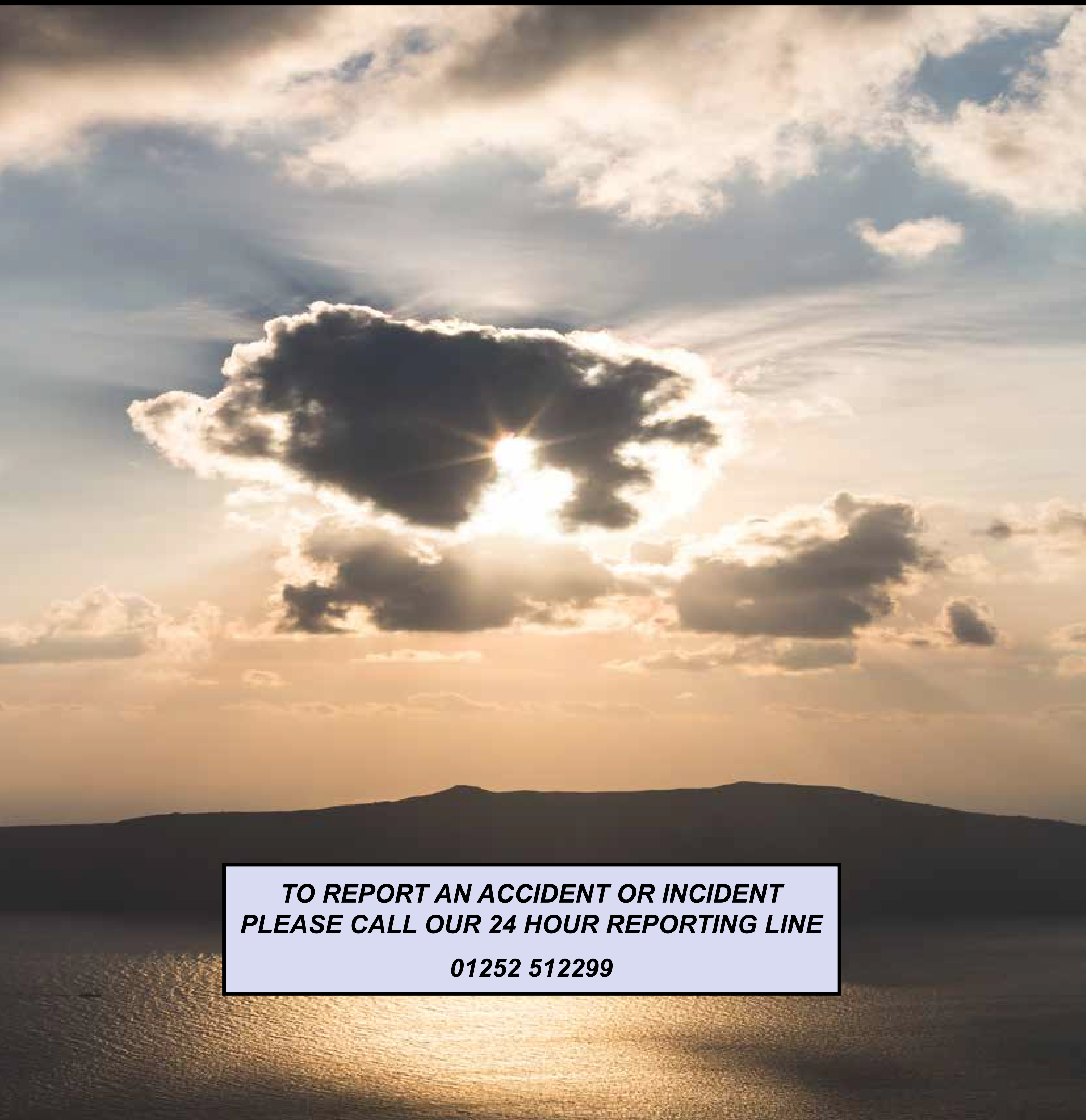
AAIB
Air Accidents Investigation Branch

AAIB Bulletin 6/2016



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AAIB Field Investigation Reports

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

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

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

SERIOUS INCIDENT

Aircraft Type and Registration:	Bombardier DHC-8-402, G-FLBC
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2009
Date & Time (UTC):	16 December 2014 at 1832 hrs
Location:	En route Glasgow to Belfast
Type of Flight:	Commercial Air Transport
Persons on Board:	Crew - 4 Passengers - 76
Injuries:	Crew - None Passengers - 1 (Minor)
Nature of Damage:	Damage to left engine and engine nacelle
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	7,847 hours (of which 6,820 were on type) Last 90 days - 185 hours Last 28 days - 59 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was en-route from Glasgow to Belfast, when an oil pressure failure and subsequent fire in the left engine prompted a diversion to Belfast Aldergrove Airport. The fire indications on the flight deck cleared several minutes after both fire bottles had been discharged into the engine nacelle. However, observations from the cabin suggested that the fire returned shortly before arrival at Belfast. The aircraft landed safely and stopped on the runway, following which the Airport RFFS confirmed there was still signs of fire. Consequently, the passengers and crew were evacuated from the aircraft, while the fire was rapidly extinguished.

The investigation revealed that the left engine oil pump assembly had failed. This was the result of fatigue cracking in an engine bearing key washer, which caused a section of the washer to be released and migrate to the engine's oil pump. Consequent mechanical failure of the oil pump assembly upset the oil flow, resulting in engine lubrication failure, internal overheat and fire.

In December 2015, the engine manufacturer issued an Alert Service Bulletin requiring specialist internal inspection of engines to be carried out, in a time span dictated by the service life of the relevant key washer. In addition to this on-wing inspection, a revision to the engine manual has been made requiring replacement of the key washer upon access, and a Service Bulletin has been issued requiring replacement on engine shop visits, for any reason. A new, improved key washer has also been introduced.

History of the flight

At 1728 hrs, the aircraft pushed back from its stand at Glasgow Airport for the scheduled 1725 hrs service to Belfast City Airport. Before the ground crew disconnected the tug from the aircraft, with the right engine running and the left engine still shut down, the ground crew's headset operator informed the commander that the aircraft's nose landing gear oleo appeared to have lost its pressure. Consequently, the commander elected to return to the stand for the problem to be rectified. The aircraft eventually departed from Glasgow at 1812 hrs.

The flight proceeded normally until 1830 hrs, when a triple warning chime sounded and the red #1 ENG OIL PRESS warning caption (for the left engine) illuminated on the flight deck. The aircraft was passing FL151, climbing to its cruising altitude of FL160, and was VMC above cloud. The flight crew turned their attention to the oil pressure gauge and saw the reading fall to zero, then show three dashes, indicating invalid information. The crew understood that three dashes could mean there had been a loss of signal from the oil pressure transmitter, so they rechecked the engine instruments and warnings and confirmed the loss of oil pressure in the left engine.

The flight crew reduced power to level the aircraft at FL160, then started to action the Quick Reference Handbook (QRH) procedure for a loss of engine oil pressure in the left engine. As they retarded the left engine power lever there was a "judder through the airframe" and the fire warning audio chime sounded briefly. They expeditiously completed the procedure and shut down the left engine but did not discharge a fire bottle as there was no longer any indication of a fire.

Declaring a PAN, the crew advised ATC that it was their intention to return to Glasgow. As they commenced the turn back, the fire warning chime sounded again and the CHECK FIRE DET caption and left engine fire handle illuminated, indicating there was a fire in the left engine. The crew discharged the first fire extinguisher bottle into the left engine nacelle and upgraded their emergency to a MAYDAY, advising ATC that they now intended to divert to Belfast Aldergrove Airport, as it was the closest suitable airfield. After 30 seconds, the fire warning for the left engine remained, so the commander discharged the second fire bottle. The fire warning then remained illuminated for several minutes, before it cleared.

In the cabin, coincident with the judder felt through the aircraft, the passengers and crew heard what sounded to some like three large "whooshing" noises, in rapid succession, and reported seeing a large blue flame emitting from the left engine exhaust. Sparks and other evidence of a fire could also be seen originating from behind the left engine cowlings, just aft of the propeller.

A company First Officer, positioning to Belfast, was sitting in a window seat on the left side of the cabin and had a good view of the engine. He saw the fire and, after conferring with the senior cabin crew member, provided the commander with a commentary on what could be seen from the cabin. This enabled the cabin crew to concentrate on the passengers and preparing for the landing at Belfast Aldergrove. Following the initial "whooshing" noises, the fire in the exhaust disappeared, and several minutes later, the fire behind the engine cowlings was no longer visible to the cabin crew or the First Officer. One minute after the engine fire warning indications in the flight deck cleared, the cabin crew confirmed they could no longer see any signs of fire[1].

To lighten the flight crew's workload, Belfast Aldergrove ATC offered to retain the aircraft on their Approach radio frequency. The crew accepted this offer. This meant that the RFFS crews, who were moving to their standby positions on the airfield and were monitoring the ATC Tower radio frequency, were not able to listen to the flight crew's radio transmissions. Instead, relevant information was relayed to them by ATC.

On the flight deck the engine fire indications had extinguished, so the commander briefed the cabin crew to expect a normal landing at Belfast Aldergrove, followed by an inspection of the aircraft by the Airport RFFS.

Shortly before touchdown, the positioning First Officer thought he saw signs of fire behind the left engine cowlings and advised the commander accordingly. The commander informed ATC there were "reports of fire from the left engine again, from the cabin, no indications in the flight deck". This was relayed, through several people, to the Airport RFFS crews as "report that there is a fire now in the cabin, but it is not confirmed." As a result, the fire crews prepared themselves for the possibility that they would have to enter a burning aircraft, with several firemen donning breathing apparatus.

The aircraft landed at 1847 hrs and was brought to a halt on the runway, having turned into wind. The fire vehicles attended immediately and the flight crew tried to establish communications with them on 121.6 MHz. They were unable to do so[2] and ATC relayed their request for the RFFS to check the aircraft for signs of fire. The fire crew observed a small fire visible through a vent grill on the left side of the left engine nacelle and advised ATC that the left side of the aircraft was on fire. This was relayed to the aircraft and the commander ordered an evacuation at 1849 hrs, while the fire crew quickly extinguished the fire.

Evacuation

The landing seemed normal to those in the cabin and the call to evacuate was unexpected. At the front of the cabin, the senior cabin crew member opened the forward left door and, on seeing no signs of fire, instructed the passengers to start evacuating. Passengers in the front right seats, who had been briefed several times on how to operate the forward right emergency exit, if instructed to evacuate, departed via the forward left door. The forward right emergency exit remained closed throughout the evacuation.

The cabin crew member at the rear of the aircraft initially opened the rear left exit and, on seeing no signs of fire, instructed the passengers to evacuate. She then opened the rear right exit and passengers evacuated through both these exits. Some passengers were

Footnote

[1] Some passengers believed they could still see signs of a small fire from behind the engine cowlings but this information was not communicated to the crew.
[2] The ATC RTF recording contained the aircraft's transmissions but nothing from the fire vehicles.

surprised at the height they were required to jump, as the rear exits are not fitted with slides, and some passengers fell on landing, incurring minor cuts and bruises[3].

There was an airport vehicle on the runway with a large illuminated sign on its roof, which read: "PASSENGERS ASSEMBLE HERE" (see Figure 1). The same message was also broadcast through the vehicle's loudspeakers. Some of the passengers, particularly those who evacuated from the rear right exit, were confused as to where to go after leaving the aircraft. Most of the fire crew were on the left side of the aircraft, where the fire had been, and within a few minutes all of the passengers were safely on board airport buses, out of the rain. A head count was conducted and, initially, it appeared that a passenger was missing. This was quickly resolved, once it was realised that the positioning First Officer had remained with the crew.

The passengers were then taken to the terminal building, where they were assessed for any injuries. There were no serious injuries; however, one lady was taken to hospital as a precaution, suffering from anxiety and chest pains. She was released from hospital later that evening.

Figure 1

Airport 'Assemble Here' vehicle

Aircraft description

The DHC-8-402 is a twin turboprop powered aircraft having a typical capacity of 78 passengers. It has a high mounted wing and consequently a relatively low cabin floor, enabling emergency escape by jumping from the exit door sills in all cases except for the forward passenger exit, the door of which incorporates integral stairs.

The engines are mounted conventionally with an approximately vertical titanium alloy firewall protecting the wing structure from damage in the event of an engine fire. The engine mounting structure consists of titanium and stainless steel components clad in

Footnote

[3] EASA issue the certification standards for large aeroplanes in CS25. Subpart D, Para 25.810 states each non-over-wing landplane emergency exit more than 1.8 m above the ground must have an approved means to assist the occupants in descending to the ground. The rear emergency exits door sills in the DHC-8-402 are 1.6 m high. The safety briefing card clearly shows there are no slides fitted to the rear exits.

carbon composite panels and doors. The air intake of each engine is below and behind the propeller and takes the form of glass reinforced plastic trunking. A sheet metal decking is positioned below the hot section of the engine. Two fire bottles are positioned in the upper lobe of the fuselage, just aft of the wing box.

Engine description

The PW150A engine is one of a family of three-shaft units which have different power outputs, but broadly similar architecture. The 150A incorporates a centrifugal High Pressure (HP) compressor of titanium alloy, driven by the HP turbine, an axial Low Pressure (LP) compressor, driven by the LP turbine, and a power turbine/shaft assembly which drives the propeller via a reduction gearbox (RGB) (see Figure 2).

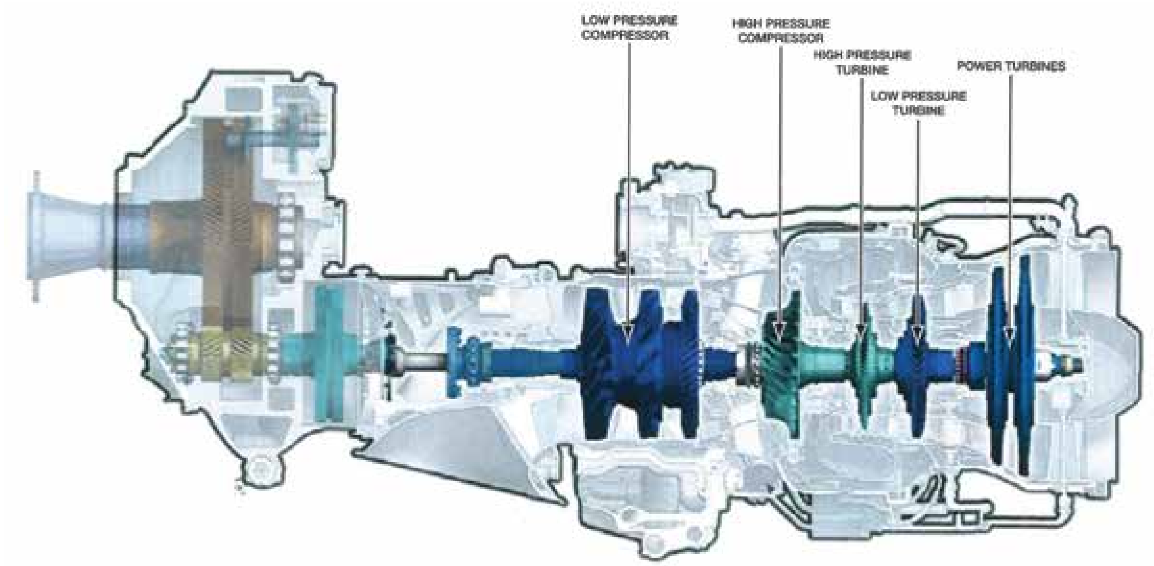


Figure 2

Major rotating assemblies in turbo-machinery and reduction gearbox

The combustor is of the reverse-flow type, with tubes (known as diffuser exit ducts) orientated circumferentially in a plane parallel with the HP compressor impellor carrying air from the tips of the impellor to 'fish-tails', which alter the flow direction to an approximately axial orientation.

The forward end of the HP shaft is located longitudinally and radially by a ball bearing at the No 4 position, in front of the impellor. The aft end of the shaft is located radially by a roller bearing (No 5), positioned forward of the HP turbine and enclosed by the reverse flow combustor (see Figure 3).

A number of parts of the HP spool rotate in close proximity to fixed parts of the engine structure in the vicinity of the No 5 bearing. Their operating clearance is assured by the No 4 bearing, preventing forward movement of the HP spool.

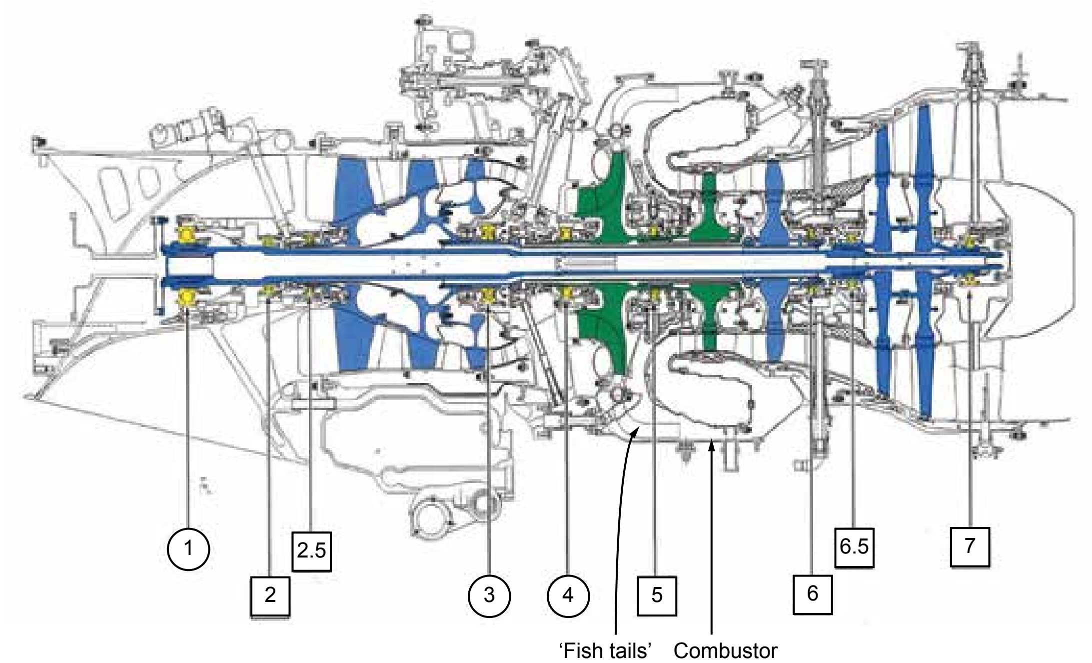


Figure 3

Layout of bearings and combuster in turbo-machinery section
(reduction gearbox not shown)

Lubrication

Lubrication is enabled by a vane pump assembly, incorporating a single pressure supply element and eight scavenge elements. The elements are arranged in two stacks, with the parallel axes orientated vertically and the individual elements joined by splined couplings (see Figure 4).

