returned from the engine-driven fuel pump and the venturi effect to produce a high volume flow at low pressure to the engine. Electric boost pumps are also fitted in each tank; these are used for engine starting, fuel transfer and as a backup to the primary ejector pumps.

The fuel supplied to each engine initially passes through an engine-driven fuel pump and then a filter, before being delivered to the engine fuel control unit. The fuel filter is fitted with a bypass valve to allow continued fuel flow should the filter become obstructed. The crew are alerted to an impending or actual bypass of the fuel filter by the relevant FUEL FLTR BYPASS annunciator panel light and the MASTER CAUTION RESET illuminating.

Fuel is not heated before it reaches the engine fuel filter and therefore an anti-icing additive must be mixed with the fuel to prevent fuel icing.

Refuelling prior to the flight

The commander reported that the aircraft was refuelled at Barcelona with 1,100 litres of Jet A-1 fuel, bringing the total fuel on board to 2,700 lb (approximately 1,500 litres). It was necessary to add a fuel system anti-icing additive during refuelling, cans of which were normally carried on the aircraft. The commander reported that he did so in Barcelona, but that on this occasion he did not realise that the can he used contained only half the amount of additive compared to the cans normally used. Consequently, the commander inadvertently added only half the required amount of additive.

Aircraft examination

The aircraft was inspected by the AAIB with an engineer from the operator’s maintenance organisation present. Fuel samples were taken from each of the two wing tanks; no water or other contamination was visible. A test for micro-organisms in the fuel was negative. Each engine fuel filter was removed and inspected; both were clean. The fluid in each filter bowl was examined and in each case there was water present, as well as fuel. The fuel filters were replaced and the filter bowls were cleaned before being refitted. Engine ground runs were carried out and engine operation was normal.

Subsequent laboratory testing of the fuel samples showed that the fuel contained much less anti-icing additive than was required.

Conclusion

The obstruction of the fuel filters was most likely caused by ice forming on the filters due to insufficient anti-icing additive being added to the fuel during the previous refuelling.

Safety actions

Following this incident the operator undertook the following safety actions:

1. A new procedure was introduced requiring crews to record, in the flight log, the quantity of anti-icing additive used at each refuelling.
2. A safety message was issued to all crew highlighting the requirement for adding anti-icing additive to some aircraft, advising them of the new recording process and reminding commanders to check sufficient quantity of anti-icing additive is on board the aircraft before leaving home base.

ACCIDENT

Aircraft Type and Registration:	Cirrus SR22, N147KA
No & Type of Engines:	1 Continental IO-550-N piston engine
Year of Manufacture:	2006 (Serial no: 1944)
Date & Time (UTC):	21 July 2013 at 1200 hrs
Location:	English Channel
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	192 hours (of which 76 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was flying from Blackbushe to Le Touquet when it disappeared from radar. Small sections of the aircraft recovered later from the sea surface indicated that it experienced a high-energy impact with the surface. The aircraft was being flown in conditions of low cloud or sea fog with little or no discernable horizon. The pilot did not have an instrument or IMC rating. The investigation did not determine the cause of the accident.

History of the flight

The aircraft was on a private flight from Blackbushe Airport to Le Touquet Airport in France. The pilot arrived at the airport at 0810 hrs and spoke to the controller on duty in the ATC tower. During this conversation, he expressed concern about the weather, specifically the cloudbase. The controller advised him that at Farnborough Airport (4 nm to the southeast) the cloudbase was approximately 1,500 ft. After some discussion, the pilot stated his intention to fly some circuits to assess the weather and, if he decided it was suitable, he would then depart for Le Touquet.

The airfield fire section refulled the aircraft to full tanks at the pilot's request. All of the witnesses who spoke with the pilot described him as being alert and in good spirits.

The aircraft took off at 0914 hrs and entered the visual circuit. The air traffic controller who witnessed the circuits described them as normal and consistent and the pilot's radio transmissions as crisp, clear and correct. After he had completed seven circuits, the pilot informed ATC of his intention to fly to Le Touquet and the aircraft departed the circuit at 0948 hrs.

The aircraft routed to the east of the Farnborough zone, south to the Midhurst VOR, then towards the Seaford VOR before setting out over the English Channel on a course consistent with a direct track towards Le Touquet. At 1020 hrs the pilot contacted London Information stating that he was crossing the coast east of Seaford. He subsequently passed an ETA for Le Touquet of 1044 hrs. No further transmissions were heard from the aircraft.

After crossing the coast, the aircraft maintained a near constant speed, height and track until 28 nm from Le Touquet. It then turned left and descended before reversing course to the right onto a track of 081º. It maintained this new track and height until just before the radar returns ceased at 1034 hrs. The French authorities initiated overdue action when the aircraft failed to arrive at Le Touquet. Search and rescue operations located wreckage on the surface of the sea in the vicinity of the last radar returns.

Meteorological information

A Met Office report, at the time the aircraft was carrying out circuits, gave the cloudbase at Farnborough as broken at 1,400 ft with visibility greater than 10 km. Visual satellite images show less cloud further south and large clear areas around the coast. Figure 1 shows a visual satellite image of the area of low cloud or sea fog. The Shoreham 0950 hrs and 1020 hrs weather reports indicated few clouds at 2,000 ft. Weather reports for Lydd Aerodrome for the same times indicated CAVOK and temperature 22ºC. However, satellite images showed a band of low cloud or fog extending through the Dover Straits and into the English Channel across the route of the aircraft. Weather reports for Le Touquet for 1030 hrs and 1100 hrs indicated visibility greater than 10 km, no significant cloud, temperature 27ºC and dewpoint 28ºC. The forecast for Le Touquet between 0900 hrs and 1800 hrs indicated wind from 090º at 7 kt and CAVOK.

Two MetForms 215[1] were issued by the Met Office covering the period of the flight; the first was valid for flight between 0200 to 1100 UTC and the second for flight between 0800 hrs and 1700 hrs. Both MetForms were amended during the previous night to reflect a late forecast of low cloud and sea fog in the English Channel. The final amendment was issued at 0520 hrs.

Airborne meteorological reports

Two airborne reports were obtained from aircraft flying approximately three minutes ahead and 12 minutes behind the accident aircraft and on a similar route. Both pilots stated that, near the English coast, the weather was hazy but there was little cloud. Both also reported that, when over the English Channel, there was an area of low cloud or fog obscuring the surface accompanied by a significant amount of haze with no discernable horizon. One pilot stated that this area of low cloud or fog extended from approximately 8 nm off the English coast to about 8 nm off the French coast.

Footnote

[1] MetForm 215 provides a forecast of in-flight weather conditions below 10,000 ft.

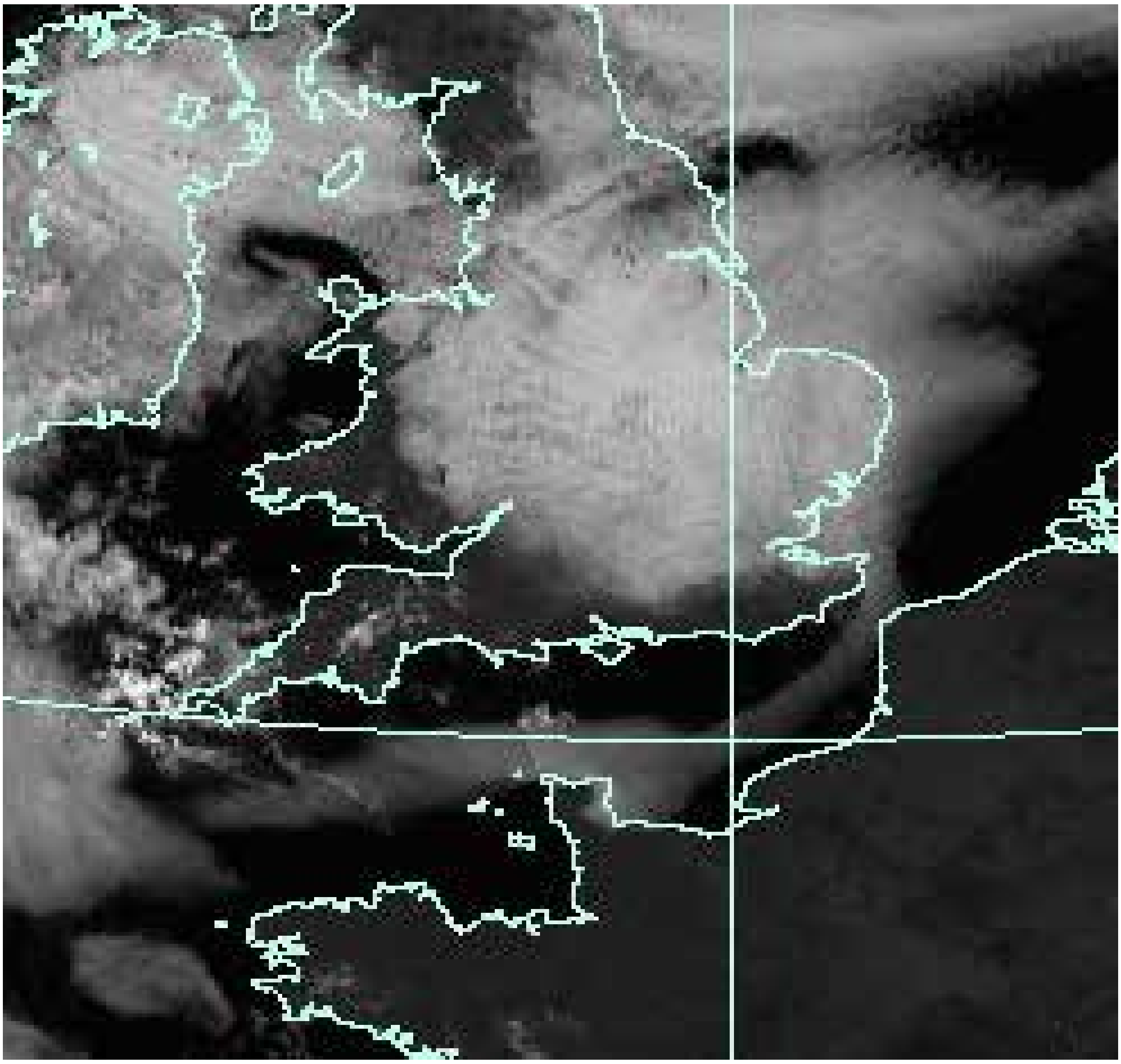

Figure 1

Visible satellite image valid at 1030 hrs on 21st July 2013
showing a band of fog or low cloud extending into the English Channel

Visual Flight Rules (VFR)

Aircraft flying under VFR outside controlled airspace at 140 kt or less and below 3,000 ft are required to maintain 1,500 m in-flight visibility, clear of cloud and in sight of the surface.

Schedule 7 of CAP 393, '*Air Navigation: The Order and the Regulations*' further restricts the holder of a Private Pilot's Licence (Aeroplanes) (PPL(A)) without any instrument rating to a minimum flight visibility of 3 km outside controlled airspace.

Pilot information

The pilot gained a Private Pilot's Licence in 2010 and had flown a variety of light aircraft since then. His logbook was recovered from the sea surface and showed that he had accrued a total of 192 hours flying time, of which 36 hours were on the Cirrus SR20 and 40 hours on the Cirrus SR22. He did not hold an instrument or IMC rating although a passenger who occasionally flew with him reported that he had, in the past, flown through cloud with the autopilot engaged. During his PPL(A) training he recorded 1.5 hours of instrument flying in his pilot's logbook. Since gaining a PPL(A), he recorded just over 4 hours of instrument flying, none of which appeared to have been under instruction.

General description of the aircraft

The Cirrus SR22 is a high performance single piston engine aircraft of conventional layout. It is certified for flight in both visual and instrument meteorological conditions and is fitted with an integrated instrument system with multi-function displays and an autopilot. The multi-function displays contain non-volatile memory that record a number of aircraft parameters. Some Cirrus aircraft are fitted with a further memory device in the tail fin, but this example was not. The aircraft is fitted with dual alternators and dual batteries to ensure redundancy of the electrical system. The aircraft is of composite construction and incorporates safety features including airbags in the seat harnesses, which for the front seats are attached to the seat, and a manually initiated emergency parachute system for the whole aircraft which is deployed by a solid fuel rocket. The passenger cabin can be heated using air that is warmed by a heater muff on the engine exhaust system.

Wreckage recovery

There was not a defined accident site because the aircraft impacted the sea; however, the subsequent search and rescue operations located several pieces of floating wreckage and personal items. The crew of the attending lifeboat also reported a strong smell of fuel in the area where the wreckage was found. Floating wreckage was recovered and transported to the AAIB for examination. This included both main cabin doors, a section of the rear fuselage containing the baggage door, a section of the rear fuselage containing part of the rear fuselage access panel, the top engine cowling, pieces from the top and bottom skin of both wings and a number of items of interior trim including the carpet from the front foot wells. The pilot's flight bag and a rucksack were also recovered. The high degree of fragmentation suffered by the recovered items suggested the aircraft had been subject to a high energy impact. A liferaft was also recovered; it had been torn from its cover bag but had not inflated.

Three weeks after the accident a recreational diver reported to the Coastguard that he had come across some aircraft wreckage that he believed was from the accident aircraft, approximately nine miles from where the original floating wreckage was found. Enquiries by the AAIB confirmed that this was likely to be from the accident aircraft. This wreckage reportedly consisted of the cabin floor and parts of the rear bulkhead with three seats attached; the forward port seat was missing and appeared to have been torn away from its mounting. Parts of the wings were attached but only as far outboard as the main landing gear legs, to which the wheels remained attached. The three tail surfaces were lying nearby and appeared to be connected by their control cables. There was no sign of the engine or the instrument panel and its displays. The possibility of recovering the wreckage was explored but its offshore location and the potential for the parachute deployment rocket to be live indicated that the hazards of a recovery operation were excessive for the limited new evidence that it might provide, especially given the likelihood that it may already have been moved by currents.

The AAIB were aware of other independent search and recovery efforts but at the time of writing nothing further had been recovered.

Detailed inspection of the recovered wreckage

Damage to the structure and latches of both main cabin doors indicated both were locked closed at the moment of impact.

The two larger pieces of rear fuselage contained part of the channel that enclosed the aircraft parachute straps. The cover panels were also found and appeared to have detached from the forward end rearwards, suggesting they were detached by disruption due to the impact rather than by deployment of the emergency parachute.

The front face of the top engine cowling had deep score marks consistent with firm contact against the rotating aft-face of the propeller spinner backplate.

The fragments of wing were distributed approximately equally between the left and right wings, and the pieces were all relatively small but included the fuel filler cap and neck from both wings. The largest piece, approximately 1,000 mm by 300 mm, contained the aileron trim actuator whose position indicated that some left aileron trim was applied.

Maintenance records

The aircraft was maintained by a Cirrus approved service centre and had been maintained by the same facility for most of its operation. The last Annual inspection had been completed on 2 August 2012 and the only recorded work since then was a tyre change on 20 May 2013. As the aircraft was being operated on the United States (US) 'N' register, it was being maintained in accordance with Federal Airworthiness Requirements (FARs).

Examination of the maintenance records showed that the propeller, the magnetos and the cabin heater muff had exceeded the manufacturer's recommended overhaul limits. These components had been inspected and found serviceable at the last Annual Inspection in August 2012. This deferment was, however, allowable within the FARs.

A pilot who had flown the aircraft the previous day stated that the aircraft had been operating normally.

Recorded information

Recorded data for the accident flight was available from several radar heads. Most of the flight was detected by the radar head at Pease Pottage in Mid Sussex as a combination of primary and secondary returns. The aircraft was fitted with a Mode S transponder that transmitted the groundspeed and true track together with altitude (with ± 50 ft resolution) for each secondary return. The sweep rate for Pease Pottage was 6 seconds. The latter part of the track was also recorded by a French radar head located near Boulogne-sur-Mer.

This track was also a combination of primary and secondary returns; however, the Mode S groundspeed and true track angle were not recorded even though the radar at Boulogne-sur-Mer was capable of receiving them.

The ground track of N147KA is illustrated in Figure 2 (Pease Pottage in green and the last 21 returns of Boulogne in red) and shows the aircraft in the circuit at Blackbushe before tracking towards the Midhurst and Seaford VORs and crossing the coast at Beachy Head.

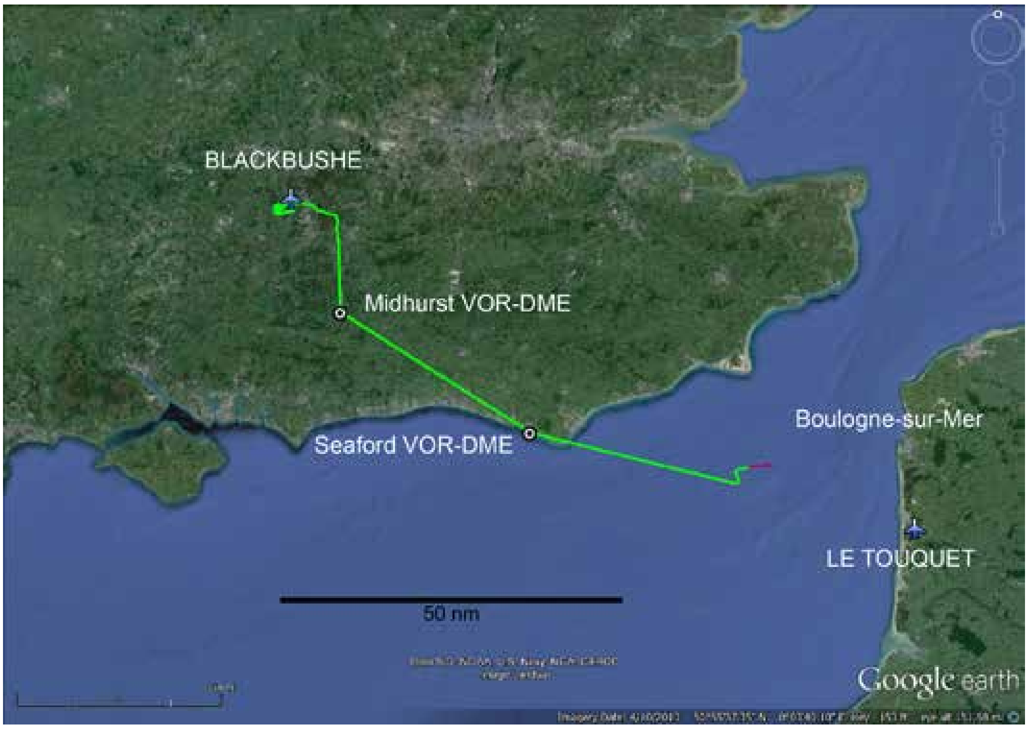

Figure 2

Overview of the accident flight radar tracks

Figure 3 shows the groundspeed, true track and altitude (adjusted to 1018 hPa) from the aircraft. The figure shows it in the circuit at Blackbushe where eight circuits were flown and then flying towards the Midhurst VOR at approximately 1,230 ft. It then climbed to approximately 1,930 ft amsl before flying overhead the Seaford VOR and turning toward Le Touquet, crossing the coast at 1019:29 hrs.

At 1030:45 hrs, about 25 nm from Beachy Head, the groundspeed began to reduce from a nominal 140 kt. Shortly afterwards the aircraft began to descend and, at 1031:16 hrs, turned left from a track of 105ºT. The minimum altitude recorded in the turn was 1,030 ft amsl on a track of 22ºT. The aircraft continued the turn to about 320ºT before turning back to the right onto a track of 81ºT towards Boulogne-sur-Mer. The descending turn is illustrated in Figure 4.