The assembly is driven by a shaft from the accessory gearbox which passes vertically into the 'driving' section and incorporates a shear neck. This driving section consists of the pressure supply element and four scavenge elements. A spur gear at the top of the driving section meshes with a similar spur gear at the top of the parallel 'driven' section. Four further scavenge elements are installed in the driven section of the unit. These include the scavenge pump for the RGB.

Air bled from the gas path (known as 'blowdown') pressurises some of the bearing cavities to increase scavenge flow when that created by the relevant scavenge pump is insufficient to prevent flooding of the cavity.

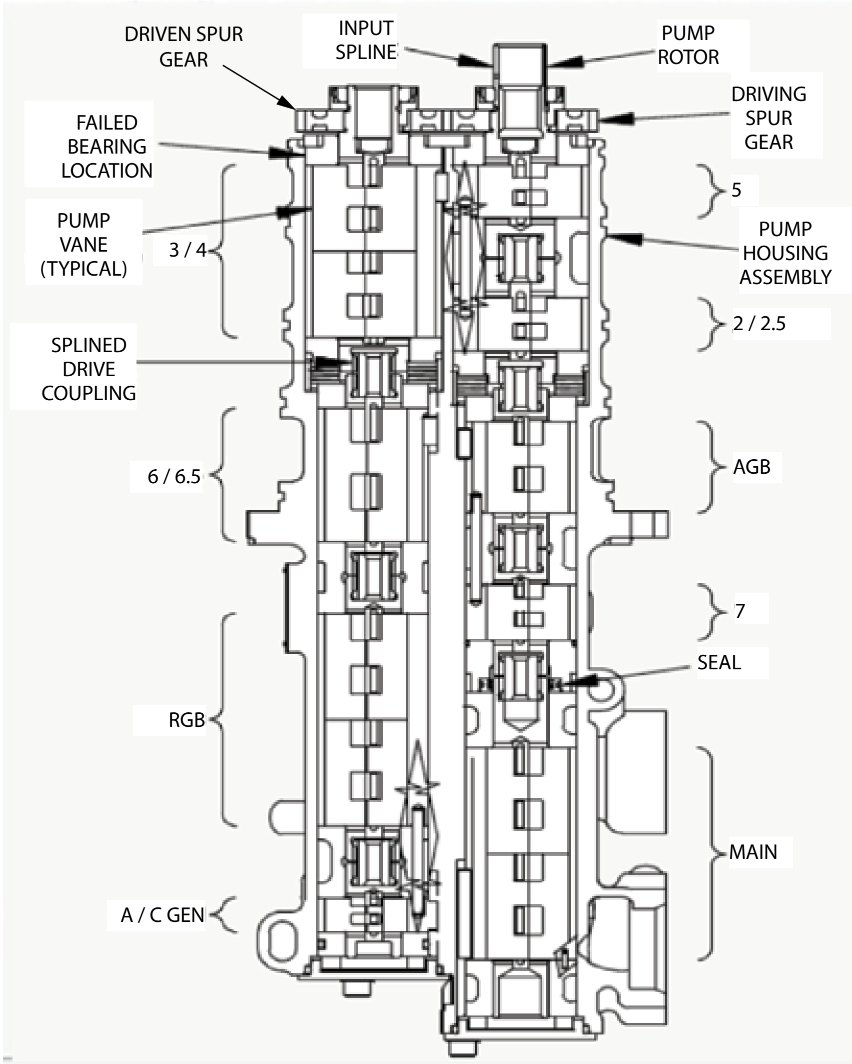


Figure 4

Layout of oil pump assembly

Engine fire detection system

In the event of a fire or overheat condition in the engine nacelles, the fire detection system provides indications and audio warnings on the flight deck. In the event of detection, the respective engine fire warning lights are illuminated and an audio warning triggered. The fire warning lights consist of an ENGINE FIRE PUSH TO RESET caption on each pilot's glareshield panel, PULL FUEL OFF handles, for each engine, in the overhead panel and a CHECK FIRE DET light on the Caution and Warning Panel (CWP). The latter is illuminated when the fire control system senses either an engine fire, APU fire, detector loop circuit malfunction or if the fire extinguisher levels are low. This warning is reversible, meaning that if any of the triggering parameters are reset the light will extinguish.

Other

The fixed structure of the engine is predominantly of titanium alloy. The engine mounting structure within the nacelle incorporates tubular stainless steel members, whilst the cowling materials are predominantly of titanium and composites.

Most power plant functions are controlled via a Full Authority Digital Engine Control (FADEC) and a Propeller Electronic Control (PEC). These supply data to the EMU, which can be downloaded for diagnostic purposes.

Additional engine information

The normal flow rate of oil into the RGB and bearings in the engine operating condition at the time of the event was such that a volume equivalent to that of the oil tank would be expected to enter the turbomachinery and gearboxes over a period of approximately 17 seconds. Consequently, with pressure supply to the RGB taking place and no corresponding scavenge occurring, the oil tank would empty and starvation of oil to the turbomachinery bearings would begin after a little over 17 seconds.

The titanium alloy materials used extensively in the engine have a low thermal conductivity. Consequently, rubbing contact can raise local temperatures rapidly, since the energy created results in heating at and close to the point of contact, and the heat dissipates slowly into more distant parts of the engine structure.

A sustained titanium fire requires a substantial supply of oxygen and will normally only continue within the core of an engine when the compressors are delivering air at an elevated pressure and flow rate.

Aircraft examination

The aircraft was examined by the AAIB the day after the event. It was noted that localised heat blistering of the paint was present on the external faces of both inboard and outboard aft engine access doors on the left nacelle. On opening the aft doors, extensive heat damage and/or smoke blackening was evident over the visible section of the engine, on the cowlings and numerous components mounted both on the engine and attached to the nacelle structure. The decking beneath the engine had suffered heat damage and distortion.

The section of the engine visible on opening the forward nacelle doors was relatively free from smoke and heat damage. It was noted, however, that the oil level was at the bottom of the range visible in the sight glass.

A number of services (pipes and cables) mounted on the engine and support structure appeared significantly heat damaged.

Examination of the engine outer casing revealed a series of holes in the insulation blanket around the lower part of the combustor unit, and a number of small 'fish-tail' components, from within the combustor, were lying on the decking below the engine casing. The intake system decking directly beneath the engine restricted the extent to which external damage on the underside of the engine could be viewed.

Viewed from the rear of the jet pipe, the power turbine could be seen to turn when the propeller was rotated by hand. Attempts at turning the LP compressor manually were unsuccessful, as were attempts at turning the accessory driveshaft, indicating that the HP shaft was probably seized.

Examination of the firewall did not indicate any significant heat damage.

Each of the three magnetic chip detectors on the engine was examined. Those from the reduction gear and the generator drive area were found to be clean. However, the detector from the turbomachinery lubrication area was found to be heavily contaminated with metallic debris. Oil samples were taken from the reduction gearbox volume and from the generator drive area. No oil could be extracted from the turbomachinery area.

Both flight deck fire-handles were found in the ‘pulled’ position and examination of the left LP fuel valve confirmed it to be at the ‘closed’ setting. Examination and weighing confirmed that both fire bottles had been fired and were fully discharged.

The aircraft was subsequently returned to service following removal and replacement of the complete left nacelle structure and systems forward of the firewall. A replacement left engine was also installed.

Engine examination

The engine was transported to the operator’s engineering base for examination. The complete nacelle structure and the cowlings, from the firewall forward, were similarly transported to enable detailed examination to take place. Once the engine was suspended, without the intake system decking in position, it was possible to see the damage to the combustor area more clearly and large holes in the insulating cover could be observed close to the 6 o’clock position (see Figure 5).

Substantial burn damage and disruption was evident to pipes, cables and other services external to the engine casing at a number of locations. In particular, a hole was evident in a fuel pipe adjacent to the large hole in the combustor. The pipe in this area was coated in metal splatter.

Considerable heat damage to the fire protection shielding on the fuel manifold was evident. However, no other physical penetration damage or disruption was evident to the exterior of the engine casing.

The engine was then shipped to the manufacturer’s facility for a strip examination. The lubricant was left in the engine during shipment.

Following arrival at the manufacturer’s plant, the oil from the reduction gearbox was drained and it was noted that substantially more oil than normal was present in that unit.

Figure 5

Accelerated wear type failure was noted in a number of bearings, particularly the No 4 bearing. Unusual dryness was noted in undamaged bearings Nos 6.5 and 7, at the rear of the engine. Study of the internal engine features indicated that failure of the No 4 bearing would have permitted forward displacement of the HP spool, leading to extensive contact damage between the forward face of the HP compressor impellor and its casing. Such damage was clearly evident when the impellor and casing were examined.

A major proportion of the titanium alloy structure of the engine had been destroyed, apparently by fire. This damage was widespread, but particularly concentrated in the structural volume between the gas flow path and the centreline, behind the impellor and in the region of the No 5 bearing. The mounting web of the No 5 bearing had been destroyed by fire.

Gross tip damage to the HP turbine blades was evident. This was consistent with rotating blade tip contact with the casing, due to loss of location of the outer race of the No 5 bearing following destruction of its mounting web. It was also consistent with over-fuelling of the engine, as a result of non-standard flow conditions arising from turbomachinery damage and reduction of rpm below the demanded value, owing to impellor rubbing and elevated frictional torque in the HP shaft.

Examination of the combustor

Damage to the combustor casing took the form of a number of holes lying radially in the plane of the exit from the HP impellor. These punctures had occurred apparently as a result of hot debris passing through the casing, after first impacting and penetrating the inner faces of some of the 'fish-tails'. The diffuser exit ducts, leading from the impellor exits, appeared to have directed this high energy material - a number of 'fish-tails' had separated from the ducts and themselves passed through the largest of the holes in the combustor.

Detailed examination of the lubrication system and bearings

As previously noted, the oil tank was observed to be effectively empty when the aircraft was first examined. No oil was present in the turbo-machinery section of the engine but samples were successfully taken from the RGB and the accessory gearbox.

Examination revealed that the No 4 bearing had deteriorated as a consequence of a grinding effect on one of the races, permitting forward movement and contact of the titanium alloy impellor with its casing. The bearing condition was consistent with the effect of continuing operation, without any initial damage but an absence of lubricant. Nos 6.5 and 7 bearings were noted to be undamaged but unusually dry, as would be expected when oil starvation occurred for a short period of operation.

Preliminary examination of the oil pressure/scavenge pump assembly indicated that the upper bearing of the 'driven' element of the pump was damaged and internally deformed, allowing both axial and radial movement of the gear, thus permitting it to come out of mesh with the corresponding 'driving' gear. The complete pump assembly was seized ie none of the elements could be rotated.

The disengaged gears normally transfer the drive from the input shaft to a stack consisting of scavenge pumps for the Nos 3/4 and 6/6.5 cavities, AC (alternating current) generator drive and the RGB. The shear neck on the input drive to the combined pressure/scavenge pump assembly was intact and metallurgical examination indicated that its strength would have been in the normal range.

The oil pressure/scavenge pump unit was subjected to X-ray computed tomography (CT) scanning, before being forwarded to its manufacturer for examination. That examination revealed that a lateral breakout failure of the upper bearing of the driven stack (see Figure 6) had allowed its axis to be displaced, permitting disengagement of the gears.

This had resulted in loss of drive to all the scavenge pumps, except for No 2/2.5, 5 and 7, and that for the accessory gearbox. Dismantling revealed that numerous vanes were jammed in their slots in the rotors and evidence of significant overheating was present.

Laboratory examination of various items of debris from the pump initially indicated that the reason for vane seizure was the presence of re-solidified titanium in the slots and in the spaces below some of the vanes: titanium alloy is not used in the manufacture of the pump unit.

Figure 6

Failed upper bearing
No 3/4 scavenge pump

Further information

Coincidentally, another similarly burnt out PW150A engine, installed in another operator's aircraft, was received for investigation by the engine manufacturer. The damage was reported to be similar to that on the engine from G-FLBC, except that the shear neck of the drive to the oil pump had failed. Investigation of the second engine failure revealed a failed condition of the No 4 bearing key washer.

It appeared that debris from the failed washer had entered the No 3/4 scavenge pump section, leading to a condition which had overloaded and failed the shear neck on the pump driveshaft in that aircraft. Consequent loss of all oil pumping functions had caused starvation and led to total loss of delivery flow and pressure.

The close similarities between features of the above two engines led to a laboratory examination of the key washer salvaged during dismantling of the G-FLBC engine. It was confirmed that fatigue cracking had been present in the component (situated immediately forward of the No 4 bearing - see Figure 7). Consequently, overload failure had ultimately occurred, releasing part of the washer. The released fragment then appeared to have travelled through the gallery to the 3/4 cavity scavenge pump. Such an eventuality would normally result in seizure of the pump assembly and failure of the shear neck on the driveshaft. On this occasion, however, (in G-FLBC) it appeared that the action of lubricant within the pump assembly coupled with the geometry and orientation of the fragment did not create sufficient torque reaction to fail the shaft. Nonetheless, it created sufficient side load on the uppermost 3/4 cavity vaned scavenge pump to fail the top bearing in the driven scavenge pump stack.

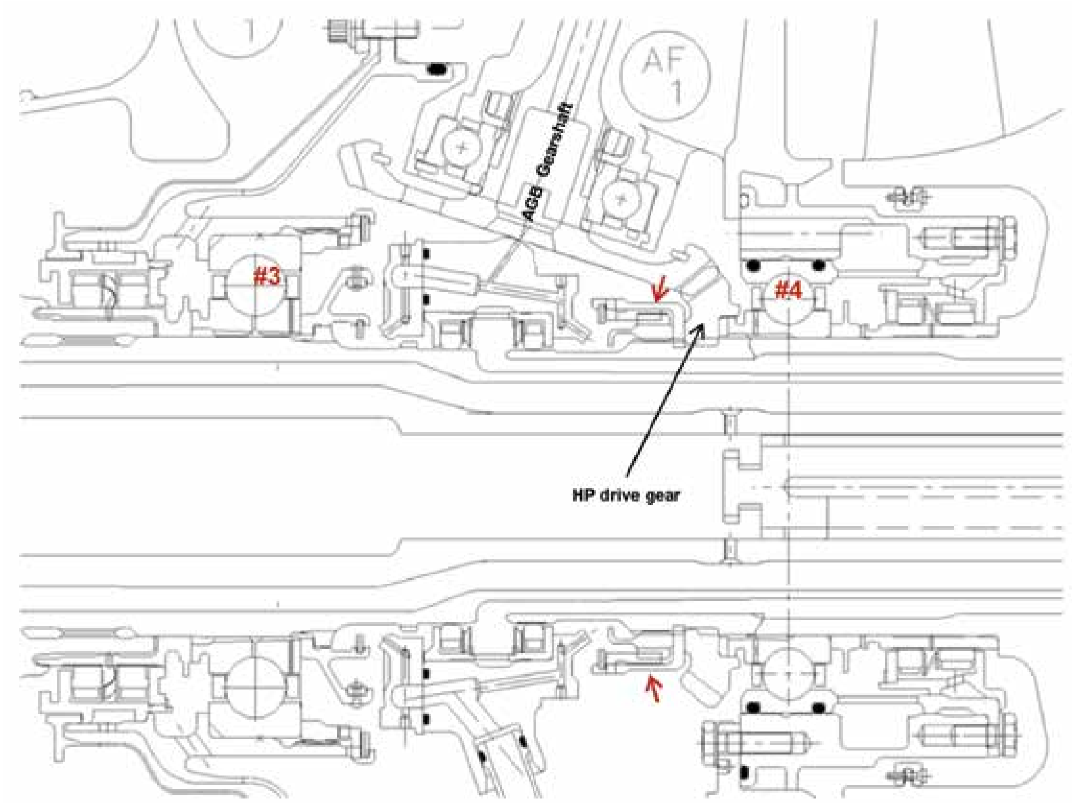


Figure 7

Red arrows show position of failed key washer
(between bearings #3 and #4)

The debris adhering to the magnetic chip detector for the turbomachinery was thought to include released material from the key washer. The similarity in the steel type employed to that forming components subsequently damaged by continuing operation of the inadequately lubricated engine, however, made it impossible to identify conclusively key washer debris.

Fire detection system

The fire detection loop from G-FLBC was tested, in accordance with the manufacturer's Aircraft Maintenance Manual (AMM), by the operator at their main engineering base. It was found to comply with the specified requirements.

Recorded information

The aircraft was fitted with a 2-hour CVR and a Flight Data Recorder (FDR) which recorded just over 26 hours of operation. Each engine also had an associated EMU which recorded fault and status events, along with a snapshot of engine parameters from two minutes before to one minute after each event. EMU data for the left engine was downloaded, decoded and analysed by the engine manufacturer. These recorded data sources were combined and are summarised in the 'History of the flight'.