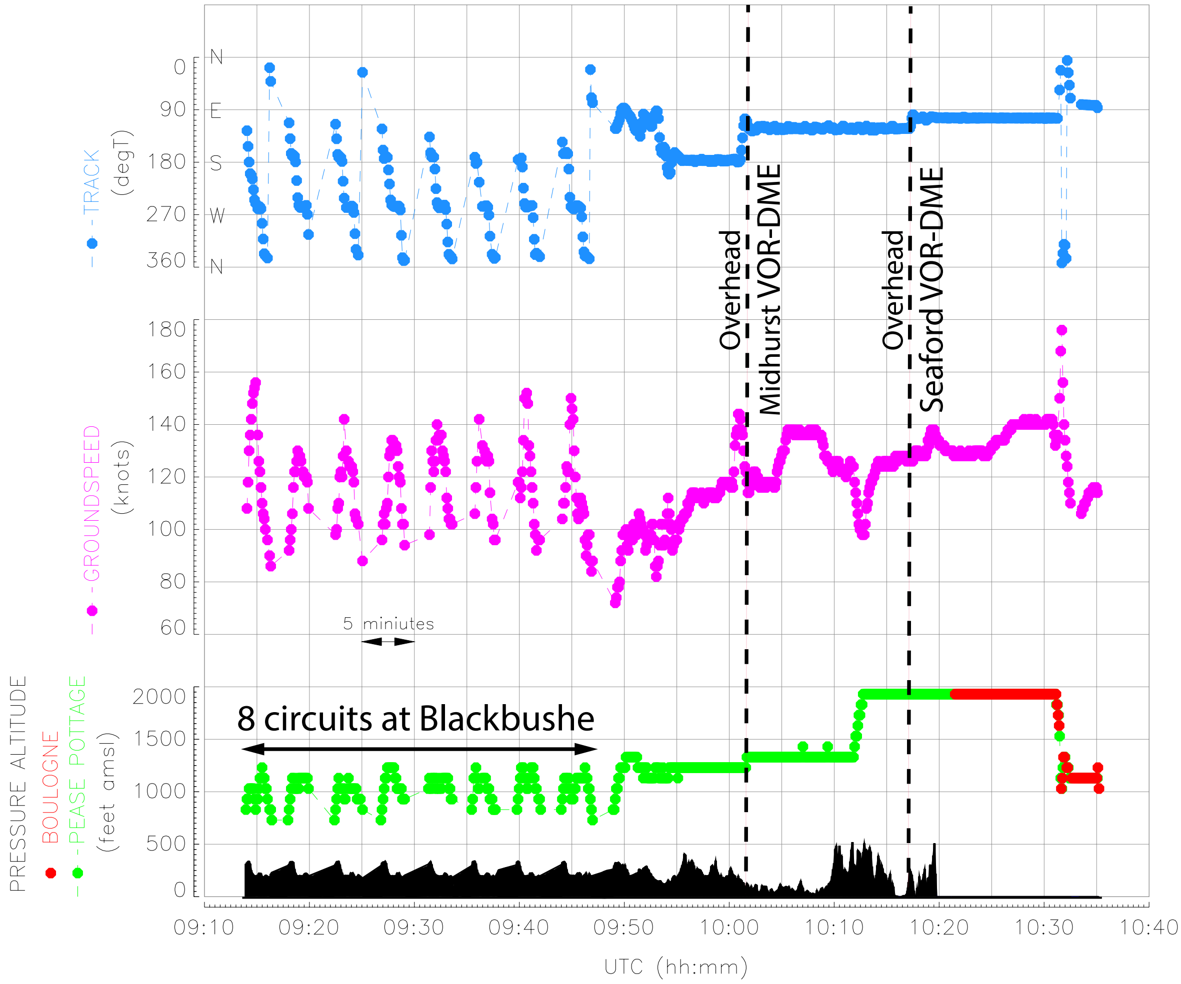

Figure 3

Radar Mode C & S recorded data for accident flight with terrain height below flight path

The last secondary radar return recorded by Pease Pottage, at 1035:05 hrs, indicated that the aircraft was at 1,130 ft amsl on a track of 87ºT. There were two additional secondary radar returns, recorded by Boulogne radar, at 1035:07 hrs and 1035:13 hrs, with the aircraft reporting altitudes of 1,230 ft amsl and 1,030 ft amsl respectively. The position of these two returns also confirmed a change in track to the right. Radar coverage was then lost as the aircraft approached the edge of coverage of both radar heads due to line-of-sight limitations for targets at or below approximately 1,000 ft amsl.

Analysis

The pilot was concerned about the weather before he departed and had expressed specific concern about the cloudbase. In order to assess the weather, the pilot flew several circuits before departing to Le Touquet. He flew his initial departure from Blackbushe at a height that was consistent with the aircraft operating below the cloudbase in that area. His subsequent climbs, as he flew further south, may have corresponded with improving weather. The initial track to the southeast appeared to have been manually flown, while the constant height

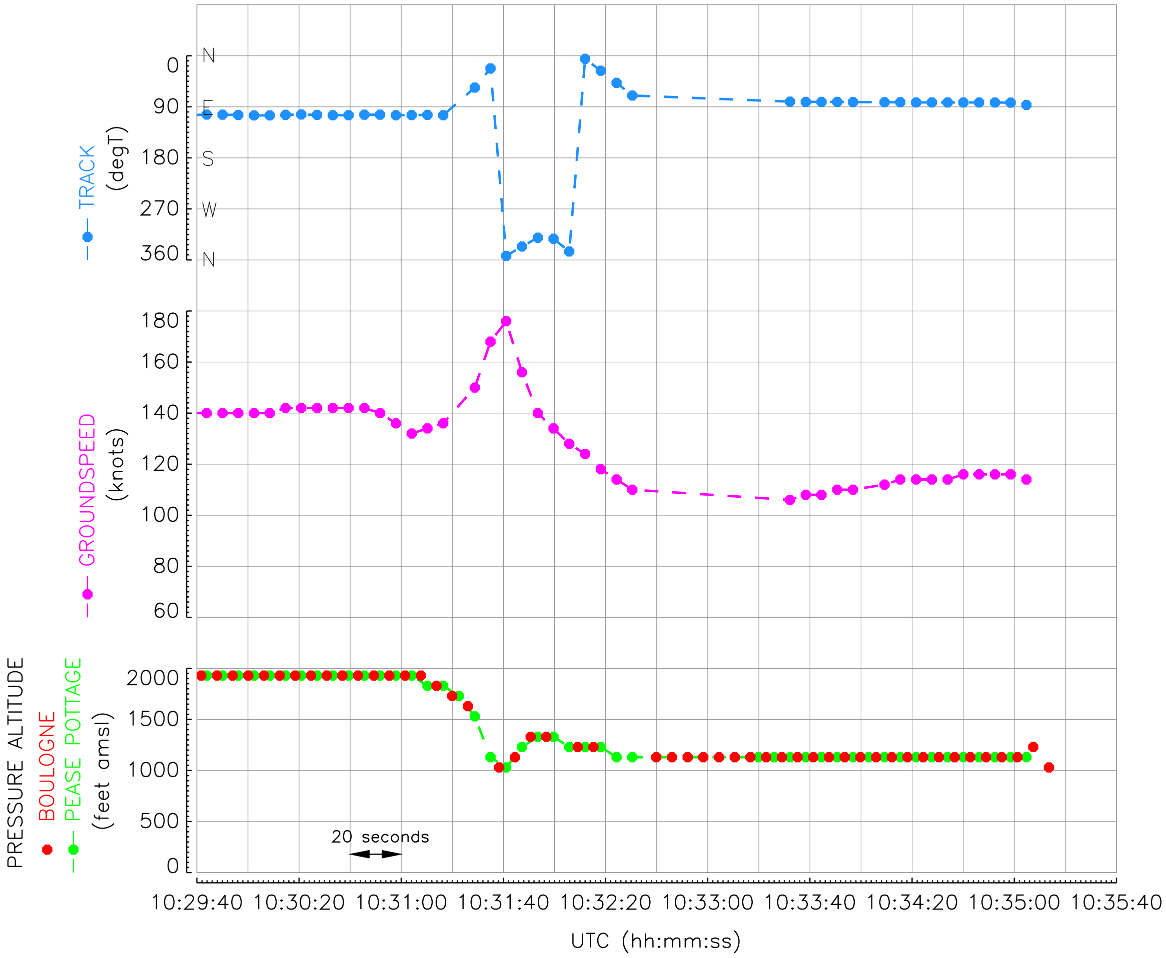

Figure 4

Recorded data showing the track, groundspeed and altitude of the aircraft during the descending turn through to the last contact.

and track indicated that he may have engaged the autopilot once tracking towards Midhurst VOR. The autopilot appeared to have remained engaged until the aircraft commenced the descending left turn, then re-engaged once the aircraft was straight and level at the lower altitude.

Although the final radar points indicated a slight change of track and variation in altitude, the absence of subsequent returns provided insufficient information to draw conclusions.

The pilot was only qualified to fly under VFR, but was flying in conditions that would have prevented him remaining in sight of the surface. Disengagement of the autopilot in the hazy conditions and lack of a discernable horizon would have made it very difficult for him to control the aircraft manually using visual flight techniques. Furthermore, as the pilot did not have an instrument or IMC rating and had only very limited experience of flying on instruments, it would have been be very difficult for him to maintain manual control of the aircraft using instrument flying techniques.

The significant fragmentation of the aircraft and the reported detachment of the pilot's seat indicated that the aircraft impacted the surface of the sea with high energy. Witness marks on the top engine cowling indicated that the propeller was turning at the time. The similar damage to both wings suggested both struck the surface at the same time.

The maintenance records and a statement from the pilot who flew the aircraft the previous day indicated that the aircraft was operating normally at the end of the previous flight.

The propeller, the magnetos and the cabin heater muff exceeded their manufacturers' recommended overhaul limits. Although allowed by the regulations under which the aircraft was operating, this deferment increased the likelihood of their failure in service. A crack in the cabin heater muff might allow exhaust gases into the passenger cabin. However, in view of the warm ambient temperature at the time of the accident, it is unlikely the heater was in use.

Safety action

As a result of discussions arising from this accident and others, the CAA is considering enhancing publicity to the GA community concerning the operation of light aircraft equipped with advanced avionic and ballistic recovery systems.

Conclusion

The investigation did not determine the cause of the accident. However, immediately prior to it, the pilot was flying in meteorological conditions that were not suitable for flight under VFR and he did not have the qualifications required to operate under IFR. Disengagement of the autopilot in these circumstances would have made it very difficult for him to control the aircraft manually. The lack of evidence that the pilot used the emergency parachute system and absence of any emergency radio transmission means that pilot incapacitation could not be discounted as a factor.

AAIB correspondence reports

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

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

The accuracy of the information provided cannot be assured.