A review of the FDR data during the taxi-out and initial climb confirmed that the recorded engine parameters were the same for both engines. During the climb, at 1827:37 hrs the EMU recorded a fault code corresponding to a *'turbo machinery chip detection'*. Two minutes and 43 seconds later, it recorded a *'main oil filter impending bypass'* fault code, followed fourteen seconds later by a *'low oil pressure'* fault code. The former is triggered when the oil filter is approaching its maximum capacity and bypass of the main oil filter is about to occur.

One second later, at 1830:35 hrs, the FDR recorded a MASTER WARNING and a left engine low oil pressure warning, which is triggered once oil pressure reduces below 44 psi. The EMU also recorded a *'main oil pressure exceedance flag'* which is triggered if the oil pressure is less than 45 psi. The CVR recorded the flight crew acknowledging this warning with the aircraft climbing towards its cruising altitude of FL160. Just after both engine power levers were retarded at the top of the climb, engine data started to differ between the left and right engines (see Figure 8). At 1831:36 hrs, the EMU recorded an *'engine flameout'* on the left engine. Thirteen seconds later, the FDR recorded a change of state in the CHECK FIRE DET light on the CWP, along with a MASTER WARNING. This was activated for five seconds, then cleared. The CVR recorded the flight crew acknowledging the warning, which occurred just after the left engine power lever had been retarded as part of the engine shutdown procedure.

At 1833:27 hrs, CHECK FIRE DET was again triggered and this time remained until the FDR recording ended, just over 13 minutes later. The status of the engine fire bottles was not recorded, although the CVR recorded the flight crew confirming that both fire bottles had been discharged. It also recorded them declaring a MAYDAY and requesting a diversion to Belfast Aldergrove Airport. Of the engine fire warning lights, only the CHECK FIRE DET status was recorded. However, at 1837:10 hrs, during the subsequent descent towards Belfast, the CVR recorded the commander saying "FIRE'S GONE OUT".

Analysis

Engineering

Initiating event

It was confirmed that fatigue cracking had been present in the engine's No 4 bearing key washer (situated immediately forward of the No 4 bearing). Consequently, overload failure ultimately occurred, releasing part of the washer. The released fragment then appeared to travel through the gallery to the No 3/4 bearing cavity scavenge pump in the oil pump assembly. It appeared that the action of lubricant within the pump, coupled with the geometry and orientation of the fragment, created sufficient side load on the uppermost 3/4 cavity scavenge pump to fail the top bearing in the driven scavenge pump stack. On this occasion, the particle did not create sufficient torque reaction to cause a failure of the shear neck on the oil pump's input driveshaft.

Failure of a No 4 bearing key washer also occurred in a similar engine during this investigation, leading to a generally similar outcome. In that event, the shear neck on the oil pump's input driveshaft failed.

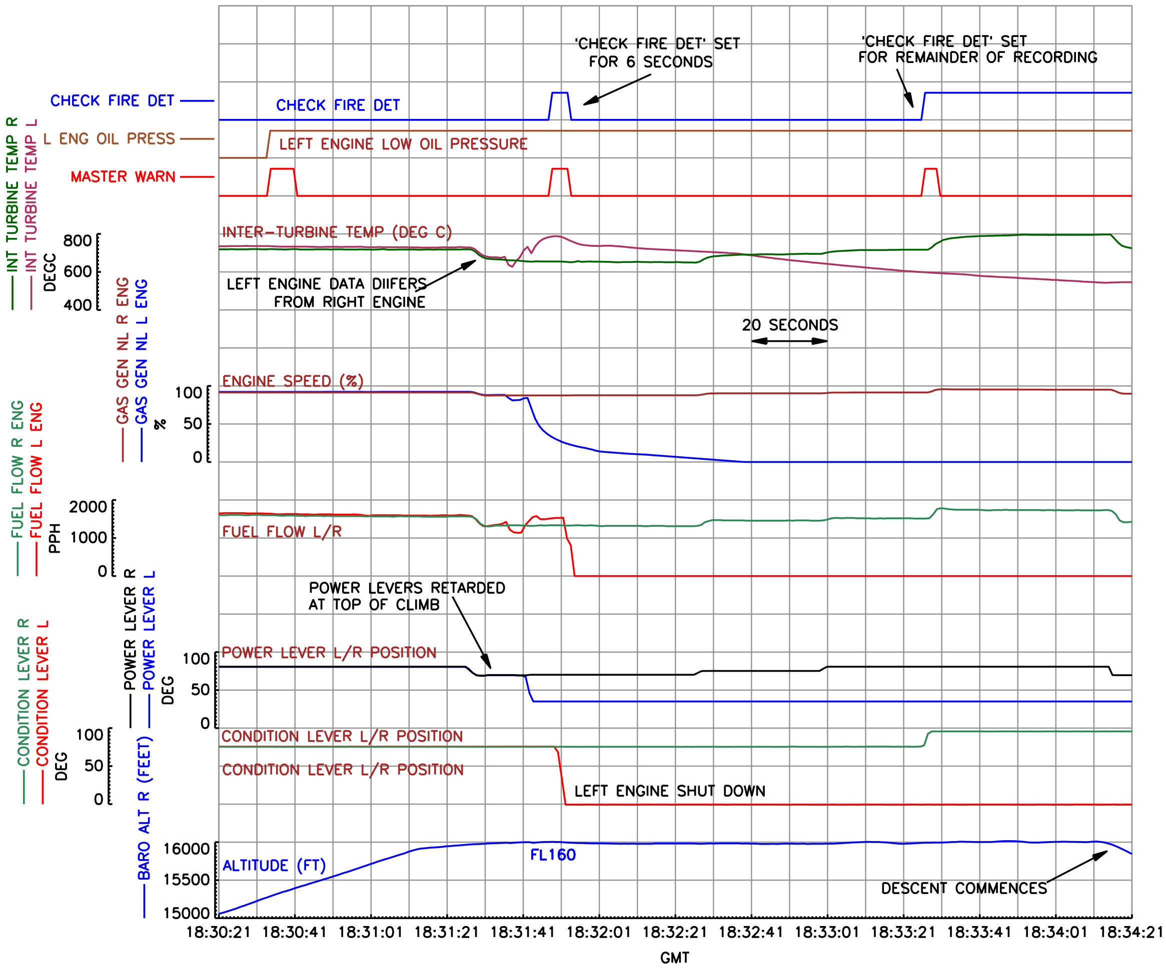


Figure 8

FDR parameters

Engine lubrication

The failure of the top bearing locating the driven gear of the engine oil pressure/scavenge pump assembly resulted in disengagement of this gear from the driving gear. Consequently, the driven gear's stack of scavenge pumps stopped. Since the pressure pump function continued, the RGB continued to receive oil. However, the RGB oil was not returned to the oil tank due to the lack of scavenge from that area. Hence, the oil tank progressively emptied and the RGB began to flood. Flooding in the RGB, as observed by the excessive volume drained before the engine strip, contributed to a low level in the oil tank, followed by overall starvation.

From detailed examination of the pressure and scavenge pump elements, it was concluded that contamination of the oil with titanium had occurred before complete engine failure. Since only the engine contains titanium components, it was considered possible that the oil pump assembly failure was the consequence of some form of failure, involving titanium, within the engine. It was subsequently deduced, however, that the presence of the blowdown system, to augment the scavenge pump performances, probably caused titanium products within the gas path to be directed into the oil system late in the failure sequence, after the scavenge pumps on the driven side of the pump assembly had ceased to rotate.

It was estimated that the pressure pump section in the engine continued to supply oil for approximately 17 seconds after the failure of the upper bearing of the driven scavenge pump stack. After this, an empty oil tank ensured that no more oil was delivered.

Final failure sequence

The loss of oil supply resulted in overheating and general deterioration of the No 4 bearing, leading to interference damage between the HP compressor impellor and casing. Loss of cooling and lubrication of the No 5 bearing would have led to the potential for local overheating and seizure. At the same time, rotating contact between the HP spool and the fixed structure in close proximity, permitted by forward movement of the spool, following deterioration of the No 4 bearing, would have created rapid frictional heating in the region of the No 5 bearing. Either of these last two mechanisms could have led to the internal fire which ultimately destroyed the No 5 bearing support web.

The recorded data indicated that low oil pressure in the left engine triggered a red MASTER WARNING. This occurred approximately 3 minutes after a turbomachinery chip warning (not displayed to the crew) had been created. The flow rate of oil to the RGB suggested that the oil tank depleted in approximately 17 seconds, after the driven scavenge pumps ceased to return oil to the tank. It, therefore, appeared most likely that initial failure of the key washer, releasing some ferrous material into the oil flow, occurred a little under 3 minutes before the failure of the upper bearing of the oil pump assembly.

Apart from the punctures in the combustor, the external casing of the engine remained intact. It appeared that the metal splatter, which impacted and passed through the combustor case and the insulation layer, was material released as a result of the rotating contact between the impellor and its casing. The same material was also responsible for creating the hole in one external fuel pipe.

Engine fire

It was concluded that fuel was liberated into a volume within the nacelle, from the holed external fuel pipe, and was exposed to the hot/burning centre of the engine carcase via the punctures in the combustor case. Much of the external heat damage to the engine is difficult to account for, other than as a result of an external fuel-fed fire. However, it is likely, from the EMU and FDR data and a study of the engine damage, that an internal fire had begun approximately 1 minute after the loss of oil pressure. Initially, burning at such a location is unlikely to have significantly altered conditions external to the engine casing or to have caused the fire warning to operate. Therefore, it is likely that an undetected internal fire persisted for a period before the combustor was penetrated and the fuel pipe became holed.

Following the fire warning, the fire suppression system was operated, both bottles being fired over a period. Although a flight crew member being carried in the cabin subsequently reported fire still being visible through gaps and louvres in the cowling, no further fire warning was reported.

Fire crew on the ground saw signs of fire beneath the cowling immediately after the aircraft landed. The nature of the titanium structure of the engine is such that the transfer of heat from within the core of the engine to visible areas on the outside casing of the unit would have been gradual. It is possible that, as a result of delayed conduction from the core of the engine, parts of the exterior casing glowed red and became visible in the darkness after the external fuel-fed fire ceased, or that a small amount of residual fuel from the engine fuel system continued to drain from the punctured fuel pipe, being re-ignited by the hot exterior of the engine casing. In addition, the elevated temperature of the exterior of the engine, once stationary on the ground, probably led to charring and smoke emission from insulation of cables and pipes on the exterior of the engine.

Safety action

On 21 December 2015, the engine manufacturer issued Alert Service Bulletin SB A35325. This requires in situ inspection of the No 4 bearing key washer and the removal from service of engines in which cracked washers are identified.

The manufacturer has used technical records to identify the service lives of key washers and, hence, priorities for inspection and maximum permitted running periods before inspections on particular engines are required to be carried out.

The inspection requires removal of a number of components from the engine, to gain access to the area of the key washer, and utilises an ultrasonic transducer to determine the presence or absence of cracking. In view of the complexity of the inspection process, the manufacturer has provided special training to operators. Where cracked washers have been identified, the corresponding engines have been removed from service.

In addition, the engine manual has been revised to instruct the replacement of the key washer upon access, and SB 35326 has been issued to instruct replacement of the key washer at engine shop visits, regardless of the reason for engine removal. Furthermore, the engine manufacturer introduced a new improved key washer in February 2016, per SB 35327.

Operations

The flight crew were presented with a loss of oil pressure in the left engine, which prompted them to initiate a return to Glasgow, their point of departure. There had been a brief fire warning while they were carrying out the QRH procedure for a loss of oil pressure but it then returned permanently and the crew elected to divert to the nearest suitable airfield, Belfast Aldergrove, as they carried out the QRH procedure for an engine fire.

Despite the engine being shut down and both fire extinguishers being discharged, the indications to the flight crew were that the fire remained for several minutes. The flight deck indications then cleared and from the cabin it also appeared that the fire had extinguished. However, shortly before landing, the flight crew received further reports from the cabin that there were, once again, signs of fire in the engine nacelle. This was communicated to the airport RFFS crews as being a fire in the cabin and they prepared themselves for the possibility that they may have to enter a burning aircraft.

Having landed safely, the aircraft was stopped on the runway. The flight crew were unable to speak to the RFFS crews direct and ATC relayed their request for the aircraft to be checked for signs of fire. Confirmation that there was a fire on the left side of the aircraft then prompted the crew to carry out an evacuation, during which there were some cuts and bruises but no major injuries.

The fire, which was visible in the engine nacelle, was quickly extinguished by the airport RFFS and, within a few minutes, the airport authorities had moved everyone to a place of safety, out of the rain.

Conclusions

While the aircraft was in the climb to its cruising altitude, fatigue cracking of the left engine's No 4 bearing key washer appears to have allowed a steel fragment to pass into the No 3/4 bearing cavity scavenge pump. This resulted in bearing damage, permitting disengagement of the drive to some of the scavenge pumps in the engine's oil pump assembly, while the pressure supply and four other scavenge pumps continued to function. The ultimate absence of oil in the engine's oil tank led to the total loss of lubrication and the rapid deterioration of dry bearings in the engine. This, in turn, caused engine shaft displacement and frictional rubs, creating internal titanium fires at a number of locations. The combustor case was penetrated, internal components were ejected and an external fire then developed.

The flight crew followed the QRH procedures for a loss of oil pressure and fire in the left engine and carried out a diversion to the nearest suitable airport. The fire extinguished after a few minutes but appeared to return shortly before the aircraft landed. The airport RFFS attended the aircraft when it stopped on the runway and observed signs of fire within the left engine nacelle. These were rapidly extinguished, while the passengers and crew evacuated from the aircraft.

In December 2015, the engine manufacturer issued an Alert Service Bulletin, SB A35325, requiring specialist internal inspection of engines to be carried out, in a time span dictated by the service life of the No 4 bearing key washer. In addition, the engine manual has been revised to instruct the replacement of the key washer upon access, and SB 35326 was issued in December 2015 to instruct replacement of the key washer at engine shop visits, regardless of the reason for engine removal. The engine manufacturer also introduced a new improved key washer in February 2016, as indicated in SB 35327.

INCIDENT

Aircraft Type and Registration:	Sikorsky S-92A, G-VINL
No & Type of Engines:	2 General Electric Co CT7-8A turboshaft engines
Year of Manufacture:	2014 (Serial no: 920226)
Date & Time (UTC):	22 August 2014 at 1805 hrs
Location:	Golden Eagle complex, North Sea
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	5,700 hours (of which 401 were on type) Last 90 days - 70 hours Last 28 days - 18 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The helicopter was operating a multi-sector flight, between rigs located approximately 60 nm north-east of Aberdeen Airport, when it landed on the wrong helideck, which was unmanned. On the third sector, it was required to fly from the Paragon Midwater Semi-Submersible 1 (MSS1) rig to the Buzzard complex helideck, a distance of 7 nm on a track of 205°M. However, the crew misidentified the Golden Eagle complex, on a bearing of 354°M from the Paragon MSS1 at a distance of 3 nm, as the Buzzard complex and landed there instead.

History of the flight

The crew were briefed to carry out a multi-sector flight from Aberdeen Airport, routing to the Scott platform, the Paragon MSS1 semi-submersible rig and the Buzzard complex, before returning to Aberdeen. Two passengers and some freight were carried outbound; one passenger was flying to the Scott platform and the other to the Buzzard. Three passengers were then due to be flown from the Buzzard complex back to Aberdeen.

The crew carried out a full pre-departure briefing, which included reviewing the weather, the route and the helidecks to be used, noting their relative positions in the complexes. The routing is shown in Figure 1.

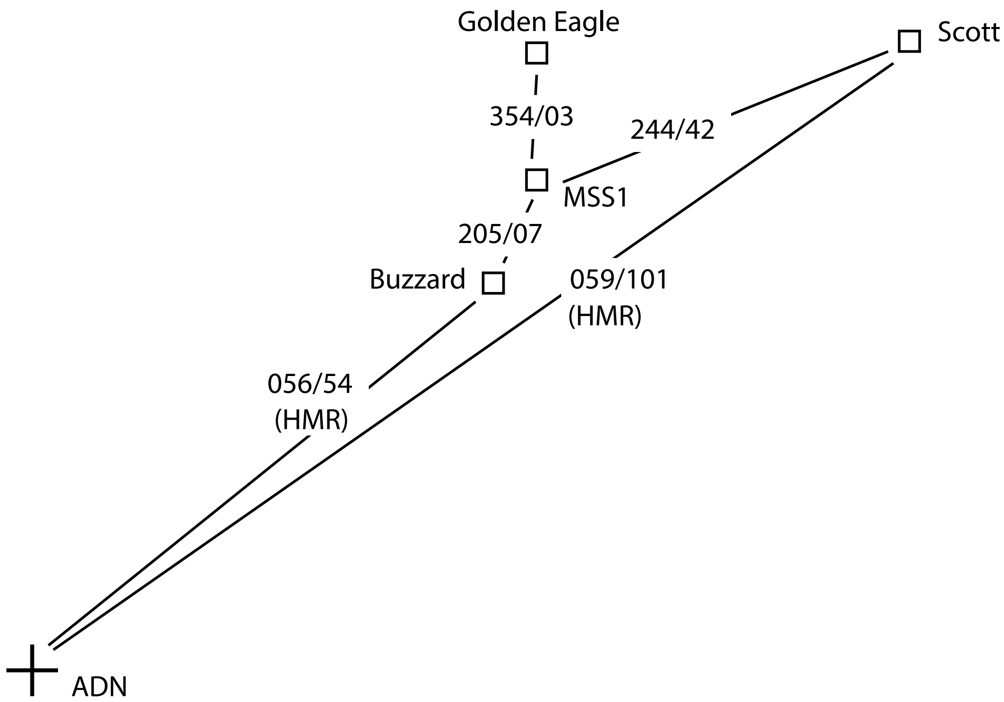


Figure 1

Helicopter routing with bearing and distances (ºM/nm) to the next waypoint.
(For illustration purposes only and not drawn to scale: HMR = Helicopter Main Route)

The commander, occupying the right seat, was an experienced offshore pilot. The co-pilot, however, had only recently completed his line check and had limited offshore experience. Both pilots were relatively new to the helicopter type. The commander would have preferred to have been the Pilot Monitoring (PM) for this short multi-sector route: operating the radio, completing the associated payload information and navigating in this busy, high workload offshore environment. However, the motion (pitch, heave and roll) of the Paragon MSSI, while within limits, was such that the commander was required to occupy the right seat to carry out the landing. In addition, the prevailing wind direction meant that the landings on the other helidecks would also be carried out by the pilot in the right seat. Therefore, the commander would have to be pilot flying (PF) throughout the offshore sectors.

Two radio frequencies are used by helicopters operating offshore. The Logistics frequency is used for obtaining weather and load information and has the callsign ‘Log’. This frequency is normally selected on VHF communications box 1. The second frequency is used to maintain a helicopter’s ‘flight-watch’ and for providing information on other helicopter movements. It has the callsign ‘Traffic’ and is also the frequency used by the crew to contact the Helicopter Landing Officer (HLO), to establish helideck availability. It is normally selected on VHF communications box 2.

The departure from Aberdeen was flown by the co-pilot but the commander took control in the cruise. The sectors to the Scott and on to the Paragon MSS1 were uneventful, with the helicopter landing on the Paragon MSS1 helideck on a heading of about 330ºM. The co-pilot, as PM, was faced with a high workload, requiring the commander to assist him with some of his tasks.

Whilst on the Paragon MSS1 helideck, the co-pilot had some difficulty obtaining the return payloads to Aberdeen from the Buzzard Log operator, but learned that another company helicopter was due to arrive at the Buzzard helideck at about the same time as G-VINL. He eventually established that their anticipated return payload, of three passengers, was cancelled and there would be no passengers on the flight to Aberdeen. Meanwhile, the other helicopter elected to slow down to allow G-VINL to land on the Buzzard helideck first. The discussion between the commander and co-pilot in G-VINL, and the high level of RTF transmissions regarding this issue, were described by the crew as 'busy and confusing', with contradictory information coming from Buzzard Log regarding the return loads for each helicopter.

The crew discussed the next sector (to the Buzzard complex) and identified the large grouping of platforms ahead of them, in their 12 o'clock, as the Buzzard complex. It looked large enough and appeared to conform to the picture provided in their Helicopter Limitations List (HLL). They were unaware that it was the Golden Eagle complex and not the Buzzard complex.

Due to the close proximity of the next destination (the Golden Eagle complex), the crew decided that they would fly the sector manually, at an altitude of 500 ft amsl, without using the Universal Navigation System (UNS) Flight Management System (FMS) to drive the lateral navigation mode of the Auto Flight System. The crew commenced the Before-Departure Checks, where the next sector's track and distance is confirmed using the FMS, when they were interrupted by the Buzzard Log operator advising them of another change to their onward payload to Aberdeen. This had reverted to the original three passengers. At no point was the compass, area Rigmap or the FMS used to confirm the position of the next landing point, although both flight crew were sure that the Buzzard was selected as the next waypoint on the FMS.

Both pilots had their Navigation Displays (ND) selected to 'sector', as normal when operating offshore, resulting in the Buzzard waypoint being outside the 40° arc displayed either side of the helicopter's heading.

The takeoff was uneventful and the commander, as Pilot Flying (PF), turned the helicopter towards the Golden Eagle complex, climbing to an altitude of 500 ft. The transit time was three minutes and the crew decided to leave the landing gear down, the brakes ON and not to re-synchronise the compass.

The co-pilot, as PM, requested "DECK AVAILABILITY" (the call required to confirm that the helideck is ready and available for landing) from the Buzzard HLO and received confirmation that the Buzzard helideck was available.

The crew then carried out the abbreviated Final Approach checklist, the first item of which states '*Landing Point…..IDENTIFIED*'. At this stage, the name painted on the helideck was not visible and the commander advised the co-pilot that confirmation of the helideck name would occur later in the final approach. As the co-pilot performed item 2, arming the flotation equipment, the crew were interrupted by the Paragon MSS1 Traffic operator asking if they had switched to the Buzzard Log. The co-pilot asked him to standby because they were at a critical stage of flight. Whilst the co-pilot was on the radio, the commander recalled identifying the helideck at the far end of the complex, as they had expected, but with its name unreadable at that stage. The superstructure of the complex passed down the right side of the helicopter but, due to the orientation and position of the helideck, they could not see it fully until they were almost alongside.

The helideck name appeared upside down, from their perspective, but, as the helicopter landed, the commander saw the helideck name 'ENSCO 120' in his rear quarter. Although the helideck was unmanned, there was no activity taking place in the vicinity of the helideck such as crane or equipment operation.

Realising their mistake, the crew immediately advised the Ensco 120 Log operator of their error and transmitted the standard on-deck radio call, stating the helicopter's callsign and the name of the deck on which they had landed.

The commander knew of the company requirement to remain rotors running on the helideck until cleared to take off by the HLO. However, he observed that there were no apparent structures or obstructions ahead and no cranes in operation, giving the helicopter an unobstructed and clear takeoff path. Aware of the helicopter's all up mass and the wind speed of 20 kt, he also estimated that it had single-engine hover performance, reducing the chance of ditching. The commander therefore considered that taking off immediately, minimising the time on deck without any fire cover (estimated to take 10-15 minutes to arrange), would be the safer option. In addition, he was aware that the other helicopter was inbound to the Buzzard complex and he did not want to cause any further delay.

The commander advised the co-pilot of his decision to take off and transmitted his intention to depart immediately to the Ensco 120 Log operator. The Log operator acknowledged the radio call and confirmed that there was nothing to affect the helicopter's departure.

The single passenger was briefed that a wrong deck landing had occurred and that they were not yet on the Buzzard helideck. A full set of Before Departure checks were carried out and the crew identified, by reference to the FMS, the correct position of the Buzzard complex. The Before Take-Off checks were completed and the helicopter departed. The flight continued without further incident and G-VINL landed on the Buzzard complex helideck, to resume its planned operation.

Meteorology

The flight was conducted in daylight and the weather offshore was good outside rain showers. The conditions at the time of the incident were reported as: surface wind from 330°-340°M at 15-20 kt, visibility greater than 10 km, scattered cloud at 1,800 ft, with moderate rain in the vicinity of the Buzzard complex. This rain obscured the Buzzard complex from the crew during the sector from the Scott platform to the Paragon MSSI.

Helideck information

The Helideck Certifications Agency (HCA) is responsible for the inspection and certification of helidecks on offshore vessels and installations operating in UK and Norwegian waters. Offshore helidecks are required to hold a valid certificate issued by the HCA on behalf of the UK operator. All helidecks mentioned in this report had valid HCA certification.

The Buzzard complex

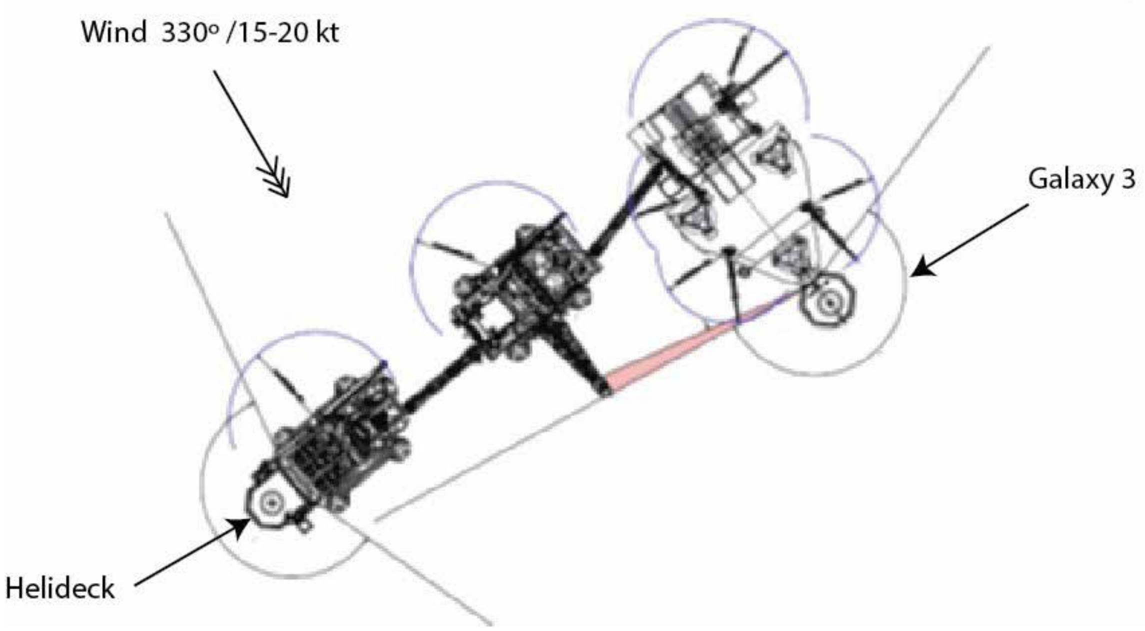


Diagram provided by the operator

Figure 2

The Buzzard complex

Three separate, fixed platforms make up the Buzzard complex (Figure 2), with the helideck on the south-western end of the complex. The average orientation of the complex is 050º/230ºM. The Galaxy 3 jackup rig is attached to the south-easterly side of the most eastern platform. The Buzzard complex lies on a bearing of 205°M from the Paragon MSS1, at a range of 7 nm. When arriving from the Paragon MSS1, the commander expected the line of platforms to pass down his right side, before turning to the right to land into wind (330°-340°M at 15-20 kt).

Golden Eagle complex

Two separate, fixed platforms make up the Golden Eagle complex (Figure 3). The helideck is on the Ensco 120 jackup rig, which is attached to the northern side of the northern platform. The Safe Caledonia semi-submersible is attached to the southern side of the southern platform. The average orientation of the complex is approximately 170º/350ºM. It lies on a bearing of 354ºM from the Paragon MSS1, at a range of 3 nm. From the Paragon MSS1, it would appear as a large mass of structures, with indistinguishable individual installations.

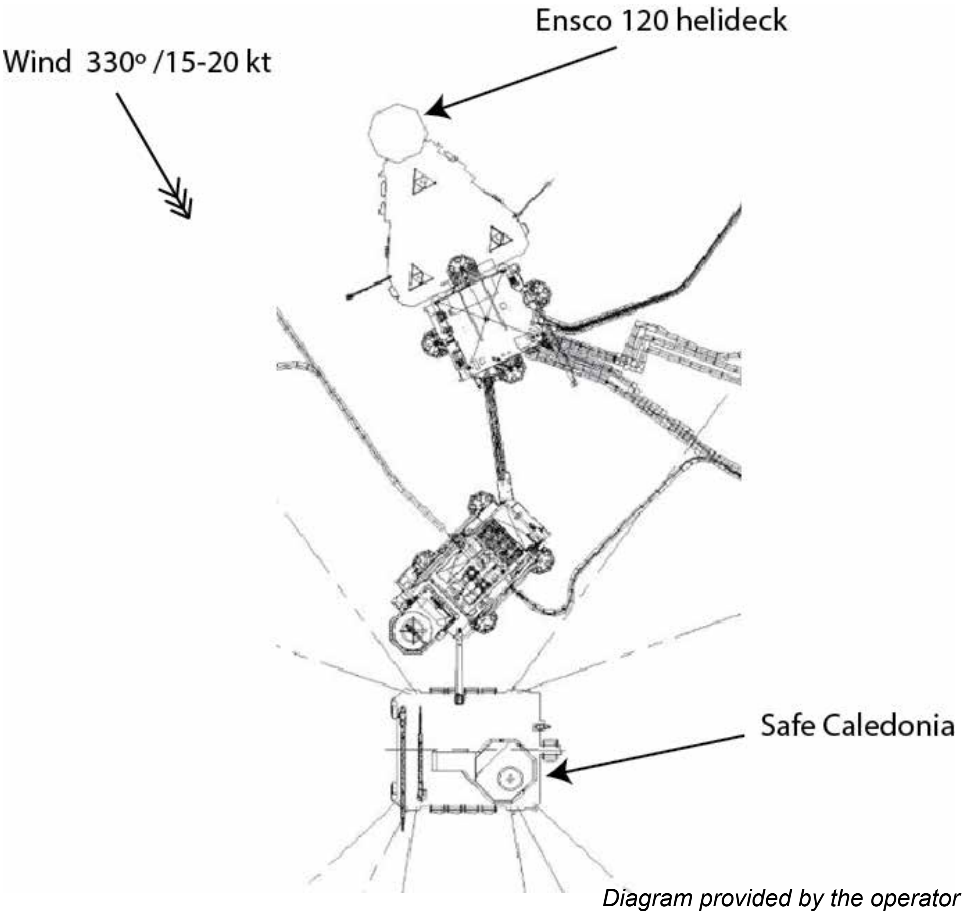


Diagram provided by the operator

Figure 3
Golden Eagle Rig complex

Navigation

The operator's policy on the navigational equipment to be fitted to its aircraft is contained in its Operations Manual. It states:

> ***'8.3.2 Navigation Procedures***
>
> *8.3.2.1 General*
>
> *Company aircraft will be fitted with navigational equipment appropriate to route and type of operation and will include:*
>
> *GPS receiver with associated flight management and display systems*
> *VOR/DME receivers and associated display systems*
> *ADF receivers and associated display systems*
> *Weather radar*
> *Maps and charts for visual navigation*
>
> *Where appropriate, the Company will provide in the aircraft library a guide to the use of navigational equipment.'*

In paragraph 8.3.2.4 'The use of GPS for Offshore Helicopter Operations', the procedures require crews on helicopters fitted with an FMS to use GPS for offshore operations, when out of range of navigation aids. The procedures also cover such matters as database validity, entering manual waypoints/routes in the FMS and the RAIM[1] (Receiver Autonomous Integrity Monitoring) check.

The FMS in G-VINL was serviceable and had been in use up to the landing on the Paragon MSS1. It would have provided the bearing and distance from the Paragon MSS1 to the Buzzard complex, had that been the next waypoint selected.

Landing on the wrong rig

The operator's Operations Manual, *Part A – Section 8 – Operating Procedures*, provides the actions to take following a landing on an incorrect rig. It states:

> *'8.5.10 Helideck Misidentification*
>
> *If a landing or an approach to a low hover has been made at a helideck other than that for which a clearance has been given, the following action is to be taken:*
>
> *If in the hover, complete the landing if safe to do so.*
>
> *Complete the after landing checks.*
>
> *Remain running on deck unless an immediate take-off is the safest option.*
>
> *Advise the installation operator of the presence of the aircraft.*
>
> *Advise the intended destination helideck of the whereabouts of the aircraft.*
>
> *Confer with the installation operator about further intentions.*
>
> *Ensure that the helideck is properly manned before contemplating taking off again.*
>
> *Do not take-off until cleared by the HLO.'*

These actions were applicable after the helicopter landed on the Ensco 120 helideck. The commander considered the item *'Remain running on deck unless an immediate take-off is the safest option'* and considered that the safest option was to depart immediately.

Analysis

The crew conducted a full pre-departure brief, which included the weather, the route plan, and the rig briefs. They also reviewed the HLL chart for all the offshore destinations.

The commander correctly identified that the highest workload during the multi-sector flight would be experienced by the PM. With a relatively inexperienced co-pilot, he would have preferred to carry out that role but had to fulfil the role of PF for the offshore sectors, due

Footnote

[1] RAIM monitors the integrity of GPS signals in a receiver system.

motion of the Paragon MSSI and the wind direction. This had the effect of increasing his (PF) workload, when assisting the PM.

Whilst on deck on the Paragon MSS1, the commander misidentified the Golden Eagle complex as the Buzzard complex because it was a large complex of installations and fitted his mental image and expectation of the orientation of the Buzzard complex. He did not use the FMS, Compass or Rigmap to determine the correct destination, and the limited familiarity of the co-pilot with the area may have led him to accept the assessment of the commander. The crew were also distracted during their Before Departure checks, by radio calls from the Buzzard Log operator regarding payloads.

The knowledge that another helicopter was inbound to the Buzzard but that G-VINL was number one to land, added a perceived time-pressure. However, there was no safety critical reason to expedite their departure.

During the final approach to the Ensco 120 helideck, the crew called for and obtained "deck availability" from the Buzzard HLO, supporting their belief that they were approaching the correct installation. The crew then carried out the abbreviated Final Approach checklist item, '*Landing Point…..IDENTIFIED',* but were not able to read the name on the helideck and the commander was not aware that he was approaching the wrong deck. The commander had advised the PM, in his briefing, that confirmation of the helideck's name would occur later on final approach, due to the rig orientation.

After realising they had landed on the incorrect rig, the crew carried out the '*Helideck Misidentification'* procedure. They completed the first six of the eight actions correctly but, considering the circumstances, the commander believed that he was complying with the requirement to '*Remain running on deck unless an immediate take-off is the safest action',* by taking off. Although the helideck was not properly manned, the crew interpreted the radio operator's response that there was nothing to affect their departure as tacit approval of their decision.

In summary, the following factors probably contributed to the commander believing that the Golden Eagle complex was the Buzzard complex:

1. The Golden Eagle complex resembled the Buzzard complex when viewed from the Paragon MSS1 helideck.
2. As they approached the Golden Eagle, the complex opened out and it was seen to be a line of installations, considered similar to the Buzzard complex.
3. The crew had received "deck availability" from the Buzzard HLO.
4. The Ensco 120 helideck was located at the far end of the complex, similar to that expected on the Buzzard complex.

The co-pilot's lack of familiarity with the area may have led to him accepting the assessment of the commander. However, the commander's assumption that the Golden Eagle complex was the Buzzard complex would have been clarified had they used the FMS, as required in the company navigation procedures.

Conclusions

The visual appearance of their next destination, whilst on deck on the Paragon MSS1, was the sole method of identification used by the crew. During the subsequent short flight, the Golden Eagle complex continued to meet their expectation of the appearance of the Buzzard complex. They did not refer to the information provided by the FMS on the range and bearing of the Buzzard complex, as advised in the company's operations manual.