SERIOUS INCIDENT

Aircraft Type and Registration:	BAE 146 RJ85, EI-RJW
No & Type of Engines:	4 Honeywell LF507-1F turbofan engines
Year of Manufacture:	2000 (Serial no: E2371)
Date & Time (UTC):	24 October 2013 at 1330 hrs
Location:	Norwich International Airport, Norfolk
Type of Flight:	Not applicable
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Superficial heat damage to engine and nacelle
Commander's Licence:	Not applicable
Commander's Age:	Not applicable
Commander's Flying Experience:	Not applicable
Information Source:	Aircraft Accident Report Form submitted by the operator and inquires by the AAIB

Synopsis

During a power assurance check on the No 3 engine a fire warning appeared approximately three minutes into a full-power soak period. The presence of an engine fire was confirmed by maintenance staff outside the aircraft and the operator shut the engine down, pulled the fire handle and vacated the aircraft. The fire had extinguished prior to the arrival of the emergency services. The fire was caused by the ignition of fuel leaking from fittings between the fuel supply lines and manifolds.

Sequence of events

The aircraft was in maintenance at Norwich Airport undergoing a post-installation power assurance check on the No 3 engine. Three minutes into a full-power soak a fire warning illuminated in the cockpit. Safety staff outside the aircraft confirmed that there was a fire and the operator shut down the engine, pulled the fire handle and expelled shots of the aircraft engine fire suppression system. The operator notified the control tower for fire assistance and, along with three engineering colleagues, vacated the aircraft without further incident. Fire was still apparent between the jet pipe fairing and fan cowl doors in an area inaccessible to fire extinguishers. The fire died down and was out by the time the fire service arrived.

Engineering investigation

The engine examination found that a fuel leak had ignited in the fuel manifold area in the vicinity of the combustion chamber casing. The fuel manifold assemblies were tested by the manufacturer and it was found that the fuel leak emanated from loose fittings between the fuel supply lines and the manifolds. The manifolds were found to be serviceable. The cause of the loose fittings is unclear, however, the engine had been in storage prior to installation so it is unlikely that the fittings loosened whilst the engine was on wing.

It was noted that the fire caused only superficial damage to the engine and nacelle. The fire protection features within the engine nacelle satisfactorily contained the fire within the immediate zone.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-33A, G-POWC	
No & Type of Engines:	2 CFM56-3C1 turbofan engines	
Year of Manufacture:	1991 (Serial no: 25402)	
Date & Time (UTC):	19 November 2013 at 0112 hrs	
Location:	Edinburgh Airport	
Type of Flight:	Commercial Air Transport (Cargo)	
Persons on Board:	Crew - 3	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	58 years	
Commander's Flying Experience:	15,600 hours (of which 6,000 were on type) Last 90 days - 58 hours Last 28 days - 16 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft was loaded with the unit load devices (ULD) in the reverse order to that intended. This resulted in the aircraft CG being forward of the flight envelope limits. The crew encountered handling issues during takeoff but the aircraft landed safely at the destination.

History of the flight

The aircraft was on a cargo flight from Edinburgh Airport to Stanstead Airport. The cargo load consisted of eight unit load device (ULD) containers. The ULDs were loaded into the aircraft through a large cargo door located in the forward left fuselage. Due to the centre of gravity of the basic aircraft it was normal, when carrying mail freight, for the ULDs to be loaded with the heaviest at the rear of the aircraft, then in descending weight order towards the front of the aircraft with any empty ULDs loaded into the forward positions. The commander witnessed the ULDs arrive beside the aircraft and recalls noting that the number on the side of one of them was consistent with that on the load instruction form. The crew did not check the position of the ULDs after they were loaded in the aircraft. The operator's Operations Manual did not require the crew to check, and stated:

> *'A final check can be carried out by checking that the last ULD loaded into position (bay A[1]) was expected to be there and not in the first loaded position bay H'.'*

The commander stated that, because the turnaround had been rushed due to the late arrival of the load and fuel, this check had not been carried out.

The remainder of the pre-flight preparation continued normally. The commander, who was PF, stated that when he attempted to rotate the aircraft he experienced a greater than normal control column back-pressure that resulted in a slow and late rotation. During the climb the crew observed that approximately 1 – 1½ more units of nose-up pitch trim were required than usual. The crew discussed the situation and concluded that there may have been a loading error. However, as the aircraft was apparently flying normally, they elected to continue to the destination. During the approach the crew again noticed that more nose-up pitch trim was required than normal. After landing, the commander went to the cabin to disarm and open the doors and discovered that the ULDs had been loaded in reverse order.

Loading operation

The operator was contracted by a mail company to provide routine freight services. Prior to loading an aircraft, the mail company completed a Load Order Form that detailed a suggested load plan. Flight crew were required to check and accept this before loading commenced; the mail company would then load the aircraft. On this occasion the Load Order Form correctly reflected the intention to load the heaviest ULDs towards the rear of the aircraft but the aircraft was inadvertently loaded in reverse order with the heaviest ULDs towards the front.

Weight and balance

In the planned configuration for the aircraft load, the takeoff CG index would have been 38.8 units. The flight envelope forward limit at this takeoff weight was approximately 16 units. The actual index with the ULDs reverse loaded, was 3.8 units.

Recorded data

The FDR revealed that a pitch input was made between 133 and 137 KIAS and that the aircraft started to rotate at approximately 141 KIAS, then continued to rotate at a rate of approximately 1º/second to a pitch angle of 15º. The calculated V_R was 128 KIAS and the normal rotation rate for this aircraft is between 2.5 and 3°/second.

Analysis

The ULDs were loaded in the reverse order to that intended. As a result, the CG of the aircraft was forward of the flight envelope limit. With pitch trim pre-set to that required for the intended loading configuration, the handling pilot experienced greater than expected

Footnote

[1] Bay A is at the front of the cabin and Bay H is at the rear.

control column forces on rotation, which resulted in a slow and delayed rotation. During the flight, the pitch trim required was more nose up than usual to achieve trimmed flight. The Load Order Form showed the intended loading configuration but neither the loading team nor the flight crew noticed that the actual configuration was different.

Safety action

In order to prevent a reoccurrence, the operator now requires a flight deck crewmember to check each ULD number as it is loaded, and has adopted a 'pyramid' loading system whereby the heaviest ULDs are loaded towards the centre of the aircraft in order to mitigate the effects of any errors.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 747-436, G-BNLW
No & Type of Engines:	4 Rolls-Royce RB211-524G2-T-19 turbofan engines
Year of Manufacture:	1992 (Serial no: 25432)
Date & Time (UTC):	14 October 2013 at 0630 hrs
Location:	In flight, approx 2 hours from London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 17 Passengers - 274
Injuries:	Crew - None Passengers - None
Nature of Damage:	Fire damage to In-Flight Entertainment (IFE) unit and surround
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	14,574 hours (of which 6,578 were on type) Last 90 days - 187 hours Last 28 days - 24 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was about 2 hours from its destination, when the flight crew and some members of the cabin crew smelt an "acrid, electrical burning smell". Flames and smoke were then reported to be emanating from an item of In-Flight Entertainment (IFE) equipment located in the Galley 4 area. The cabin crew tackled the fire with BCF extinguishers but had difficulty due to continual re-ignition of the fire. It was subsequently considered that the unit had not been electrically isolated during the event and the operator has accordingly made several internal safety recommendations regarding both cabin and flight crew procedures and training.

History of the flight

The aircraft was on an overnight flight from Dallas/Fort Worth Airport, USA, to London Heathrow Airport. At approximately 0628 hrs, as the aircraft was about 2 hours from its destination, both pilots noticed a smell reminiscent to them of disinfectant, and they checked the cockpit door surveillance system to ascertain whether the forward toilet on the upper deck was being cleaned. Whilst they discussed the smell, the upper deck cabin crew member called them to report a "funny smell" and during the course of the conversation, the flight crew noted that the smell became a "strong, acrid electrical burning smell".

The call was terminated when a >SMOKE LAVATORY EICAS message was received, indicating that smoke was detected either in a lavatory or in the cooling duct of the IFE system. The upper deck cabin crew member went to investigate whilst the commander handed control to the co-pilot and consulted the Non-Normal Checklist (NNC) for the caption SMOKE LAVATORY in the Quick-Reference Handbook. There were no flight crew actions in the NNC associated with this message. The flight crew elected not to don oxygen masks nor to broadcast a distress call.

About 2 minutes later, the commander received calls from two cabin crew members who stated that flames were visible in Galley 4, situated between doors 2 left and 2 right, and these were being tackled with BCF extinguishers. An open communication line to the flight deck was maintained throughout the event. The smoke and flames were emanating from a component of the IFE equipment called the Video Modulator (VMOD), situated in the Cabin Service Director's (CSD) office in Galley 4 (Figure 1). A third cabin crew member tried to discharge the first extinguisher but mishandled it, so another crew member took over. Ultimately, five extinguishers were used because the fire appeared to re-ignite repeatedly. Eventually the cabin crew were able to report that the fire was out.

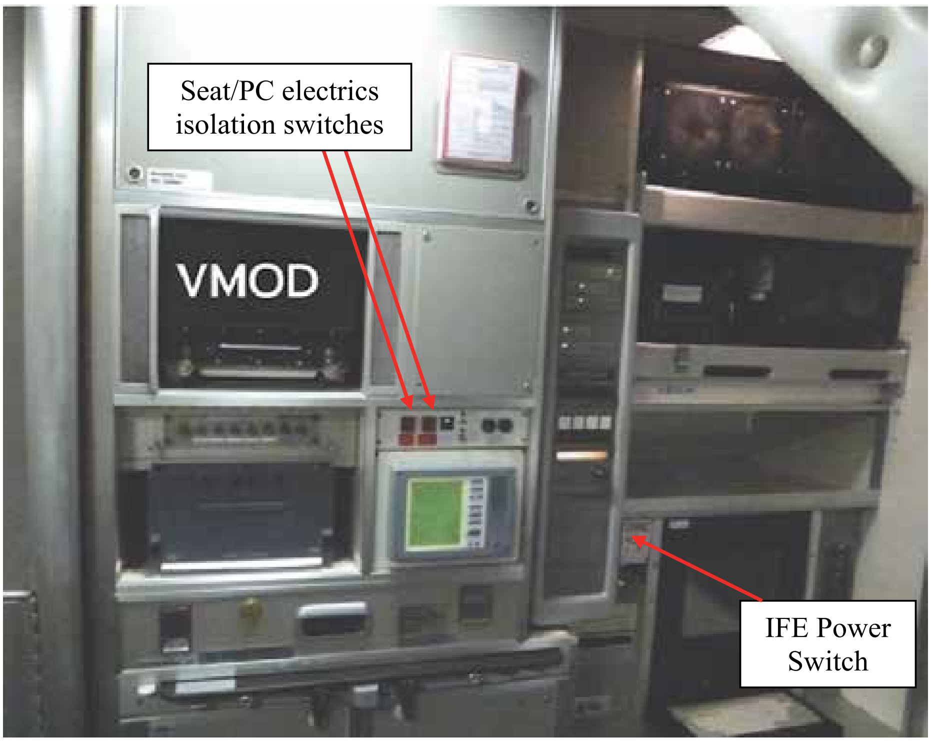

Figure 1

View of Galley 4 and CSD's office showing location of IFE VMOD and associated switches

At about this time, the flight crew consulted the 'Smoke, Fire or Fumes' NNC but did not action any of the checklist items. They considered the incident was over and they were concerned about degrading the lighting in the cabin which was a consequence of removing utility power as part of the procedure. A senior cabin crew member later called to confirm that the fire was out and the flight crew placed the air conditioning packs in 'high-flow' to try and clear the odour. The VMOD had been removed and was secured in a trolley. The event was deemed to be over by 0640 hrs and normal cabin service was resumed.

Relevant crew drills

The operator's cabin crew were issued with a type-specific 'Safety Equipment and Procedures Manual' during training and a copy was held in the CSD's office in Galley 4. The section of the manual dealing with an IFE smoke warning was prefaced with the sentence:

> *'When dealing with a potential electrical problem or fire involving the IFE system located beneath a passenger seat, seat power and IFE power must first be switched off as follows:'*

The first action was to press two guarded switches in the CSD's office (Figure 1) labelled 'SEAT/PC ELECTRICS ISOLATION' for first class and business/premium economy class cabins.

> *'This isolates power to the passenger seat controls and PC power outlet in the respective cabins. These switches illuminate ISOLATED when the isolation function is activated.'*

The next action was to press a guarded switch on another panel in Galley 4 labelled 'IFE POWER' which:

> *'Isolates power to the distributed video system.'*

Essentially the same instructions were contained in a cabin crew 'B747 Quick Reference Guide' but the operator found that its existence was only highlighted during initial training and that no initial or recurrent training was given as to its use. It was not referred to during the incident.

The flight crew 'Smoke, Fire or Fumes' NNC contained a number of actions of which number 4 was:

> *'Instruct the Cabin Crew to turn off the main IFE and PC power switches (as installed)'*

Action number 7 was:

> *'Utility power switches…………………………………………………...OFF'*

This action would have isolated a number of non-essential electrical services, including the main cabin lighting and completely de-powered the IFE system but, for the reasons stated previously, the flight crew did not carry out this checklist.

Analysis

The VMOD unit was sent to its manufacturer for investigation but, at the time of preparation of this account, their report has not been received. However it was noted that the unit is certified to self-extinguish when electrically isolated.

An internal investigation by the operator concluded that it was likely the VMOD had remained powered during the incident and this was the reason it continued to re-ignite. One of the cabin crew described how he believed he had isolated the IFE, but his description of events suggested that he had only actioned the 'SEAT/PC ELECTRICS ISOLATION' part of the 'Safety Equipment and Procedures Manual' and that this had been done from memory.

The operator's investigation included a number of Recommended Actions concerning cabin crew training, both in regard to use of checklists, operation of extinguishers and their understanding of the electrical equipment in the CSD's office.

In addition, the operator is reviewing the flight crew QRH, to ascertain whether annunciated smoke warnings such as >SMOKE LAVATORY be linked to the 'Smoke, Fire or Fumes' NNC in order to prompt flight crews to consider actioning the latter at an early stage. Flight crew training for the 'Smoke, Fire or Fumes' NNC drill, particularly use of Oxygen and the functionality of the Utility Switches, will also be reviewed.

SERIOUS INCIDENT

Aircraft Type and Registration:	Britten-Norman BN2A Mk III-2 Trislander, G-RLON
No & Type of Engines:	3 Lycoming O-540-E4C5 piston engines
Year of Manufacture:	1975 (Serial no: 1008)
Date & Time (UTC):	11 October 2013 at 1645 hrs
Location:	En route Jersey to Guernsey
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 15
Injuries:	Crew - None Passengers - None
Nature of Damage:	Cowling partially unsecured, minor damage to cowling and propeller blades
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	14,584 hours (of which 1,008 were on type) Last 90 days - 179 hours Last 28 days - 41 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Summary

Following an uneventful flight to Guernsey it was found that the cowling on the rear (No 2) engine had become partially detached as a result of the failure of one of the fasteners. This had allowed movement of the upper half of the cowling such that it had contacted the propeller, causing minor damage to the blades.

Incident details

Following an uneventful flight from Jersey the passengers were disembarking from G-RLON when the ground staff noticed that the cowling on the rear (No 2) engine had become partially detached. The commander was informed and he stated that he had noted nothing untoward during the pre-flight walk around; the aircraft handling and indications had been normal during the flight, with no abnormal noise or vibrations apparent.

Investigation

Photographs of the front of the centre engine are shown on the next page.

It can be seen that the cowling is made up of upper and lower fibreglass 'clamshells'. It was apparent that the front right hand fitting on the lower section had pulled out of the fibreglass and was missing. The resultant loss of structural rigidity would have allowed movement to occur in the upper cowling, which probably accounted for two clips, securing the upper

Photos: Aurigny Air Services Ltd

and lower sections together, having become undone on the right-hand side. The degree of movement was such that the upper cowling had made light contact with the propeller blades, leaving rub marks on them that subsequently required repair.

The organisation conducting the repairs to the aircraft commented that it was not unusual for cracks to appear in the cowlings of aircraft of this age, although this was the first that had resulted in the loss of one of the front fastener fittings. In the absence of the fitting it was not possible to establish the mechanism that led to the failure. A fleet check was not considered necessary, as engine cowling security is covered by the Daily Inspection.

The operator stated that the details of this event will be added to their continuation training syllabus.

ACCIDENT

Aircraft Type and Registration:	Agusta A109S, G-IOOZ
No & Type of Engines:	2 Pratt & Whitney Canada PW207C turboshaft engines
Year of Manufacture:	2008 (Serial no: 22090)
Date & Time (UTC):	8 December 2013 at 1910 hrs
Location:	East of Withypool, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to tail rotor and landing gear
Commander's Licence:	Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	3,147 hours (of which 428 were on type) Last 90 days - 29 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was making a night approach in misty conditions to a private landing ground which was marked by the lights from a vehicle. As he neared the site, the pilot switched on his landing light and was immediately dazzled by the glare reflected back from the mist. Although he quickly switched the light off again, the distraction led him to strike the tail rotor on a tree and the helicopter was damaged in the rapid forced landing which ensued.

History of the flight

The helicopter had departed from St Mawes, Cornwall, intending to fly to a private landing ground on Exmoor near Withypool, Somerset - this journey would take about 30 minutes. The pilot was aware that another helicopter was scheduled to land at the same site somewhat later and had arranged for landing lights and a vehicle with a radio to be present. He contacted the vehicle driver before departing St Mawes and was told that everything was set up and the weather was clear.

As he approached the site at 2,500 ft, the pilot contacted the operator on the ground and was told that "it had started to cloud over but the moon was still visible and he could be heard coming". Flying over the site at 2,500 ft QNH with the radio altimeter showing over 1,000 ft agl, the pilot could just about make out the lights below him but noted that, to the north and east of the landing site, it appeared to be totally clear. He lowered the landing gear, carried out the landing checks and tested the landing lights, setting the moveable landing light to the straight ahead position. He took up a southerly heading towards the site and descended through a thin layer of cloud over the village of Exford, commencing his approach to the landing site which he saw about a mile distant and at a height of about 500 ft; the lights, and in particular the flashing lights on the operator's vehicle, were clearly visible to the pilot at this point.

The pilot had been largely navigating using the ground lights but, at about 500 m from the site, he switched on the landing lights and was immediately dazzled by the glare from the mist which had formed at low level. He states that he was momentarily blinded and disoriented before he switched the light off again. Although only travelling at about 40 kt, he descended too rapidly and failed to see a line of trees, approximately 30 ft high, which the helicopter clipped with its tail rotor. It immediately started to yaw and the pilot force-landed in a field some 300 m short of the landing site. In doing so, the helicopter span through about 180º and the landing gear sank into the soft, wet ground, detaching the nosewheel. The pilot was uninjured. Although the main rotor had not struck the ground, the tail rotor blades and landing gear were badly damaged.

ACCIDENT

Aircraft Type and Registration:	Auster J5K Aiglet Trainer, G-AMMS	
No & Type of Engines:	1 Blackburn Cirrus Major III piston engine	
Year of Manufacture:	1951 (Serial no: 2745)	
Date & Time (UTC):	6 October 2013 at 1100 hrs	
Location:	Watchford Farm, near Honiton, Devon	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to left elevator, tailplane and fuselage	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	66 years	
Commander's Flying Experience:	7,772 hours (of which 21 were on type) Last 90 days - 10 hours Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft was taking off from a 400 m grass strip which was wet and soft. The pilot felt that the aircraft was having difficulty leaving the ground and abandoned the takeoff. He believes a combination of factors then led to the aircraft sliding sideways at slow speed into a fence beyond the end of the runway before coming to a halt.

History of the flight

The aircraft was departing Watchford Farm on Runway 23, which has a length of 400 m; the wind was westerly at 5 kt. The aircraft had been fuelled to full and the pilot and a passenger were on board, making the aircraft some 50 kg below maximum takeoff weight. The normal pre-departure power checks were completed satisfactorily. The pilot noted that the grass had been cut short on the runways and taxiways, but the surface was soft and damp after previous rain.