After landing on the Golden Eagle complex (Ensco 120 helideck), which was unmanned, the commander assessed it to be safer to take off immediately, after receiving confirmation from the Ensco Log operator, by radio. This also met a perceived time-pressure to arrive at the Buzzard complex before another inbound helicopter, which was expecting to land there after G-VINL. The flight to the Buzzard complex, and onward to Aberdeen, continued without further incident.

Safety actions

The operator carried out a prompt internal investigation into the incident and identified a number of potential safety actions for internal consideration. The following are of relevance to this report:

'1. *Section 8.3.2 of the* [company] *Operations Manual should be reviewed with regards to using multiple sources of information to confirm navigation.*

2. *All Checklists (normal and abbreviated) should be reviewed in order to incorporate an action to positively select appropriate navigation aids.*

3. *The S92 Operations Manual Final Approach Checklist (abbreviated) should be reviewed with a view to incorporating the words 'HELIDECK NAME….. confirm' as part of the checks.*

4. *The S92 Operations Manual Final Approach Checklist should be reviewed with a view to reordering the checks and making the Landing Point check the final action.*

5. *All offshore Radio Operators should be informed of the significance of landing on the wrong helideck with regards to the fire, crash and rescue cover. They should also be informed of the recommended actions which should be carried out post an unexpected helicopter landing on their helideck.*

6. *All current* [company] *pilots are to be made aware of the significance of landing on the wrong helideck by the means of a Flight Safety Circular using this incident as an example. The Flight Safety Circular should include the potential hazards and state the actions required as per the Operations Manual.*

7. *The training department should review the adequacy of teaching Unintentional Deck landings in both the Initial Line Training Lectures and also in the Command Course Syllabus.'*

ACCIDENT

Aircraft Type and Registration:	Bell 206B Jet Ranger II, G-RAMY	
No & Type of Engines:	1 Allison 250-C20 turboshaft engine	
Year of Manufacture:	1974 (Serial no: 1401)	
Date & Time (UTC):	6 June 2015 at 0805 hrs	
Location:	Near Creg-ny-Baa, Isle of Man	
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 (Helicopter)	
Commander's Age:	48 years	
Commander's Flying Experience:	786 hours (of which 71 hours were on type) Last 90 days - approximately 6 hours Last 28 days - approximately 6 hours	
Information Source:	AAIB Field Investigation	

Summary

The pilot of G-RAMY, a Bell 206B Jet Ranger II, had disembarked his two passengers and lifted off for the return flight, in an area of mountainous terrain. The wind was from 220-230°, gusting to 46 kt and the aircraft was seen to head initially into the wind. It was then seen to turn right onto a north-easterly track and the fuselage was seen to oscillate in roll. The fuselage then rotated in yaw beneath the rotor disc, more than once, and the nose of the helicopter pitched up into the rotor disc, being destroyed as it did so. The fuselage of the helicopter, its rotors and many fragments then fell separately to the ground, where the fuselage impact was not survivable for the pilot.

Examination of the wreckage showed that there had been a catastrophic failure of the helicopter's main rotor mast in flight and there was clear evidence that this had been due to heavy 'mast bumping' contact between the teeter ('static') stops on the main rotor head and the main rotor mast. This was consistent with the observed behaviour of the helicopter, where the pilot appears to have been attempting to control the aircraft in turbulent conditions.

History of the flight

Only limited witness information, and some recorded data, provided evidence relating to the accident flight. The helicopter had flown from a private landing site in Bedfordshire and landed on an unprepared private landing site close to the 'Creg-Ny-Baa'; the engine had been shut down and two passengers disembarked. The Creg-Ny-Baa is a public house on the Mountain Road north-west of Douglas, approximately 2 nm inside the northern edge of the Class D Control Zone surrounding Ronaldsway Airport.

The engine was re-started and the aircraft lifted off at around 0804 and flew on a south-westerly heading for a short distance before turning right onto a north-easterly track towards Windy Corner. No communications from the aircraft were received by Ronaldsway ATC.

One eyewitness gave the most detailed account of the final moments of the flight. He was on his motorcycle driving south along the Mountain Road (A18), north of the accident site (Figure 1). He described seeing the helicopter flying relatively low towards him, at moderate speed, before the fuselage began to oscillate in roll, pendulously, through 'a few tens of degrees' each way. The fuselage then completely rotated in yaw beneath the rotor disc, more than once. The nose of the helicopter then pitched up into the rotor disc, being destroyed as it did so. Another witness described that *'[the helicopter] had a sudden change of direction that occurred in a split second'* just prior to its descent. Other witnesses' recollections differed in detail but were broadly similar. Witnesses estimated the height of the helicopter at between 100 and 300 ft agl prior to the described oscillations.

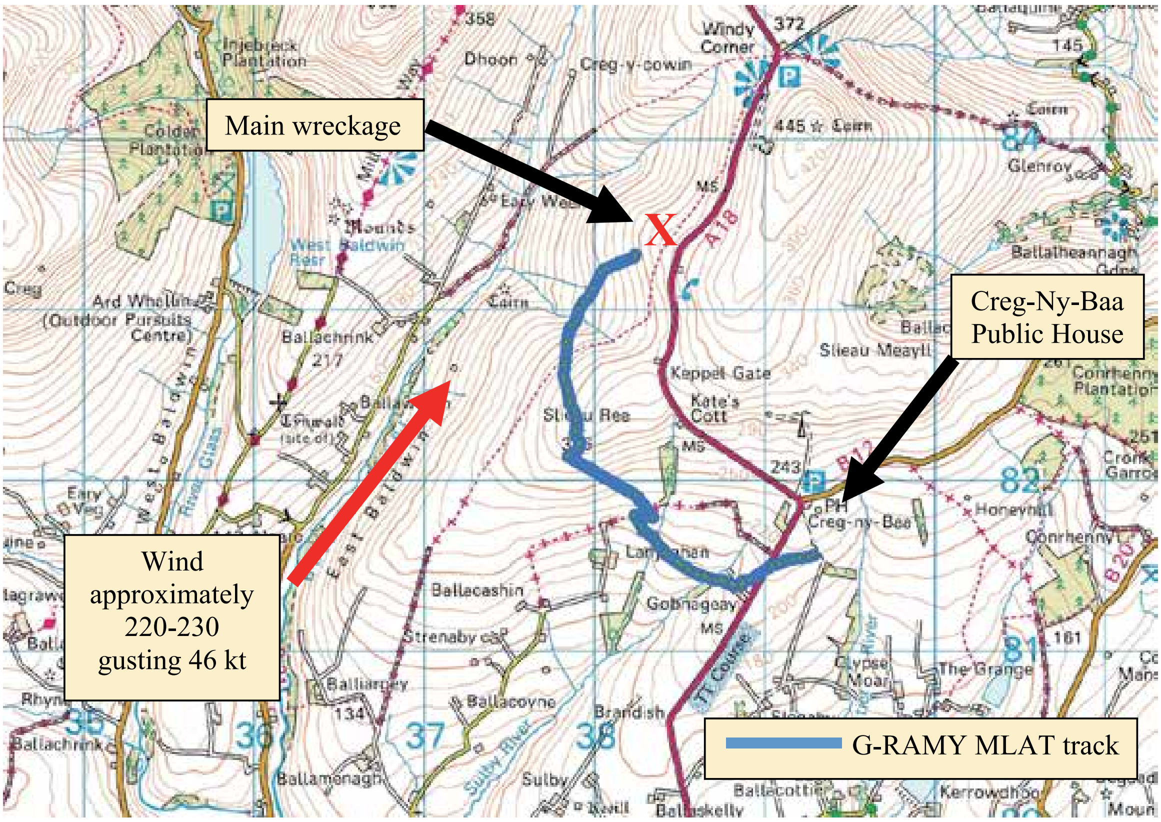


Figure 1

The accident location and recorded multilateration track

The fuselage of the helicopter, its rotors and many fragments then fell separately to the ground, where the fuselage impact was not survivable for the pilot.

Previous flight

The helicopter had departed from a private landing site at Woburn, Bedfordshire, around 0530 hrs with the pilot and two passengers on board and flew towards the Isle of Man, where it then routed towards the Creg-Ny-Baa.

At 0744 hrs, the pilot reported that he had his destination in sight, and the controller passed the Ronaldsway surface wind, which was from 230° at 22 kt, gusting to 33 kt.

The pilot flew an orbit north of Douglas and then carried out a reconnaissance of the landing site. He made an approach into wind and landed the helicopter. The final position of the helicopter recorded by radar was at 0746 hrs as it approached its landing site. The pilot shut the helicopter down and the passengers disembarked. He telephoned the manager at the flying school from which he had hired the helicopter and left a voice message informing her that he had arrived at the Creg-Ny-Baa, before starting the helicopter and lifting off on the accident flight.

Meteorology and terrain

On the day of the accident, weather conditions in England were relatively benign but those affecting the Isle of Man were more challenging.

The Ronaldsway TAF, issued at 0400 hrs, forecast surface wind from 230° at 28 kt gusting to 38 kt, visibility 10 km or more and one or two octas of cloud with a base 2,500 ft aal. The southernmost part of the Isle of Man is relatively flat and low-lying, but complex terrain further north rises to a peak of 2,037 ft amsl approximately 2 nm north of the accident site. The terrain south-west of Creg-Ny-Baa is a valley, which appeared to funnel the wind towards the accident site and the turn in the road (Figure 1) known as Windy Corner.

Data from two anemometer sites elsewhere on the Isle of Man was obtained, which showed stronger winds inland. At one site, Brandywell, 1.5 nm north-north-east of the accident site, the recorded wind direction remained relatively constant around the time of the accident, at around 220-230°, but the speed and gusts were more variable, with the highest gust, 46 kt, recorded at about the time of the accident (Figure 2).

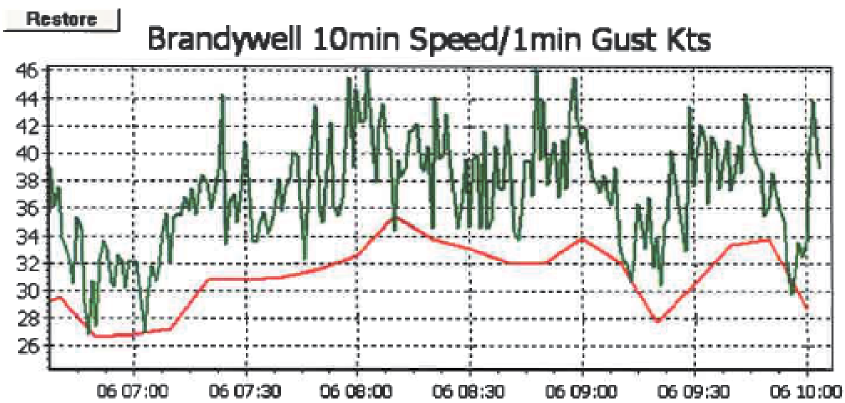


Figure 2

Wind speed and gusts recorded at Brandywell
(timeline is 6 June 0630 hrs to 1010 hrs)

An air ambulance pilot landed an Airbus Helicopters AS355 Ecureuil 2 helicopter close to the accident site shortly after the event. His experience, gained over 25 years including seven years flying air ambulance operations on the Isle of Man, amounted to approximately 8,500 hrs. He commented on the conditions in the area at the time he landed, stating that the visibility was "excellent" and the cloud base was "quite high", but the wind was "extreme" with a speed of 40 kt or higher and associated turbulence. He opined that the conditions were entirely unsuitable for a private pilot with the accident pilot's flying hours.

The pilot

The pilot learnt to fly fixed-wing aircraft before training for a PPL(H) on the Robinson R22 helicopter in 2005, after which he added a type rating on the B206 to his licence. He maintained his proficiency on two single-engined piston aeroplanes and the B206. The flying instructor who carried out his rotary-wing proficiency checks described that he had very good retention of his skills despite not flying very often, and that his general handling skills were "very good". She had discussed 'low-g' and 'mast bumping'[1] with him the day before the accident, mindful that he was an experienced fixed-wing pilot also flying a helicopter; instinctive reactions on the flying controls in fixed-wing aircraft may have undesirable results in rotary-winged aircraft.

The pilot had discussed his plan for the Isle of Man flight with the flying instructor, covering fuel planning, alternate landing sites, and other matters. She considered that he was "properly prepared" for the flight.

His total flying time was 786 hours, of which 126 hours was on helicopters. The pilot held a current Class 2 medical certificate.

Post-mortem examination

A post-mortem examination of the pilot was carried out by a consultant pathologist. He found that the pilot had died of multiple injuries. The pathologist's report noted that:

> *'the severity of the injuries to the left hand, and possibly also the right hand, are very suggestive of the pilot having his left hand, and also possibly his right hand, on the controls of the helicopter at the time of the accident. This implies that the pilot was conscious at the time the injuries were sustained. … There is no suggestion that natural disease played a part in the causation of the accident and the toxicological analyses are also essentially negative.'*

Mountain flying

'Mountain flying' is a term applied to flight operations in mountainous areas, and in the context of training refers to a range of skills which can be taught and learnt. Military rotary-wing pilots receive such training at the conclusion of their flying courses. The EU has made provision for the introduction of mountain ratings in civil helicopter licences, and

Footnote

[1] 'Mast bumping' is described further in this report, under '**Other information**'.

the EASA reflected on this in '*Additional ratings for Part-FCL licence holders RMT.0565 & RMT.0566 (FCL.016) — ISSUE 1— 25/09/2013'*:

> *'When drafting the initial requirements for Part-FCL, Member States' representatives and industry licensing experts proposed to also develop a specific mountain rating for helicopters, but due to time constraints the Agency postponed this task and offered to launch a separate task on this at a later stage.'*

As far as the investigation was able to determine, the pilot of G-RAMY had not received training in mountain flying techniques.

Flight within controlled airspace

Prior to entering or lifting off into Class D controlled airspace, a pilot must obtain clearance from the relevant ATC unit. If radio contact from the landing site was not possible (on account of terrain and the line-of-sight nature of VHF radio communications), a pilot in the circumstances in which G-RAMY lifted off could have obtained permission for his departure before losing contact with the controller on arrival, or telephoned while on the ground for permission to lift off and then established contact with the controller when a suitable height was achieved.

Published advice concerning flight in strong winds and potential 'low-g' conditions

'Allowable wind'

The Bell 206 flight manual states:

> *'OPERATION VS ALLOWABLE WIND*
>
> *Satisfactory stability and control in rearward and sideward flight has been demonstrated for speeds up to and including 20 MPH (17 knots) at all loading conditions; however, this is not to be considered a limiting value as maximum operating wind velocities have not been established.*

'Mountainous terrain'

The EASA published a document on its website entitled *'Techniques for Helicopter Operations in Hilly and Mountainous Terrain'* which stated:

> *'2.5 Turbulence*
>
> *In mountainous areas turbulence is often encountered. This can either be mechanical turbulence (due to the friction of the air over uneven ground at low levels), or thermal turbulence (due an air temperature instability at mid levels). Turbulence affects the behaviour of the aircraft in flight and increases the threat of retreating blade stall, vortex ring and LTE (loss-of-tail-rotor-effectiveness) as the ground and air speed fluctuates. For helicopters equipped with teetering rotor systems there is the additional danger of main rotor mast bumping and rotor / tail strike.'*

'Low-g' conditions and 'mast bumping'

In the USA the FAA publishes the *'Helicopter Flying Handbook'*. In *'Helicopter Emergencies and Hazards'*, in a section titled '*Low-g Conditions and Mast Bumping',* it states:

> *'Low acceleration of gravity (low-g or weightless) maneuvers create specific hazards for helicopters, especially those with semi-rigid main rotor systems because helicopters are primarily designed to be suspended from the main rotor in normal flight with only small variations for positive-g load maneuvers. Since a helicopter low-g maneuver departs from normal flight conditions, it may allow the airframe to exceed the manufacturer's design criteria. A low-g condition could have disastrous results, the best way to prevent it from happening is to avoid the conditions in which it might occur.*
>
> *Low-g conditions are not about the loss of thrust, rather the imbalance of forces. Helicopters are mostly designed to have weight (gravity pulling down to the earth) and lift opposing that force of gravity. Low-g maneuvers occur when this balance is disturbed. An example of this would be placing the helicopter into a very steep dive. At the moment of pushover, the lift and thrust of the rotor is forward, whereas gravity is now vertical or straight down. Since the lift vector is no longer vertical and opposing the gravity (or weight) vector, the fuselage is now affected by the tail rotor thrust below the plane of the main rotor. This tail rotor thrust moment tends to make the helicopter fuselage tilt to the left. Pilots then apply right cyclic inputs to try to correct for the left. Since the main rotor system does not fully support the fuselage at this point, the fuselage continues to roll and the pilot applies more right cyclic until the rotor system strikes the mast (mast bumping), often ending with unnecessary fatal results. In mast bumping, the rotor blade exceeds its flapping limits, causing the main rotor hub to "bump" into the rotor shaft. The main rotor hub's contact with the mast usually becomes more violent with each successive flapping motion. This creates a greater flapping displacement and leads to structural failure of the rotor shaft. Since the mast is hollow, the structural failure manifests itself either as shaft failure with complete separation of the main rotor system from the helicopter or a severely damaged rotor mast.'*

Recorded information

The air navigation service provider on the Isle of Man was in the process of commissioning a new multilateration surveillance system, which records aircraft position approximately every second using the aircraft's transponder. Their staff stated that because the system was not yet commissioned, the accuracy of this recorded data could not be assured.

Position data for G-RAMY's reported takeoff time was provided from this system and is shown in Figure 1. The track began near the Creg-Ny-Baa at 0804:01 hrs. The track then broadly followed that described by eyewitnesses and ended at 0805:18 hrs, approximately 120 m from the location of the main wreckage.

Engineering

Aircraft history

The helicopter was constructed in 1974 and was first registered in the UK in September 1995, having previously been registered in the USA. There were three registered owners before the current one, who acquired the aircraft in November 2000.