Takeoff flap was selected, full power applied and, as the aircraft commenced its takeoff roll, the pilot noted that full static engine rpm was achieved. He lifted the tail and the aircraft accelerated normally; however, as he applied back pressure to lift off at a speed of 55-60 kt, it became airborne but immediately sank back onto the ground. Whilst the aircraft appeared to continue accelerating, it lifted off again but "seemed reluctant to stay airborne". Since it was approaching the end of the mown runway, the pilot decided to abandon the takeoff, closing the throttle and applying the brakes. As it travelled towards the boundary fence the pilot tried to turn the aircraft away but it now skidded sideways and ran into the wire-and-post fence side-on but at slow speed.

The pilot shut down the engine and he and his passenger vacated the aircraft. They initially thought that there had been no damage, however closer inspection showed damage to the left tailplane and rear fuselage caused by contact with a fence post.

Conclusions

The pilot cites several reasons for the aircraft failing to become airborne and its subsequent failure to stop. He states that he had previously operated out of Watchford Farm but in an Auster 6A, which has a longer wingspan and therefore a lower wing loading. This, coupled with a relatively high takeoff weight and light wind conditions, probably accounted for a longer ground run than he was expecting. In retrospect, he believes that he would have become airborne if he had continued the takeoff but, at the time, abandoning it seemed the safest course of action.

Once the decision to abort had been made, he believes that a combination of damp grass on the runway and overrun area and a downslope, led to the aircraft failing to stop.

ACCIDENT

Aircraft Type and Registration:	Jabiru SPL-450, G-BZST
No & Type of Engines:	1 Jabiru 2200A piston engine
Year of Manufacture:	2001 (Serial no: PFA 274A-13616)
Date & Time (UTC):	1 August 2013 at 1315 hrs
Location:	Dunkeswell Aerodrome, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nose landing gear and propeller, engine shock-loaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	64 years
Commander's Flying Experience:	999 hours (of which 109 were on type) Last 90 days - 12 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was flying a short leg from Exeter to Dunkeswell prior to a longer trip planned for the next day. On final approach to Runway 17 at Dunkeswell, he and his passenger noticed a fox crossing the runway ahead of them, something which the pilot says is not unusual for this airfield. However, the distraction caused him to round out too high and at too low an airspeed. The aircraft dropped heavily onto the runway but the pilot initially believed it had not been damaged.

He taxied towards the grass in front of the flying clubhouse and applied the brakes to allow another aircraft to vacate the space he intended to park in. Upon doing so, the nose dipped sharply and the propeller struck the grass, stopping the engine. Upon examination it was found that the nose landing gear suspension rubber bushes had burst and some were missing completely, whilst the propeller had lost about 6-7 mm from each tip and had a large split along its length.

ACCIDENT

Aircraft Type and Registration:	Jodel D117, G-AZKP	
No & Type of Engines:	1 Continental Motors Corp C90-14F piston engine	
Year of Manufacture:	1956 (Serial no: 419)	
Date & Time (UTC):	14 September 2013 at 0940 hrs	
Location:	Farm strip at Blair Atholl, Perthshire	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Right wing and main spar	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	72 years	
Commander's Flying Experience:	4,534 hours (of which 45 were on type) Last 90 days - 6 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot had visited the destination airstrip on numerous occasions in a variety of different aircraft. The weather was fine, with a generally light south-westerly wind. The pilot observed that the flag on the tower of Blair Atholl Castle, near the destination airstrip, was completely slack so he elected to land in a westerly direction. The approach was made at 45 kt and the touchdown was normal. Suspecting the grass to be wet, the pilot allowed the aircraft to decelerate, initially without braking. At first the aircraft rolled straight down the middle of the strip. When the brakes were finally applied, it swung to the right and the pilot was unable to correct it using left rudder and brake. Realising that the aircraft was going to leave the mown strip, he shut down the engine and continued to apply left brake. The aircraft left the strip about 70 metres short of the end and the right mainwheel entered a ditch obscured by long grass.

ACCIDENT

Aircraft Type and Registration:	Maule MT-7-235 Super Rocket, G-HIND	
No & Type of Engines:	1 Lycoming IO-540-W1A5 piston engine	
Year of Manufacture:	1997 (Serial no: 18037C)	
Date & Time (UTC):	15 August 2013 at 1900 hrs	
Location:	Private strip, County Durham	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Leading edge of both wings dented	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	74 years	
Commander's Flying Experience:	2,007 hours (of which 1,100 were on type) Last 90 days - 24 hours Last 28 days - 18 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot intended to land at Perth Airport, but as his progress was slower than estimated and insufficient daylight remained to reach his destination, he decided to divert to a friend's airstrip. As he overflew the airstrip he saw sheep on the runway threshold but assessed that sufficient landing distance remained. During the final approach the sheep moved further along the runway, causing the pilot to abort the landing. He commenced a go-around and turned the aircraft into wind, which was towards rising ground. The aircraft failed to clear some trees and passed through their upper foliage, sustaining dents to the wing leading edges. The pilot then proceeded to Durham Tees Valley Airport where he landed without further incident. He reported that there were no noticeable handling difficulties.

CAA Safety Sense leaflet 12, Strip Sense, contains useful information about operating at unlicensed aerodromes and private airstrips. It cautions:

> *'It is vital to remove all livestock from the runway prior to take-off and prior to landing. Thus, if animals have access to the strip, assistance by a friend or farmhand is essential. Animals are unpredictable.'*

The full leaflet can be found at: http://www.caa.co.uk/docs/33/20130121SSL12.pdf

ACCIDENT

Aircraft Type and Registration:	Piper PA-34-200 Seneca, G-BASM	
No & Type of Engines:	2 Lycoming IO-360-C1E6 piston engines	
Year of Manufacture:	1973 (Serial no: 34-7350120)	
Date & Time (UTC):	24 October 2013 at 1500 hrs	
Location:	Denham Aerodrome, Buckinghamshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Aircraft substantially damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	60 years	
Commander's Flying Experience:	1,216 hours (of which 535 were on type) Last 90 days - 0 hours Last 28 days - 0 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional information provided by the aerodrome operator and the maintenance organisation	

Synopsis

The aircraft was landing on Runway 06 at Denham Aerodrome following a flight from Andrewsfield Aerodrome, Essex. The aircraft overran the end of the runway, travelled through a fence and across a road, before coming to rest in a field. The aircraft was substantially damaged in the accident but the pilot was not injured and was able to vacate the aircraft unassisted.

History of the flight

Following annual maintenance at Andrewsfield Aerodrome, Essex, the aircraft's engines were ground run for approximately two hours. A week later they were run again for about 15 to 20 minutes. The next day, the pilot arrived to collect the aircraft to fly it to Denham, where it was usually kept, a flight time of about 20 minutes. The aircraft had been at the maintenance facility for several months and the pilot had not flown for more than three months.

The pilot reported that, before departure, he refuelled the aircraft with 230 litres (60 USG) of fuel and carried out a water drain check. The flight to Denham was uneventful and the weather conditions on arrival were fine, with a surface wind from between 120° and 160° at between 4 kt and 8 kt. The pilot joined the circuit via the base leg for Runway 06 but the Air Ground (A/G) operator requested that he carry out a go-around, because he was close to another aircraft in the circuit. The pilot increased power and went around but reported that both engines then started to "run rough" and he was unable to maintain height. He turned onto the crosswind leg early and advised others, on the radio, that he had two rough running engines. The A/G operator acknowledged this and notified the aerodrome RFFS.

The pilot checked the fuel selector and attempted to resolve the rough running by adjusting the throttle, the mixture and the carburettor heat, but without apparent improvement. He turned onto final approach at around 350 ft aal, maintaining a higher than usual airspeed of 85 kt to 90 kt, and made a 'finals' call. The A/G operator observed the aircraft, low on final approach. As it floated down the runway, the pilot decided he would not go-around because there might not be enough power. He estimated that the aircraft touched down about half way along the runway and, despite applying heavy braking, he was unable to stop it departing the paved surface. The aircraft continued through a fence, which formed the aerodrome boundary, across a public road and before coming to rest in a grass field. The pilot was uninjured and vacated the aircraft, which had sustained considerable damage. He subsequently dismantled the aircraft to recover it from the field.

Discussion

In his own assessment of the accident, the pilot considered that he had landed at too high a speed. He also thought that fuel contamination might have caused the rough running engines. However, he had not experienced any problem with the engines en-route.

There is no overhead circuit joining procedure at Denham. Inbound aircraft are required to establish two-way radio contact with the A/G operator, callsign Denham Radio, and join an extended base leg, giving way to circuit traffic. Runway 06 at Denham has an asphalt surface, is 775 m in length and has an LDA of 706 m (2,316 ft). Abbreviated Precision Approach Path Indicators (APAPI), set at 4.5º, are available on the left hand side of the runway. The Landing Ground Roll for the PA-34-200 at maximum weight in standard conditions, with nil wind, is approximately 427 m (1,400 ft).

ACCIDENT

Aircraft Type and Registration:	Rans S7 Courier G-CBNF	
No & Type of Engines:	1 Rotax 912 ULS piston engine	
Year of Manufacture:	2002 (Serial no: PFA 218-13762)	
Date & Time (UTC):	9 November 2013 at 1536 hrs	
Location:	Netherly Airstrip, Aberdeenshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Minor)	Passengers - 1 (Minor)
Nature of Damage:	Right main landing gear wheel detached, propeller damaged, engine shock-loaded, right aileron and wing damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	63 years	
Commander's Flying Experience:	1,063 hours (of which 14 were on type) Last 90 days - 4 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

As the aircraft approached the grass airstrip its airspeed reduced below normal. Despite applying power, the pilot was unable to arrest the increased rate of descent that developed and the aircraft touched down heavily, causing the right main wheel to break off and the aircraft to veer right. When it reached the edge of the strip, the right gear leg dug into soft ground and the aircraft inverted. The pilot and passenger exited safely. The pilot attributed the accident to his not fully monitoring airspeed during the final approach.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna FRA150L Aerobat, G-BCKU
No & Type of Engines:	1 Continental Motors Corp O-240-A piston engine
Year of Manufacture:	1974 (Serial no: 256)
Date & Time (UTC):	25 November 2013 at 0755 hrs
Location:	Shaw Fell, Kirkcudbrightshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damaged beyond economic repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	458 hours (of which 324 were on type) Last 90 days - 56 hours Last 28 days - 20 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was engaged on a routine flight to check the owner's livestock on his farm. At a height of about 500 ft agl, the engine lost power and the pilot elected to force-land in a plantation of mature Sitka Spruce trees. The aircraft was badly damaged and had come to rest pitched vertically nose-down amongst the trees; however, the pilot was unhurt and described the landing as "comfortable". He was of the opinion that carburettor icing may have been responsible for the engine failure, despite him having taken the normal precautions.