Documentation relating to the aircraft included engine and airframe logbooks. The Airworthiness Review Certificate (ARC) was due to expire on 11 February 2016. The most recent maintenance was an Annual Inspection, carried out on 22 May 2015 at 3,067.6 airframe and engine hours, 4,880 engine cycles; this represented the final logbook record. The Technical Log was recovered from the wreckage and recorded three flights since the last inspection, totalling 2.1 hours up to the 5 June, the day before the accident. No technical defects had been recorded.

Accident site details

The helicopter had come down onto a heather and grass covered hillside. The main rotors were found approximately 120 m northwest of the main wreckage, with no other wreckage items in the area in between; it was thus immediately apparent that separation had occurred whilst airborne. A trail of light debris items extended for approximately 500 m from the main wreckage in a north-easterly direction. The items included pieces of transparency from the windscreen and other windows, fragments of cabin interior trim and light pieces of structure from the nose and air intake area. Closer to, and slightly downwind of, the main wreckage were two deep holes in the ground, at the bottom of which were found the battery and a ballast weight; both these items had been in the helicopter nose and the depth to which they had penetrated the earth indicated they had been ejected at altitude.

The fuselage had landed in an inverted attitude with the tail boom almost detached. The tail rotor blades had sustained crushing damage as a result of ground contact but showed little evidence of rotation. The tail rotor driveshaft had separated close to the point where the tail boom joined the fuselage, with evidence of a torsional failure that indicated the shaft was being driven at impact. Despite the fact that the main rotor blades had departed in flight, there was no evidence that they had struck any part of the tail boom.

The top of the cabin, the flying control components on the transmission deck, together with the engine, sustained severe crushing damage as a result of the inverted impact attitude. The engine oil tank had burst open and the filler cap had come off despite the rim of the filler neck appearing un-deformed. Residual oil was present around the tank and an oil film was noted on the horizontal stabiliser.

Examination of the main rotors and rotor head revealed that the rotor mast had failed approximately 3 inches below the rotor head lower surface. It was evident that the mast had failed as a result of bending overload after coming into violent contact with one of the teeter, or static stops; see Figure 3. A deep cut in the ground close to where the rotors were found indicated that the rotor disc had struck the earth in a near-vertical attitude and one blade had broken under the sudden bending and compressive load. Both blades had been extensively scuffed over an area around their mid-span points, with the most severe damage being on the leading edges and undersides.

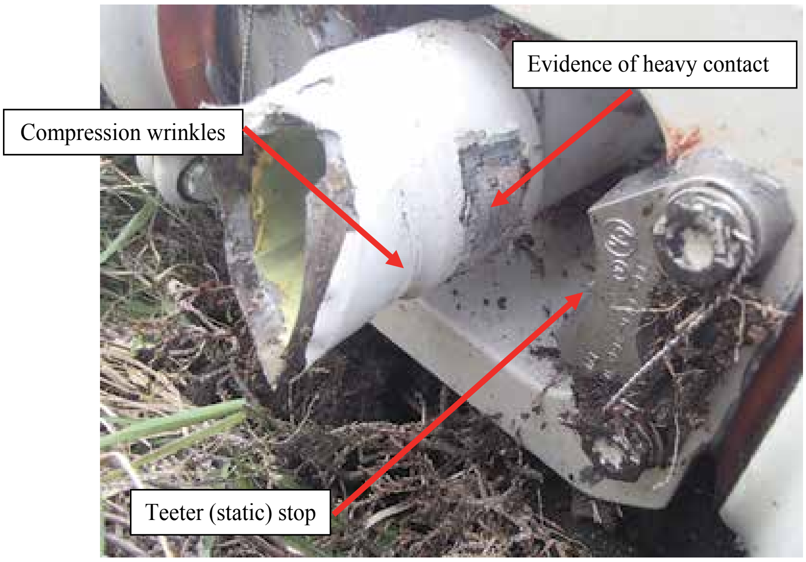


Figure 3

View of fractured mast, showing evidence of contact between mast and teeter ('static') stop

The wreckage was gathered together before being removed from the site; it was then transported to the AAIB's facility at Farnborough for additional examination.

Detailed examination of the wreckage

Airframe – general

The flying control system on the Bell 206 consists of bellcranks, rods and levers, hydraulically boosted by three hydraulic actuators; these transmit the cyclic and collective pitch inputs from the pilot. The tail rotor pitch inputs are operated via control tubes, but with no hydraulic assistance on most aircraft, including G-RAMY. The hydraulic power is provided by a pump mounted on the front of the main rotor gearbox. The pump has an integral fluid reservoir. However, during the detailed wreckage examination the reservoir was not identified, so it was not possible to confirm fluid contents at the time of the accident.

The flying controls were all accounted for and the fractures were attributed to overload. These had occurred during the impact with the ground and the yaw pedals on the left side had been disconnected from the rest of the system. The flight control components located on the cabin roof, forward of the main gearbox, had sustained particularly severe damage as a result of the inverted impact. The piston tubes of the hydraulic servos, also located in this area, had been severely distorted in the impact and there were numerous failures of the associated hydraulic lines, all consistent with overload. The control rods between the servos and the swashplate assembly, which controlled the cyclic and collective main-rotor blade pitch, had broken into a number of sections, again, as a result of the inverted impact. The pitch-change links that had connected the rotating swashplate with the rotor blade pitch horns had each failed at the approximate mid-point; the fractures were attributed to overload and were consistent with the in-flight departure of the rotor blades.

The tail rotor blades had sustained bending damage but were not fractured; the lack of chordwise scuffing suggested low rpm at impact. It was found that an overload failure had occurred in the tail rotor mast (the output shaft from the tail rotor gearbox), close to its junction with the tail rotor hub.

Main rotor blades

As already noted, there were areas of scuffing and paint transfer on the underside of both blades. These areas started approximately 90 and 104 inches from the centre of the hub and were not symmetrical. The paint marks were consistent with the blades having struck the right side of the nose of the helicopter, this conclusion being supported by the observed damage to the structure and that fragments from the nose were recovered from the furthest downwind part of the debris trail. Additional confirmation was provided by the VOR instrument, which had been located in the upper right area of the instrument binnacle but was found some distance from the main wreckage as a result of being struck by a blade, leaving a characteristic indentation in the casing. One blade exhibited a scuffed region that began a relatively short distance, 42 inches, from the hub centre, the result of the blade underside coming into contact with the front of the glassfibre fairing on the cabin roof. The combined information enabled a precise assessment of where the rotor blades had struck the airframe, illustrated in Figure 4.

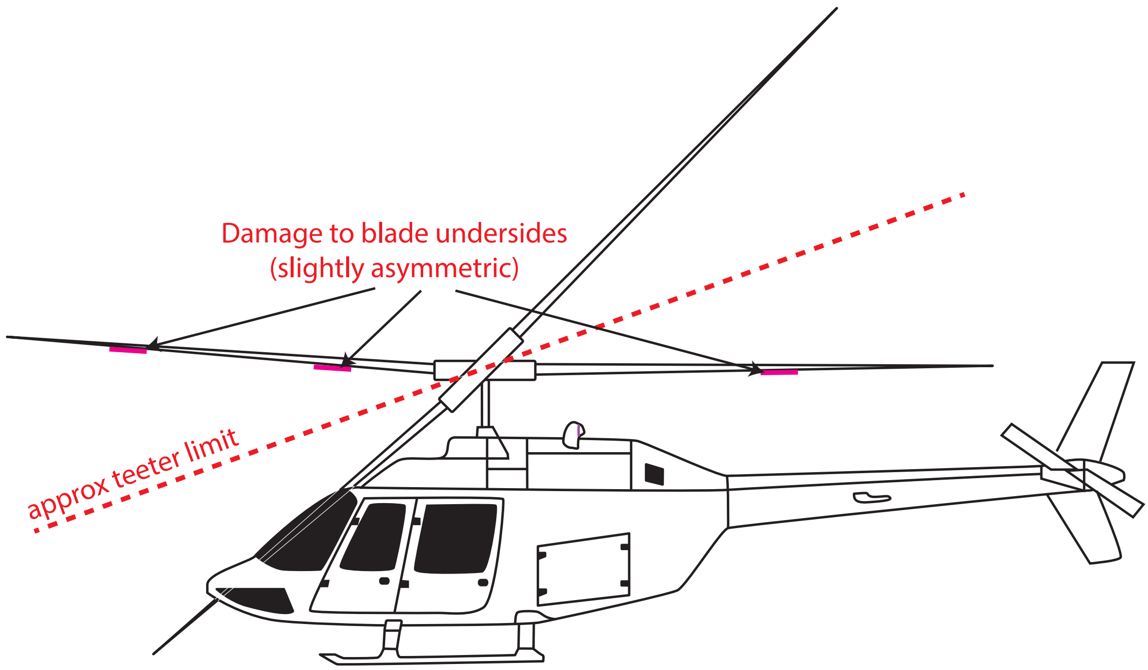


Figure 4

Showing blade strike location on fuselage

The hub assembly had remained intact although it was clear that the static (teeter) stops had come into heavy contact with the mast, such that they applied severe, reverse bending loads in the spanwise plane of the blades. Figure 5 shows the relative angular motion that occurred between the mast and hub.

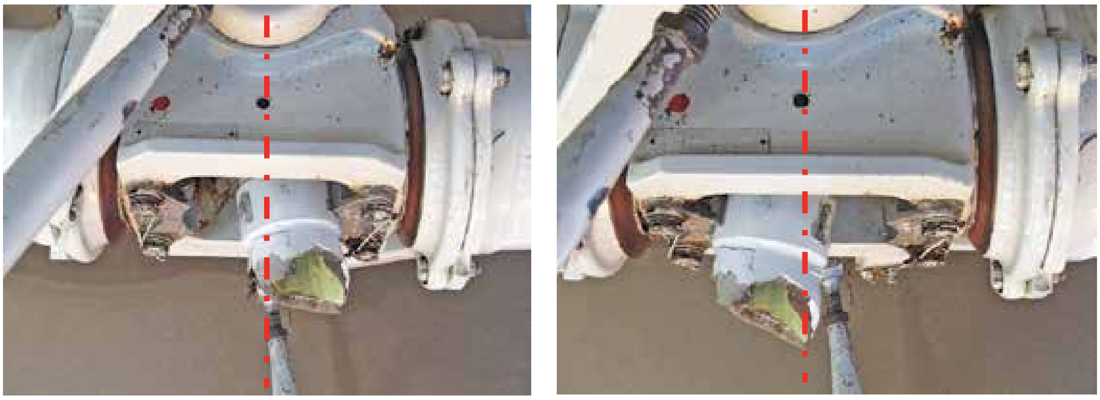


Figure 5

View of hub showing angular movement between hub and mast, resulting in heavy mast contact with teeter stops

The bending loads had been higher in one direction, as can be seen in Figure 5, where the surface of the mast adjacent to the static stop contact displayed compression wrinkles. The mast had become permanently bent in that direction, although the final failure was probably closer to the opposite direction, as evidenced by a shear lip, also visible in Figure 5. This feature, together with the permanent deformation of the mast and the 45° shear plane of most of the fracture face, indicated that the mast failure was the result of bending overload, which, in itself, was characteristic of 'mast bumping'. Such events can involve a large number of bending reversals within a short time. However, in this case, the relatively clean nature of the fracture face, in conjunction with the rotor blades being intact when they separated from the airframe, suggested that the bending failure occurred within one or two revolutions.

Transmission system

The main rotor gearbox had remained attached to the transmission deck although it had been rotated aft as a result of the mast contacting the ground during the inverted impact. Despite this the gearbox was intact with superficial damage to the casing. Manually rotating the input driveshaft caused corresponding rotation of the mast and subsequent removal of the top case revealed the internal components to be in good condition. The gears had remained in mesh and rotated smoothly and freely. No debris was apparent on the magnetic chip detector.

The driveshaft from the engine was in several pieces, as were the drive couplings, parts of which were not recovered. The damage was consistent with shaft misalignment that would have occurred during the impact with the ground. Despite this impact, the freewheel unit was found to function correctly.

A number of fractures were observed in the tail rotor driveshaft, all consistent with impact damage. All the coupling assembly between the shaft segments had remained intact, although there was considerable distortion as a result of shaft misalignment that would have occurred as a result of impact damage to the tailboom. It was also noted that the hanger bearings on the driveshaft rotated freely.

The tail rotor gearbox had remained intact, although the splined connection with the final tailboom driveshaft segment had become disconnected during the impact. The gearbox input shaft could be rotated by hand, which smoothly turned the fractured output shaft (the tail rotor mast). The chip detector was clear of debris, although the gearbox contained very little oil. No reason was established for this.

Engine

The inverted impact had resulted in severe damage to the engine and its controls; however there was no evidence of a pre-impact disconnect of the controls.

The engine was removed from the airframe and taken to a UK overhaul facility and was disassembled in the presence of representatives from the AAIB, engine and helicopter manufacturers.

The external fuel lines had remained secure, with one exception, which was considered the result of impact forces on the fuel pipe. The fuel filter bypass button was found extended but examination of the filter element revealed no contamination and the low-pressure filter was also clear, with the filter bowl full of fuel.

The compressor had sustained severe crushing damage. The first rows of blades in the axial stage were bent against the direction of rotation from contact with the compressor shroud. The impeller stage had been in heavy contact with the shroud, which had sustained significant abrasion damage. It is likely that this resulted in the metal spatter found on the first-stage nozzle shield and there were impact marks, consistent with compressor blade debris, present on all the turbine wheels and nozzles.

There was no evidence of pre-impact damage in any bearings or accessory gears and there was evidence of adequate lubrication. Similarly, there was no evidence of pre-impact damage in the power turbine governor, fuel pump or fuel control unit and the fuel nozzle, when flow-tested, was within the specified requirements.

In summary, the damage observed within the engine was consistent with normal operation, with the evidence of metal spatter and rotational damage indicating that the engine was operating at the time of impact.

Other information

'Mast bumping'

'Mast bumping' occurs when a helicopter's teetering ('static') stops, within the main rotor hub, make contact with the mast, such that it deforms and, in certain circumstances, results in complete failure. The phenomenon is peculiar to two-bladed, teetering head systems, such as fitted to the B206 helicopter. The manufacturer states that:

> *'Mast bumping is a phenomenon that is extremely rare and is associated with 'low-g' manoeuvers or excessive manoeuvring either intentionally or from over-controlling the helicopter.'*

Excessive flapping is required in order for the hub to contact the mast and, according to textbooks on the subject[2], flapping amplitude is increased by:

- Gusty wind conditions
- Sudden attitude changes caused by abrupt cyclic inputs
- Sideways flight at or near the helicopter's maximum allowable speed
- Flight under 'low, zero or negative g' conditions

Of these, 'low-g' is considered to be the most dangerous for mast bumping and can occur as a result of applying forward cyclic control, such as in a push-over manoeuvre or reacting to a sudden up-draught. This results in reduced blade angle of attack and increased induced flow into the rotor disc, which in turn leads to significantly reduced thrust being produced by the main rotor and, as a consequence, can result in low, zero or even negative 'g'. In a zero-thrust condition, the fuselage is no longer directed by the rotor disc and is free to move in any direction. The most significant force acting on it is the tail rotor thrust, generally to the right. Because the thrust line is above the centre of gravity there will be a roll to the right, irrespective of the disc attitude, accompanied by a yaw to the left. On its own, the right roll will reduce the clearance between the hub and the mast and, if left cyclic control is then used in an attempt at correction, it will produce upward flapping in the right side of the disc such that the clearance further reduces to the point that mast-bumping contact occurs. Under normal, 'positive-g', conditions the left cyclic input would have produced a horizontal component of total rotor thrust to the left, creating a moment that would have brought the helicopter back to the required attitude.

Previous 'mast-bumping' event investigated by AAIB

A similar pattern of structural damage was seen in a fatal accident which occurred to an Agusta Bell B206 Jet Ranger, G-SHRR, on 11 August 1997 at Nether Kellet, Lancashire. The helicopter was engaged on a gas pipeline inspection and was cruising at a height of around 600 ft agl at a speed of 80 kt. It was observed to perform an abrupt turn to the right, described as flat or only slightly banked. Shortly afterwards it was seen to roll

Footnote

2 '*Principles of Helicopter Flight'* by W J Wagtendonk and '*The Helicopter Pilot's Guide'* by Steven P Sparrow were referred to in the compilation of this Bulletin report.

rapidly to the left and pitch down. One main rotor blade struck the nose and the aircraft fell to the ground. The weather conditions were generally benign, with a variable surface wind of 5 kt or less. The full report was published in AAIB Bulletin No 4/99, File Reference EW/C97/8/6.

Examination of the wreckage indicated that the aircraft had suffered a severe mast bumping incident, although there was no clear technical reason for the cause. There was evidence of multiple bending load reversals on the mast prior to failure, probably more than had occurred on G-RAMY. However the position of the main rotor blade strikes on the fuselage was virtually identical.

Analysis

The pilot held a valid licence, medical, and type rating, and the aircraft was serviceable for the flight. Although the weather conditions affecting the previous flight, until it neared the Isle of Man, had been benign, conditions on the island were not and strong gusty winds up to 46 kt were affecting the Creg-ny-Baa area. As the aircraft flight manual, FAA handbook, and EASA document stated, strong winds pose a challenge to helicopter operations. In turbulence, mast bumping is a particular hazard. However, there was no wind limit published in the flight manual.

The lift-off occurred within the controlled airspace around Ronaldsway, but without clearance. The choice of a downwind flight path, following the first moments of the flight, might have reflected a desire on the pilot's part to fly out of the controlled airspace promptly.

There was no evidence of pre-impact failure of the flying controls and the examination of the engine indicated that it was operating at the time of the impact with the ground. It is noteworthy that one of the eyewitnesses described the aircraft oscillating from side to side shortly before the main rotor blade sliced into the nose. This is likely to have been an indication of the pilot's control inputs in his attempts to cope with the gusty conditions. A control system failure, such as a disconnect, would be more likely to cause a steady divergence in one direction. The observed oscillatory motion therefore suggests that the system was intact. Thus, the available evidence indicates clearly that the accident occurred as a result of mast bumping, leading to structural failure of the main rotor mast.

The multilateration surveillance system recorded the helicopter travelling approximately downwind, although it was not possible to derive an accurate groundspeed. This agreed with the available witness information. The location of the main wreckage, a short distance upwind from the battery and ballast weight, which had become detached from the aircraft whilst airborne, suggests that there may have been an abrupt change of heading immediately before, or perhaps during, the break-up; this accords with one eyewitness account of the flight. Similar behaviour was observed prior to a similar mast bumping event that occurred, in benign weather conditions, in 1997. The strong wind conditions that prevailed on the day of the G-RAMY accident, which may have intensified as the aircraft progressed higher up the valley, is likely to have caused the pilot to make large control inputs in his attempts to maintain a stable flight path in the turbulent conditions. The strongest recorded gusts of wind coincided with the time of the lift-off and this coincidence may have contributed to the accident. The relatively lighter winds at Rondaldsway, which were passed to the pilot, would not have alerted him to the much stronger winds near the Creg-Ny-Baa.

Appropriate training in mountain flying techniques and the associated hazards could have assisted the pilot in executing the flight successfully, or making a decision not to fly in the challenging wind conditions which prevailed.

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.

INCIDENT

Aircraft Type and Registration:	Agusta AW139, G-CHBY
No & Type of Engines:	2 Pratt & Whitney Canada PT6C-67C turboshaft engines
Year of Manufacture:	2010 (Serial no: 31310)
Date & Time (UTC):	17 April 2015 at 0853 hrs
Location:	Amethyst A1D platform, North Sea
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 10
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	6,981 hours (of which 200 were on type) Last 90 days - 108 hours Last 28 days - 28 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The helicopter was carrying out a scheduled flight, transporting ten passengers to the Normally Unmanned Installation (NUI) A2D, in the Amethyst Field in the Southern North Sea. The flight crew were carrying out line training and inadvertently landed on the NUI A1D, which was a similar platform located 2 nm ahead of the A2D in the direction of flight.

History of the flight

The flight crew comprised two captains, one of whom was a line training captain and was the Pilot Handling (PH). He was occupying the left seat and was the commander of the aircraft. The pilot in the right seat was new to the type and undergoing line training. He was the Pilot Monitoring (PM). This was his fourth line training flight and he had accumulated a total of 21 flying hours on the aircraft type. Both pilots had been aircraft commanders on the S76C++ and had extensive experience of operating in the Southern North Sea and on the route being flown.

The crew reported for duty at 0445 hrs and carried out a three-stop shuttle flight, before returning to Humberside Airport for a rotors-running refuel. Ten passengers were then boarded for a flight to the Amethyst Normally Unmanned Installation (NUI) A2D platform. The route and platform positions are shown below (Figure 1).

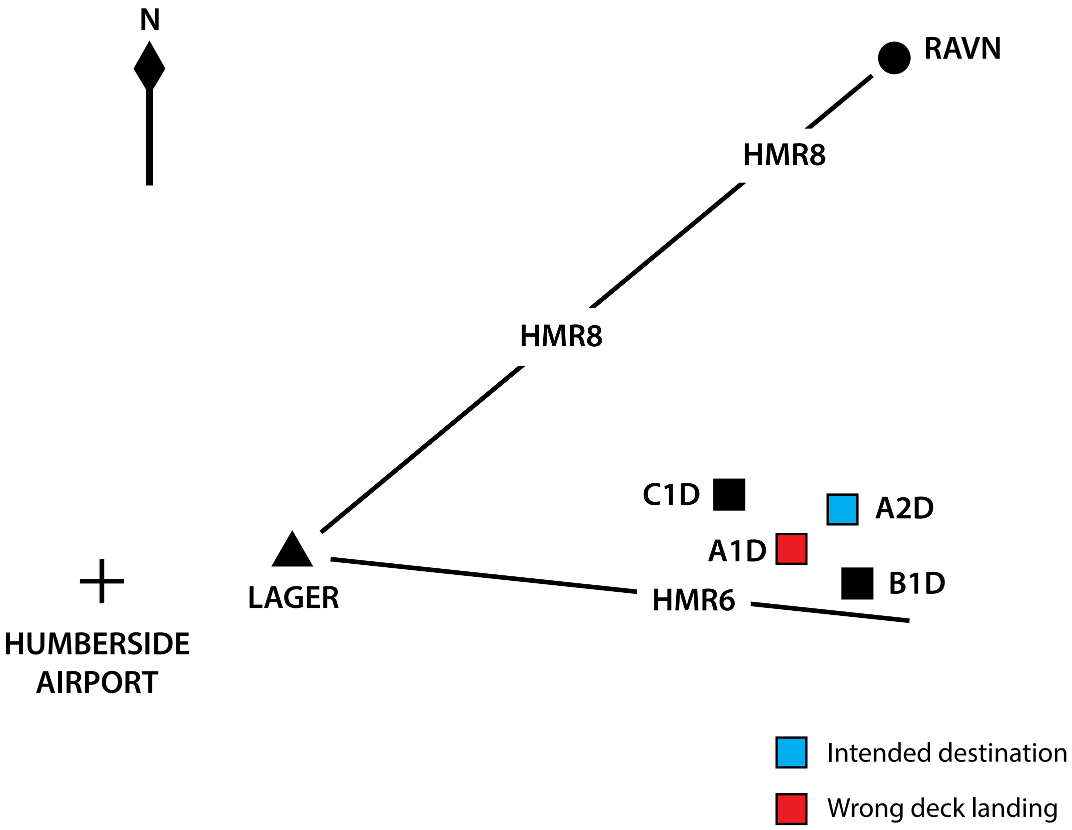


Figure 1

Diagram showing the relative position of the route and the platforms in the Amethyst field.
(Not drawn to scale: HMR = Helicopter Main Route)

A standard departure was flown from Humberside Airport and the helicopter climbed to an altitude of 2,000 ft amsl. It routed to waypoint LAGER, then direct to the Amethyst A2D. The route had been correctly entered into the helicopter's Flight Management System (FMS) and the Auto Flight System was engaged, with the Lateral Navigation (LNAV) mode controlling the helicopter's track.

The crew communicated with Anglia Radar ATC for offshore radar coverage, as standard, and called the Perenco Log operator, who was located on the Revenspurn North Platform (RAVN), some 28 nm north of the Amethyst Field, and the point of contact for the Amethyst A2D. The Log operator advised the crew of the latest weather and the details of the standby vessel in the vicinity of the A2D. (Because of the distance of the Revenspurn from the Amethyst field, low altitude communication was unreliable and the standby vessel ensured that a proper flight-watch could be maintained.) Having established radio contact with the standby vessel, the crew discontinued with the Anglia Radar radio frequency.

The crew were visual with the Amethyst field as they coasted out over the sea and knew the geographical layout of the platforms. The weather in the Amethyst field was good, with a wind of 035°/10 kt, and they carried out the Approach checks before commencing a descent to a height of 400 ft at the usual position. The Auto Flight System remained engaged and the

Altitude Select mode was used for the descent. The Heading mode was used for directional control, replacing the LNAV mode, and the helicopter's heading was adjusted to the right of the direct track, to allow for a turn into wind during the final approach to the platform.

With 2 to 3 nm to go to the platform, level at a height of 400 ft, the Finals checks were completed and the helicopter was turned towards the platform, onto an into wind heading of 060°M. As briefed, the landing was to be carried out by the left seat pilot. The crew then identified the platform ahead as the A2D, whereas it was, in fact, the A1D. The two platforms appear almost identical and it was reported that, given the distance, they may have misread the name plate on the side of the platform, which was a large rectangular yellow board with the name 'AMETHYST A1D' in red letters, mistakenly transposing the number 1 on the name plate for a number 2.

Having made this early identification, the crew then concentrated on flying the approach as part of the training element of the flight. The subsequent landing on the helideck, on which the name is also displayed, was uneventful and the helicopter departed for Humberside after the passengers were clear of the deck.

After the helicopter's departure from the platform, the mistake was identified. The flight crew offered to return and transfer the passengers to the correct platform but, as the A1D was not cleared for AW139 operations, this was not possible and the helicopter returned to Humberside Airport.

Navigation

There are four platforms in the Amethyst field and the position of each platform is stored in the helicopter's FMS as 'user waypoints'. Unless added to the 'active route', 'user waypoints' do not appear on the Primary Flight Display (PFD). With the radar operating, the PFD shows raw radar returns (from the platforms) and inputs from the FMS, only showing the locations of the platforms loaded as 'user waypoints' in the 'active route'. With the A2D loaded as the destination 'user waypoint', the A1D appeared as a raw radar return ahead of it. When the radar was selected to 'standby', as part of the Finals checks, the radar return disappeared and only the A2D 'user waypoint' remained. With the descent complete and the helicopter level at a height of 400 ft, the A2D was visually obscured behind the A1D.

The Amethyst A1D and A2D are virtually identical platforms, with the same size helidecks and identical structures. Part of the Helideck Information Plate for the A1D is shown below (Figure 2). Being similarly orientated, they also have an identical profile when approached from any direction. The one recognisable difference, at the time, was a radar tower on the A1D, which imposed a prohibited landing sector on the deck from 178°M to 208°M. This radar tower did not exist on the A2D. Both helidecks had a D-value[1] of 17.46 metres and could accommodate the size of an AW139, which has a D-value of 16.66 metres. However, only the A2D was cleared for the maximum all-up weight (MAUW) of an AW139.

Footnote

[1] 'D-circle' means a circle, usually hypothetical unless the helideck itself is circular, the diameter of which is the 'D-value' of the largest helicopter the helideck is intended to serve.

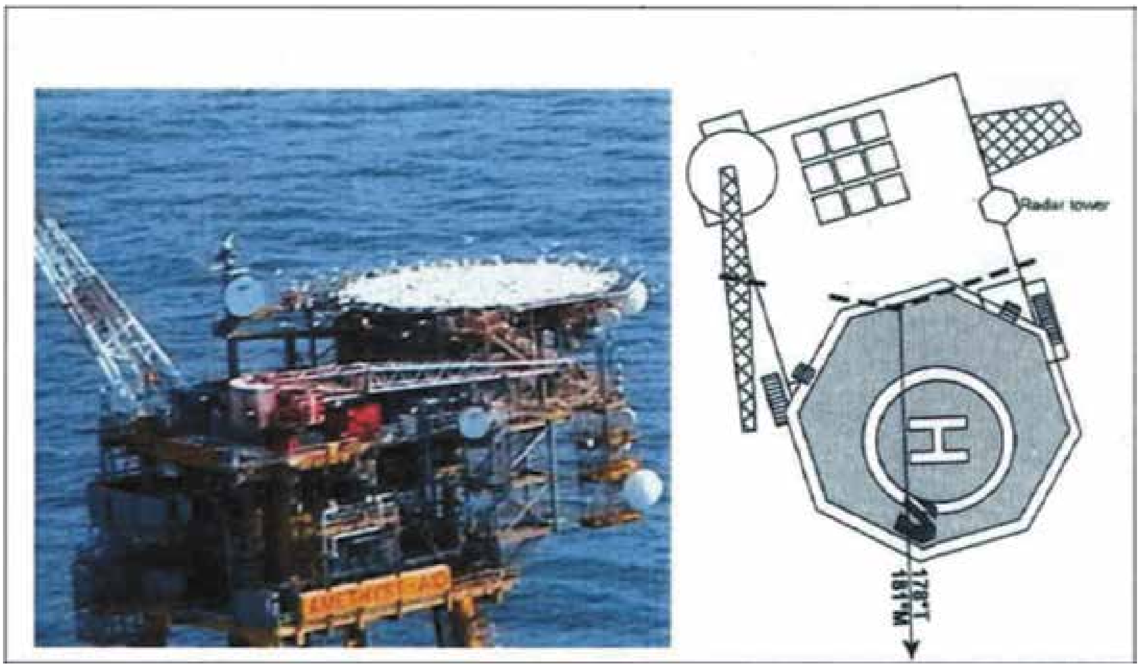


Figure 2

The A1D platform showing the nameplate and helideck layout

Procedures

The expanded Approach and Finals checklists are contained in the operator's Flight Operations Manual, Part B. They provide the detail of what should be checked. During flight, crews use a Normal Operating Procedures (NOP) Single Sheet Checklist, with less detail.

The identification of the destination is item 10, the last item, in the Finals checklist. In the expanded checklist it is set out as follows:

> *'10 DESTINATION……………………………………………….......IDENTIFY/GPS*
>
> - *Identify by visual means and by noting GPS bearing and distance before committing to land. Confirm clearance to land received.'*

The NOP Single Sheet Checklist provides the following only:

> *'10 DESTINATION………………………………………………….IDENTIFY/GPS'*

Both pilots were familiar with the need to confirm the correct destination was being approached, by reading the name plate attached to the platform or the name displayed on the helideck. However, they had recently carried out simulator training which involved offshore operations where names were not always displayed on the simulated vessels or platforms, and identification was confirmed by it being the only helideck programmed for the training.

Discussion

The crew members were properly licensed and qualified to conduct the flight. They were also familiar with the route being flown and the platforms in the Amethyst field. The good weather meant that the platforms were visible to the crew as they coasted out over the sea. The flight progressed normally with the helicopter descending to a height of 400 ft at the usual position, with all checks and radio calls completed. It is not clear at what point the A1D was mistaken for the A2D. Reading the platform's name plate or the name on the helideck was the normal means of identification. It is possible that reading the platform name from a distance may have led to the crew misreading the '1', in A1D, for a '2'.

When the radar was set to standby, as part of the Finals checks, only a single platform waypoint would have been shown on the PFD, and visible ahead was a single platform. This was the A1D which, from the crew's perspective, was obscuring the A2D platform.

At this point, the crew were focussed on flying the final approach, as part of the line training, having earlier 'confirmed' the platform as their destination. The final opportunity to identify the platform was in the final stages of the approach, when the name was displayed on the helideck. However, the mistake was not noticed.

The crew concluded that the wrong deck landing was the result of early identification of the A1D as the A2D, either through not reading the name plate or misreading it. They also considered that a recent intense period of offshore simulator training, where the name on the simulated platforms and vessels was not read, may have been a contributory factor.

SERIOUS INCIDENT

Aircraft Type and Registration:	Cessna 525A, Citationjet CJ2, G-TBEA
No & Type of Engines:	2 Williams International FJ44-2C turbofan engines
Year of Manufacture:	2003 (Serial no: 525A-0191)
Date & Time (UTC):	9 January 2016 at 1807 hrs
Location:	Norwich International Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 3
Injuries:	Crew - None Passengers - None
Nature of Damage:	Landing gear, landing gear doors and under side of aircraft
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	4,190 hours (of which 732 were on type) Last 90 days - 87 hours Last 28 days - 22 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Having backtracked the runway the aircraft turned and lined up for takeoff. The crew believed that the lights they could see ahead were the runway centreline lights. Soon after beginning the takeoff run the left wheel departed the paved surface and onto grass with the aircraft then veering left. The takeoff was rejected.

The aircraft had been lined up with the runway's left edge lights, having not followed the green turning circle taxiway lights to their conclusion.

History of the flight

The aircraft was on a chartered flight from Norwich International Airport to Manchester International Airport. On board were two flight crew and three passengers. The commander was the PF and taxied the aircraft. At the time Runway 27 was in use and was wet. The wind was from 170° at 15 kt, the visibility was in excess of 10 km and it was dark.

After an uneventful start the aircraft was cleared by ATC to taxi from the SaxonAir Apron via Taxiways Echo and Tango to Holding Point Alpha 2. As the aircraft passed Tango the commander incorrectly turned onto Taxiway Charlie. Realising the mistake he stopped the aircraft and the co-pilot informed ATC that they had taken the wrong turning. The aircraft was then re-cleared to Holding Point Charlie Two and then to enter, backtrack, and line up and wait on Runway 27. As the aircraft entered the runway the commander initially followed the runway centreline lights and then the green turning circle taxiway lights on the threshold of Runway 27, to the right (see Figure 1). The aircraft then turned to the left to line up on what the crew believed was the runway centreline, and was cleared for takeoff.

Soon after the aircraft started accelerating it veered rapidly to the left. The commander tried to keep it straight by applying right rudder and differential braking. However, he quickly realised the left wheel was on the grass and aborted the takeoff. As the aircraft decelerated and came to rest it slewed around to the right due to the application of right rudder and wheel brakes.

After the aircraft had stopped the commander shutdown the engines and the co-pilot informed ATC that the aircraft had gone onto the grass. The commander determined that the passengers had not sustained injuries. He then opened the cabin entry door to check for any sign of smoke or fire. As there were none he elected to remain on the aircraft until the RFFS arrived, which they did shortly thereafter.