ACCIDENT

Aircraft Type and Registration:	Socata TB10 Tobago, G-BSDL
No & Type of Engines:	1 Lycoming O-360-A1AD piston engine
Year of Manufacture:	1980 (Serial no: 156)
Date & Time (UTC):	7 November 2013 at 1225 hrs
Location:	Fenland Airfield, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose landing gear collapsed and engine detached
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	155 hours (of which 11 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was being flown into Fenland Airfield for scheduled maintenance. On the downwind leg to land, the engine stopped abruptly and a forced landing in a ploughed field was carried out. The aircraft was badly damaged as a result of the forced landing.

History of the flight

The aircraft was being flown from Retford/Gamston Airport to Fenland Airfield for an annual maintenance check. The flight was uneventful and the pilot contacted Fenland when about 5 miles north-west of the airfield. He was given the QFE and advised that the runway in use was 26R. He carried out the pre-descent checks, including switching on the fuel pump and selecting carburettor heat. On levelling out at circuit height, he deselected the carburettor heat and turned from the crosswind leg to downwind, where he performed the downwind checks, including fuel pressure and quantity, and selected 10º of flap. However, as he passed abeam the runway threshold the engine stopped suddenly. A scan of the instruments and controls did not reveal any abnormalities and the action of pushing the throttle and propeller levers fully forward had no effect.

The pilot immediately turned left base and radioed that he had an engine failure and was going "straight in". Feeling that, at the time, he would make the runway, he raised the nose to keep just below the stall warning speed and lined up on the runway. Here he realised that he still had flap selected, so he retracted them, remarking that the reduction in drag was "noticeable". However, it was now clear that he would not reach the runway and he had to touch down in a ploughed field some 500 m short of the threshold. Although he attempted to keep the nosewheel off the ground as long as possible, the field was ploughed at right angles to the direction of travel and, after about 30 m of ground roll, the nosewheel touched down and immediately collapsed. The engine detached as the aircraft came to an abrupt halt . The pilot was uninjured but was extremely dazed by the deceleration, taking some time to gather his thoughts and exit the aircraft. He was met by a rescue crew from the airfield.

The maintenance company advise that a visual examination of the engine has not revealed any obvious reason for the failure.

SERIOUS INCIDENT

Aircraft Type and Registration:	Socata TB10 Tobago, G-FAIR
No & Type of Engines:	1 Lycoming O-360-A1AD piston engine
Year of Manufacture:	1981 (Serial no: 241)
Date & Time (UTC):	23 September 2013 at 1010 hrs
Location:	Rayne Hall Farm, Braintree, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Fire damage to engine and engine cowlings
Commander's Licence:	Private Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	2,529 hours (of which 436 were on type) Last 90 days - 8 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

On the late downwind leg to land at Rayne Hall Farm, the pilot sensed that the engine was not running smoothly and had "missed a couple of beats". Carburettor heat had been applied, and he suspected carburettor ice might be responsible, so he executed a precautionary high approach. A successful landing was carried out but, as the aircraft came to a halt on the runway, the engine stopped and smoke could be seen emerging from the upper engine cowling on the right side. His passenger jumped out and could see a small fire coming from the underside of the cowling, which he quickly extinguished using the on-board fire extinguisher.

The cowlings were removed and a lot of sooting and fire damage could be seen. On switching on the electrical fuel pump, fuel could be seen pouring from the underside of the carburettor.

The maintenance organisation visited the aircraft two days later and removed the carburettor, which they took back to their workshop for testing. They were unable to reproduce the leak and a strip inspection did not find any defects. They believe that a transient case of the float sticking may have caused overfuelling of the carburettor.

ACCIDENT

Aircraft Type and Registration:	Vans RV-9A, G-CDCD
No & Type of Engines:	1 Wilksch WAM-120 diesel engine
Year of Manufacture:	2004 (Serial no: PFA 320-13925)
Date & Time (UTC):	6 August 2013 at 1020 hrs
Location:	1 mile South West of Wellesbourne Mountford Airfield, Warwickshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Damage to both wings, nose landing gear and fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	195 hours (of which 27 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional investigation by the AAIB

Synopsis

The aircraft was flying circuits but on the downwind leg of the second circuit the engine stopped and appeared to windmill. The pilot turned the aircraft into wind and selected a field for a forced landing. Unfortunately, the aircraft overran and struck a fence, hedge and small trees, tipping onto its nose and coming to rest in a vertical, nose-down attitude.

Two anomalies were subsequently found which could have caused the engine to fail. Contaminated fuel was drained from the filter bowl and three of the four bolts which secured a timing gear to the crankshaft were found to have failed and exhibited extensive high cycle fatigue. It could not be confirmed which mechanism had caused the failure.

History of the flight

The pilot intended to fly a detail comprising three circuits. The first circuit was completed successfully and the pilot commenced the second, calling downwind as required adjacent to the upwind end of the runway. All the checks had been completed, including changing the fuel tank selector from right to left[1] when, at the end of the downwind leg and at about

Footnote

[1] The pilot has stated that he did this largely from force of habit following a long flight, after which there could be an issue with balancing fuel. With hindsight, he believes this was probably not an appropriate action in the circuit.

1,000 ft agl, the engine stopped. The propeller appeared to be windmilling but the fuel pressure gauge was indicating zero. He switched the fuel tank back to right but all attempts to restart the engine were to no avail.

The pilot turned the aircraft into wind and chose a suitable field for a forced landing. The aircraft touched down in the selected field with about 60 m to run before a wire fence and hedge. On striking the fence and a small tree it tipped onto its nose and came to rest slightly over the vertical, resting against some trees and an overhead cable on the other side of a single-track road. The pilot was released from the aircraft by the emergency services some time later with only a minor injury.

Engine examination

The engine was removed and returned to its manufacturer for examination. It is an indirect-injection two-stroke diesel engine with three inverted cylinders and is designed to run on AVTUR fuel. It does not require electrical power to continue running after starting, and the fuel injection system is entirely hydro-mechanical. The exhaust valves are the only conventional valves and these are opened and closed by a camshaft which is driven from a timing gear bolted to the end of the crankshaft (Figure 1). If the timing is lost, the valves will invariably make contact with the pistons.

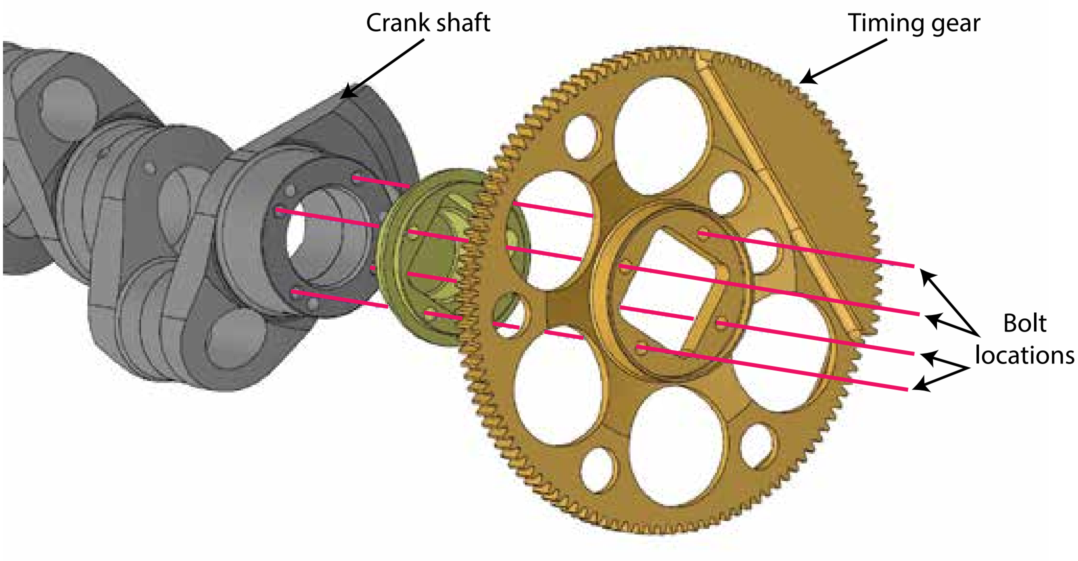

Figure 1

Exploded diagram showing attachment of timing gear to crankshaft.
(Diagram courtesy Wilksch Airmotive)

The AAIB examined the engine at the manufacturer's premises in the company of an engineer from the Light Aircraft Association (LAA). All three pistons had made repetitive contact with the exhaust valves, although the impacts did not appear to have occurred over a long period of running. It was found that three of the four bolts holding the timing gear to the crankshaft had failed; all three bolts had fractured at the head/shank interface and one had failed in the thread as well. They were recovered and sent for metallurgical examination, which found that all the fractures bore the characteristics of high-cycle fatigue cracks whilst the two that only had head fractures had fatigue cracks developing in the threaded region where the third had failed. The manufacturer advised that the bolts were made from AISI 8740 chrome molybdenum steel.

Two of the bolts were also tested for hardness, and for their elemental composition using Energy Dispersive X-Ray (EDX) techniques. The bolts appeared to be deficient with respect to chromium and nickel content and were somewhat below minimum specification when tested for hardness (as a guide to calculate the tensile strength).

The manufacturer advised that the bolts were to a revised standard introduced by Wilksch Service Bulletin WA-SB-005 dated 8 July 2009. This had followed an in-service failure and introduced a change, in the specification of the bolts, from a commercial grade steel with relatively loose tolerance of the thread form to a higher standard of both material and thread form. The SB requested owners to send back the replaced bolts and it is understood that no failure or cracks in these have been found. It also contained detailed instructions for the bolt replacement to ensure that the correct torque is achieved.

Fuel contamination

As part of the engine dismantling, the manufacturer had emptied the fuel filter bowl and was concerned at what was found (Figure 2). The fuel was a dense black colour and there was a high percentage of water present: in the manufacturer's estimation, there was enough to cause the engine to stop.

Figure 2

Photograph of fuel taken from filter bowl. Upper, dark layer is discoloured fuel and the lighter, lower layer is water

Discussion

There are at least two potential reasons why this engine failed, contaminated fuel being, in the estimation of the engine manufacturer, the more likely. Metallurgical examination of the failed timing gear bolts showed evidence of high-cycle fatigue but, because of the nature of the internal damage to the engine, the manufacturer considers it unlikely that this failure occurred in flight. It is more likely that the damage occurred when the rotating propeller struck the fence.

Whether the cause of this engine failure was contaminated fuel or bolt failure, safety issues have been exposed and are being addressed. The apparent gross fuel contamination is beyond the control of the manufacturer but the LAA advise that they intend to highlight the need for regular fuel quality checks in their monthly publication, '*Light Aviation*'. The WAM-120 diesel engine is only in service in small numbers and all owners are known to the manufacturer. The LAA will be working with the manufacturer to ensure that critical internal engine work, such as was involved in this incident, is overseen by competent and authorised personnel.

ACCIDENT

Aircraft Type and Registration:	Quik GTR, G-CHFU
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2012 (Serial no: 8612)
Date & Time (UTC):	24 November 2013 at 1235 hrs
Location:	Broadmeadow Farm, Hereford, Herefordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to wing fabric, structure and propeller
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	145 hours (of which 52 were on type) Last 90 days - 0 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot had performed the required pre-flight checks and the aircraft was taking off from Runway 28 of the farm strip. The wind was from the north-north-east at 3 to 4 kt, gusting 16 kt. The aircraft had covered some 50 m and was approaching takeoff speed when it suddenly veered to the right. The pilot tried to correct the swing and applied forward pressure on the control bar, hoping to become airborne. However the turn appeared to tighten and the aircraft left the runway, sliding on its right side into the adjacent field. The pilot shut down the engine and vacated the aircraft without injury. He attributed the loss of directional control to a sudden gust of wind, possibly in conjunction with the soft, damp grass of the runway.

ACCIDENT

Aircraft Type and Registration:	QuikR, G-CGLO
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2010 (Serial no: 8508)
Date & Time (UTC):	23 November 2013 at 1200 hrs
Location:	Farm strip near Farley, Salisbury, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - 1 (Serious)
Nature of Damage:	Wing struts and leading edges broken. Damage to pod and nosewheel
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	175 hours (of which 11 were on type) Last 90 days - 12 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst taking off from a stubble field, the pilot was unable to maintain directional control and the aircraft tipped onto its right side. The suitability of the field and the possibility that he had tried to become airborne at too low an airspeed were cited by the pilot as possible factors in the accident.

History of the flight

The aircraft had arrived at Farley after a flight from Deenethorpe, Northamptonshire and the pilot and passenger intended to conduct a short flight around the village. The pilot inspected the stubble field and, although a little damp, it seemed reasonably firm to him. He got back into the aircraft and commenced the takeoff roll towards the east, in line with small grooves in the field. The wind was blowing from the north at an estimated 7 mph and the aircraft seemed to the pilot to be accelerating a little more slowly than usual even though full power was applied. At what he thought was normal lift-off speed, he pushed the bar forward to rotate. At this point, the aircraft started to 'fishtail' and the pilot is uncertain whether it momentarily became airborne but he was unable to correct with his feet as a swing to the right developed, so he believes the nosewheel at least may have left the ground.

The aircraft tipped onto its right side and came to a halt some 20 m to the right of the intended takeoff path. The pilot unbuckled his harness and assisted his passenger to do the same. He had suffered a broken forearm and his passenger a gash to her right shin, both injuries requiring stays in hospital.

In his analysis of the causal factors, the pilot questions whether the field was suitable for the operation. Despite his precautionary inspection and the fact that his father had also inspected it the day before, it may have been somewhat too soft and damp. He feels that he may have tried to become airborne at too low an airspeed and that, with the nosewheel off the ground, he was unable to steer the aircraft and correct the swing which developed.

INCIDENT

Aircraft Type and Registration:	Rotorsport UK MTOsport, G-PAFF
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2011 (Serial no: RSUK/MTOS/039)
Date & Time (UTC):	28 December 2013 at 1540 hrs
Location:	Graveley Airfield (farm strip), Hertfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Rotor blade indentation and rudder tip split
Commander's Licence:	Private Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	330 hours (of which 330 were on type) Last 90 days - 5 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The pilot had just landed from a previous flight and repositioned the aircraft for an immediate takeoff. As he pulled the control column back and advanced the throttle he felt a heavy jolt through the controls. He immediately aborted the takeoff and stopped the aircraft to assess the situation. It became clear that the rotor blades had struck and damaged the top of the rudder. The rotor strike was caused by an excessive rearward tilt of the rotor disc, due to insufficient rotor speed combined with the acceleration of the aircraft.

History of the flight

The pilot had carried out several previous flights during the afternoon and had repositioned from his fourth landing for an immediate takeoff. Thinking that the aircraft had enough rotor rpm, he pulled back on the control column and applied full power. As he did so he felt a heavy jolt back through the controls. Realising something was wrong he aborted the takeoff and brought the aircraft to a halt in order to assess the situation. Upon inspection of the aircraft it was apparent that the rotor blades had struck the top of the rudder towards the trailing edge causing damage to both blades and the rudder. There was no other damage to the aircraft and no injuries were sustained.

Analysis

The pilot, in his post-incident analysis, realised that he had not checked the rotor rpm gauge prior to pulling the control column back. He estimated that he may only have had a rotor speed of between 120 and 140 rpm. This was below the safe minimum 200 rpm required for takeoff. The pilot also noted that he was not using the rotor pre-rotator at the time. The low rotor rpm, aft movement of the stick and the increase in engine power (and therefore thrust and acceleration), combined to cause the rotor disc to tilt rearwards low enough to strike the top of the rudder.

Miscellaneous

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

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

BULLETIN CORRECTION

Aircraft Type and Registration:	Zenair CH 601UL Zodiac, G-BZFV
Date & Time (UTC):	15 June 2013 at 1830 hrs
Location:	Glebe Farm, Sibson, Leicestershire
Information Source:	Aircraft Report Form submitted by the pilot and enquiries by the LAA and AAIB

AAIB Bulletin No 12/2013, page 62 refers

Given the severity of the damage, the classification of this occurrence is changed from incident to **accident**, consistent with ICAO Annex 13 definitions.

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

2/2010 Beech 200C Super King Air, VQ-TIU at 1 nm south-east of North Caicos Airport, Turks and Caicos Islands, British West Indies on 6 February 2007.

Published May 2010.

3/2010 Cessna Citation 500, VP-BGE 2 nm NNE of Biggin Hill Airport on 30 March 2008.

Published May 2010.

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

Published September 2010.

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

Published September 2010.

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

Published November 2010.

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

Published November 2010.

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

Published December 2010.

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

Published September 2011.

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

Published November 2011.

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

Published February 2014.

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

http://www.aaib.gov.uk

GLOSSARY OF ABBREVIATIONS

aal	above airfield level
ACAS	Airborne Collision Avoidance System
ACARS	Automatic Communications And Reporting System
ADF	Automatic Direction Finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
AOM	Aerodrome Operating Minima
APU	Auxiliary Power Unit
ASI	airspeed indicator
ATC(C)(O)	Air Traffic Control (Centre)(Officer)
ATIS	Automatic Terminal Information System
ATPL	Airline Transport Pilot's Licence
BMAA	British Microlight Aircraft Association
BGA	British Gliding Association
BBAC	British Balloon and Airship Club
BHPA	British Hang Gliding & Paragliding Association
CAA	Civil Aviation Authority
CAVOK	Ceiling And Visibility OK (for VFR flight)
CAS	calibrated airspeed
cc	cubic centimetres
CG	Centre of Gravity
cm	centimetre(s)
CPL	Commercial Pilot's Licence
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EAS	equivalent airspeed
EASA	European Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EGPWS	Enhanced GPWS
EGT	Exhaust Gas Temperature
EICAS	Engine Indication and Crew Alerting System
EPR	Engine Pressure Ratio
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FAA	Federal Aviation Administration (USA)
FIR	Flight Information Region
FL	Flight Level
ft	feet
ft/min	feet per minute
g	acceleration due to Earth's gravity
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
hrs	hours (clock time as in 1200 hrs)
HP	high pressure
hPa	hectopascal (equivalent unit to mb)
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IP	Intermediate Pressure
IR	Instrument Rating
ISA	International Standard Atmosphere
kg	kilogram(s)
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
KTAS	knots true airspeed
km	kilometre(s)
kt	knot(s)
lb	pound(s)
LP	low pressure
LAA	Light Aircraft Association
LDA	Landing Distance Available
LPC	Licence Proficiency Check
m	metre(s)
mb	millibar(s)
MDA	Minimum Descent Altitude
METAR	a timed aerodrome meteorological report
min	minutes
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
N	Newtons
N_R	Main rotor rotation speed (rotorcraft)
N_g	Gas generator rotation speed (rotorcraft)
N_1	engine fan or LP compressor speed
NDB	Non-Directional radio Beacon
nm	nautical mile(s)
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
OPC	Operator Proficiency Check
PAPI	Precision Approach Path Indicator
PF	Pilot Flying
PIC	Pilot in Command
PNF	Pilot Not Flying
POH	Pilot's Operating Handbook
PPL	Private Pilot's Licence
psi	pounds per square inch
QFE	altimeter pressure setting to indicate height above aerodrome
QNH	altimeter pressure setting to indicate elevation amsl
RA	Resolution Advisory
RFFS	Rescue and Fire Fighting Service
rpm	revolutions per minute
RTF	radiotelephony
RVR	Runway Visual Range
SAR	Search and Rescue
SB	Service Bulletin
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TAF	Terminal Aerodrome Forecast
TAS	true airspeed
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TGT	Turbine Gas Temperature
TODA	Takeoff Distance Available
UHF	Ultra High Frequency
USG	US gallons
UTC	Co-ordinated Universal Time (GMT)
V	Volt(s)
V_1	Takeoff decision speed
V_2	Takeoff safety speed
V_R	Rotation speed
V_{REF}	Reference airspeed (approach)
V_{NE}	Never Exceed airspeed
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional radio Range

AAIB
Air Accidents Investigation Branch