Aerodrome information

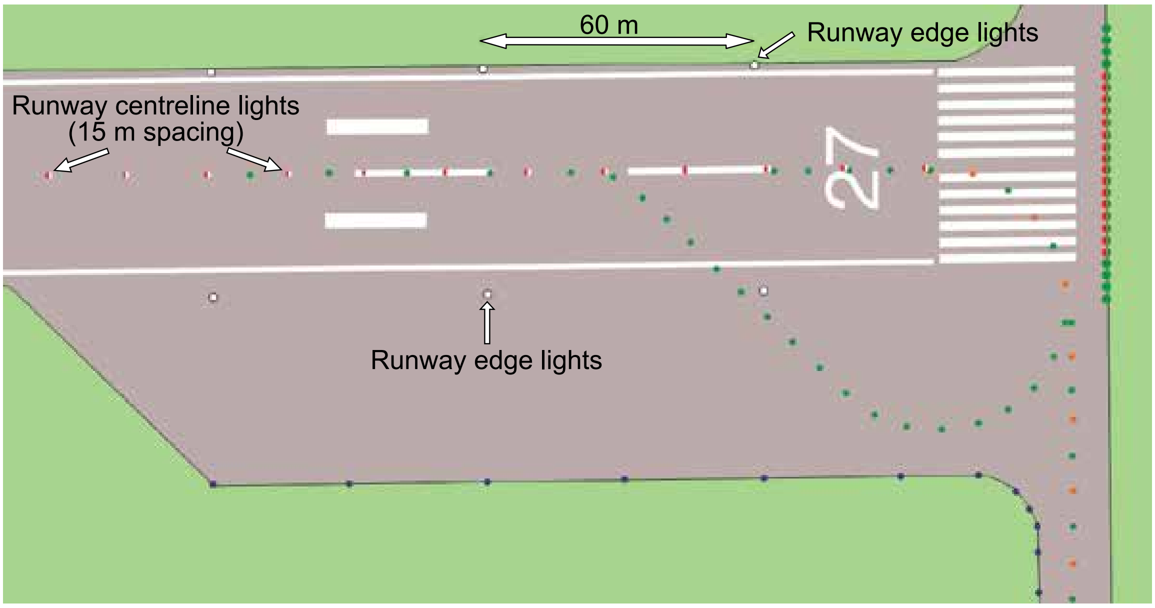


Figure 1

Runway 27 turning circle lights

The incident occurred at night. All lighting on Runway 27 was subsequently checked and found to be functioning normally.

The commercially available chart used by the crew stated the following:

> *'WARNING*
> *At both ends of rwy 09/27 its width is twice that of the associated edge lights due to extra pavement at one side.'*

Crew's comments

The commander stated that he lined the aircraft up with white lights ahead and to the right of the aircraft, believing these were the runway's centreline and right edge lights respectively, thus confirming he was properly aligned with the runway centreline. He does not recall looking deliberately to the left. However at the time he believed "the picture" looked correct.

He believes that he lined the aircraft up with the runway's left edge lights having not followed the green turning circle taxiway lights all the way around, but having "undercut them". Due to the extra pavement parallel to the runway, he did not realise he was lined up on the left edge prior to takeoff.

He added that he always includes the taxi chart in his briefing to the other pilot before requesting taxi clearance, but on this occasion he did not highlight the warning printed on the chart. Additionally he believes that, had he correctly followed the original taxi clearance and lined up via Holding Point Alpha Two, this event is unlikely to have happened.

The co-pilot commented that his attention may have been inside the cockpit too much during the line up and setting of engine thrust. He added that had he been more "heads up" he may have spotted the mistake.

Previous events

The CAA MOR database contained 14 recorded events involving misidentification of runway edge lights as centreline lights. This covered a period from 1982 to 2015 and involved 12 different aircraft types and ten different airfields. Four were investigated by the AAIB:

1. ATR42-300, G-TAWE, at Prestwick on 22/1/2006.
   AAIB reference EW/G2006/01/16
2. Piper PA-34-200T, G-MAIR, at Bristol on 12 December 1996,
   AAIB reference EW/C96/12/3
3. Fokker F27 Mk 200, G-BHMX, at Teeside on 7 December 1990,
   AAIB reference EW/C1186
4. Gulfstream III (G-1159A), N103CD, Biggin Hill Airport, Kent on 24 November 2014,
   AAIB reference EW/C2014/10/01, published in AAIB Bulletin: 12/2015

The report into the accident involving N103CD included the following Safety Recommendation:

> **Safety Recommendation 2015-038**
>
> It is recommended that the International Civil Aviation Organisation [ICAO] initiate the process to develop within Annex 14 Volume 1, '*Aerodrome Design and Operations*', a standard for runway edge lights that would allow pilots to identify them specifically, without reference to other lights or other airfield features.

ICAO responded that Safety Recommendation 2015-038 will be referred to the Aerodrome Design and Operations Panel (ADOP) within ICAO for further study. The next meeting of the relevant ADOP Working Group is scheduled for the first quarter of 2016.

Safety actions

The operator issued an Information Notice, on 15 January 2016, to all its pilots, reminding them that taxiing is a critical part of the flight. It stated in part:

> *'…*
>
> 4. *When cleared to line up brief on what you expect to see.*
> 5. *Once lined up, carry out a gross error and sense check:*
>   a) *Confirm heading indications against runway orientation*
>   b) *Confirm lined up on the centreline ie a dashed and not a solid line.*
>   c) *If at night, compare centreline lights (if applicable), edgeways lights, taxi light etc are what you expect to see in accordance with the plate.*
>
> *…'*

SERIOUS INCIDENT

Aircraft Type and Registration:	Dassault Falcon 20D, G-FRAR
No & Type of Engines:	2 General Electric Co CF700-2D-2 turbofan engines
Year of Manufacture:	1969 (Serial no: 209)
Date & Time (UTC):	21 September 2015 at 1500 hrs
Location:	Lyme Bay, South of Dorset
Type of Flight:	Aerial work
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Minor damage to upper surface of horizontal tailplane
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	8,737 hours (of which 4,423 were on type) Last 90 days - 127 hours Last 28 days - 68 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was on a live-firing target towing mission in Lyme Bay. The target was struck and appeared to become unstable, and the crew elected to cut the cable. Approximately 10 m of cable remained attached to the aircraft. One end became looped around the winch, which is mounted under the wing, and the other end became lodged in the horizontal tailplane. The aircraft landed without further incident.

History of the flight

The aircraft was on a target towing mission for a warship in a notified danger area in Lyme Bay. The aircraft was flying at 1,700 ft amsl and 300 KIAS, with the target trailed 23,000 ft behind and 40 ft above the sea surface.

During a live-firing exercise the crew recognised the target had sustained a hit because the aircraft yawed to the left; this is normal. Immediately afterwards the aircraft lurched to the left, possibly as a result of the target striking the water. The crew detected that that the target was unstable and the Target Tow Operator (TTO), who was monitoring the target, cut the cable by activating the primary cable cutter switch on his control panel. The pilot flying felt a light vibration through the airframe and rudder pedals, and the TTO observed on his camera monitor that a length of cable remained, and that it appeared to be "corkscrewing" behind the aircraft. He believed that the cable was probably striking the tailplane area. The pilot monitoring attempted to cut the cable by activating the secondary cable cutter switch in the cockpit, but this had no effect.

The crew declared an emergency and, after a discussion with ATC, they decided to land on Runway 08 at Bournemouth, as this offered an approach over the least populated area. The aircraft was configured to land with the flaps up, to minimise the risk of the cable fouling the control surfaces on the wing. Shortly after the landing gear was lowered the cable ceased banging against the airframe and the TTO reported: "It's hooked up on something…I think it's the tail." The aircraft landed without further incident.

After the flight the TTO discovered that one end of the 10 m length of cable was lodged between the elevator and the horizontal tailplane, and that there was a loop in the cable that had snagged on the winch (Figures 1 to 4). The cable was removed from the gap between the elevator and the horizontal tailplane; this was a simple task and there was no evidence to suggest that the elevator had not been operating effectively during the incident.

Figure 1

Image of aircraft showing winch and tail plane

Figure 2

Image showing one end of the cable looped around the winch

Figure 3

Image showing damage to the tailplane leading edge

Figure 4

Image showing cable lodged in the gap between the horizontal tailplane and the elevator

Aircraft information

The Falcon 20 is a business jet with a fin-mounted horizontal tailplane, aft mounted engines and swept wings. The elevator is a hydraulically-powered flying control.

The aircraft was fitted with a target towing winch, which was mounted on a pylon under the left wing, at around mid-semi-span. Inside the winch outrigger is a cable cutter; this can be activated from either the cockpit or the TTO's control panel. The target was 2.9 m long and weighed 53 kg.

The TTO sits on the left side of the cabin ahead of the wing leading edge in a rear-facing seat, next to a window. In front of the TTO there is a monitor, which can be selected to view video images from the left or right underwing cameras, and a control panel.

G-FRAK, a similar aircraft to G-FRAR, was the subject of an AAIB Field investigation as a result of a target-towing accident in April 2015. A detailed description of the aircraft, the target towing system and its operation can be found at: https://www.gov.uk/aaib-reports/aaib-investigation-to-dassault-falcon-20d-g-frak

Discussion

It is likely that, after being hit, the damaged target struck the water and its subsequent motion was complex, with a high degree of variation in cable tension. The 10 m section of cable that remained attached had separated at both ends, but had become snagged on the winch because of a loop that had formed after the target detached. There was a cut at the winch end which was likely to have been the result of activating the cable cutter. The break at the trailing end may have been a result of a failure of the cable in overload, after the target was hit and before the cable cutter was activated.

Although the cable became lodged between the elevator and the horizontal tailplane, there was no evidence that it had restricted the operation or the elevator.

The operator is considering a modification to introduce a 'weak-link' in the cable and a modification to the winch to reduce the likelihood of snagging.

SERIOUS INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-JECR
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2006 (Serial no: 4139)
Date & Time (UTC):	3 February 2016 at 1659 hrs
Location:	En route Birmingham to Aberdeen
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 54
Injuries:	Crew - 1 (Minor) Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	34 years
Commander's Flying Experience:	6,700 hours (of which 5,000 were on type) Last 90 days - 163 hours Last 28 days - 54 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries by the AAIB

Synopsis

The aircraft was climbing to Flight Level (FL) 190 but, at FL170, the crew heard a loud noise followed by the sound of rushing air and the commander suspected a rapid loss of cabin pressure. He initiated an emergency descent and both crew donned oxygen masks. The aircraft diverted to Manchester Airport, flying at FL100 with the cabin depressurised, and subsequently made an uneventful landing.

No structural or mechanical faults were found, although two components from the pressurisation system were removed and sent to the manufacturer for investigation.

History of the flight

The aircraft had taken off on a flight from Birmingham to Aberdeen and was climbing to FL190. As it passed over the Pennines at about FL170, the crew heard a 'mechanical' noise followed by a loud and distracting sound of rushing air. The commander quickly diagnosed a cabin pressurisation fault, which he reported was confirmed by the cabin altitude gauge registering a high rate of climb and the PRESSURISATION FAULT light illuminating on the cabin pressurisation overhead panel. However, the crew reported that there was no CABIN PRESSURE warning on the Central Warning Panel and no audio warnings.

The co-pilot, who was the pilot flying (PF), levelled off at FL174 and selected ALT HOLD on the autopilot. Both pilots were experiencing a sensation of light-headedness, tightness of the chest and tingling in their fingers, so the commander ordered the use of oxygen and the co-pilot initiated an emergency descent by setting VERTICAL SPEED on the autopilot with a descent rate of 3,500 fpm. The autopilot was then selected to FL100 and a MAYDAY was declared.

In the passenger cabin, the crew heard neither the mechanical noise nor the sound of rushing air. They did experience the change of aircraft attitude and the change in engine note as the descent was initiated. The Senior Cabin Crew Member (SCCM) quickly contacted the flight crew on the interphone who confirmed that an emergency descent was being carried out. The SCCM ordered the cabin to be secured before both cabin crew members took their seats to await further instructions. Both had experienced their ears 'popping' and one had felt faint and went onto oxygen.

Upon levelling out at FL100, the commander completed the emergency descent check list and consulted the PRESSURISATION FAULT light drill, but instead decided it would be preferable to divert and land as soon as possible. He accordingly completed the check list for unpressurised flight and decided to divert to Manchester. He briefed the cabin crew accordingly and announced his intention to the passengers. The aircraft subsequently landed at Manchester Airport without further incident.

Engineering investigation

The aircraft was inspected on the ground, paying particular attention to the condition of door seals – no defects were found. In accordance with the Fault Isolation Manual procedure, for the PRESSURISATION FAULT light, both the Cabin Pressure Controller module and the Outflow Valve were replaced. The aircraft then underwent a pressurisation check, during which it performed normally, and afterwards returned to service. Analysis of the Flight Data Recorder indicated that a CABIN PRESSURE warning had not been annunciated, which would occur had the cabin altitude risen above 10,400 ft.

The Cabin Pressure Controller module and the Outflow Valve were returned to their manufacturer for strip examination. Testing there showed no defects with the Controller module but the Outflow Valve failed a number of tests and was found to have contamination and wear issues. It is considered that the valve was unserviceable and had been responsible for the depressurisation.

ACCIDENT

Aircraft Type and Registration:	Cessna 172S Skyhawk, G-ENNK
No & Type of Engines:	1 Lycoming IO-360-L2A piston engine
Year of Manufacture:	2000 (Serial no: 172S8538)
Date & Time (UTC):	31 March 2016 at 0606 hrs
Location:	Sherlowe Airstrip, Shropshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Aircraft inverted; probably damaged beyond economic repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	73 years
Commander's Flying Experience:	8,000 hours (of which 1,000 were on type) Last 90 days - 58 hours Last 28 days - 29 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was attempting to take off from Sherlowe airstrip, using grass Runway 15 which is approximately 240 m long. However, he realised that the aircraft was not accelerating quickly enough to reach flying speed as the ground was too soft. He abandoned the takeoff and the aircraft ran off the end of the runway and into a soft, cultivated field where it flipped inverted.

The pilot was uninjured and evacuated the aircraft unaided. He stated that he regularly operated from Sherlowe airstrip and had calculated that Runway 15 gave a 40% margin for soft ground based on the performance figures for a short-field takeoff quoted in the Pilot's Operating Handbook.

The Cessna 172S Pilot's Operating Handbook (POH) shows that, for a short-field takeoff, the minimum ground roll required to lift off from a flat, level and dry paved surface is 186 m at 0ºC ambient temperature and 2,200 lb All-Up Weight. The POH notes that 15% should be added to the ground roll when operating from a dry grass runway which means that the minimum calculated ground roll is 214 m. There was thus a margin of 12% to offset against the soft, damp runway conditions.

The CAA's Safety Sense leaflet 7c '*Aircraft Performance*' contains a paragraph which urges pilots to establish a decision point at which takeoff can be safely abandoned without overrunning if a pilot is not happy with his aircraft's or his engine's performance.

Bulletin Correction

A correction was issued concerning this Bulletin on 14 July 2016 amending the airfield name to Sherlowe, correcting the length of the runway and adding paragraph three. Full details of the correction will be published in the August Bulletin (8/2016).

ACCIDENT

Aircraft Type and Registration:	1) Grumman AA-5 Traveller, G-BASH 2) Cessna 172N Skyhawk, G-BRBI
No & Type of Engines:	1) 1 Lycoming O-320-E2G piston engine 2) 1 Lycoming O-320-H2AD piston engine
Year of Manufacture:	1) 1973 (Serial no: AA5-0319) 2) 1978 (Serial no: 172-69613)
Date & Time (UTC):	2 February 2016 at 1540 hrs
Location:	Popham Airfield, Hampshire
Type of Flight:	1) Private 2) N/A
Persons on Board:	1) Crew - 1 Passengers - None 2) Crew - None Passengers - N/A
Injuries:	1) Crew - None Passengers - N/A 2) Crew - N/A Passengers - N/A
Nature of Damage:	1) Propeller and engine shock-loaded 2) Wing
Commander's Licence:	1) Light Aircraft Pilot's Licence 2) N/A
Commander's Age:	1) 62 years 2) N/A
Commander's Flying Experience:	1) 1,074 hours (of which 600 were on type) Last 90 days - 2 hours Last 28 days - 1 hour 2) N/A hours (of which N/A were on type) Last 90 days - N/A hours Last 28 days - N/A hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot reported that he had made a local flight from Popham in order to maintain currency. The wind was from 260° at 18 kt, gusting to 28 kt, and the grass was wet.

After an uneventful landing on Runway 26 the aircraft vacated the runway and became stuck in soft ground. The pilot called on the radio for assistance but, shortly afterwards, found he was able to continue taxiing. After about 50 m he lost control of the aircraft on a slight downslope. It then swung left and collided with the left wing of a stationary aircraft. The aircraft sustained damage to its propeller and the engine was shock-loaded. The other aircraft's left wing was damaged.

The pilot commented that he had underestimated the effect of the wet grass, downslope and gusty tailwind, adding that the cause was pressure he put on himself to maintain currency.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-161 Cadet, G-BPJS
No & Type of Engines:	1 Lycoming O-320-D3G piston engine
Year of Manufacture:	1988 (Serial no: 2841025)
Date & Time (UTC):	23 February 2016 at 1138 hrs
Location:	Fairoaks Airport, Surrey
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Bent nose landing gear leg
Commander's Licence:	Student pilot
Commander's Age:	41 years
Commander's Flying Experience:	10 hours (of which 10 were on type) Last 90 days - 10 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The student pilot was landing on asphalt Runway 24 at Fairoaks, having performed two previous successful touch-and-goes. His instructor, watching from the control tower, saw the aircraft make an apparently normal touchdown but, when all three wheels were on the ground, it appeared to swing to the right and then to the left before leaving the runway paved surface and coming to a halt on the grass. The reported wind was 330°/6 kt and the runway surface had been dry.

The student reported that he had landed centrally on the runway but had felt that the right wing had been slightly raised. He used the rudder to steer the aircraft to the right but realised that he had over-corrected and now had to use left rudder to compensate. He believes that he may have inadvertently touched the left brake as well, putting the aircraft into a skid and causing it to slide off the runway. Upon examination, it was found that the nose landing gear leg had been bent to the left.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-161 Cherokee Warrior III, G-EHAZ	
No & Type of Engines:	1 Lycoming O-320-D3G piston engine	
Year of Manufacture:	2002 (Serial no: 2842168)	
Date & Time (UTC):	1 April 2016 at 1400 hrs	
Location:	Breighton Aerodrome, North Yorkshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Aircraft severely damaged	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	44 years	
Commander's Flying Experience:	3,639 hours (of which 2,500 were on type) Last 90 days - 305 hours Last 28 days - 67 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot reported that following the takeoff from the grass runway, he intended to conduct a touch-and-go before flying to his home airfield at Kemble. The circuit was flown as normal and after touchdown full power was applied. The aircraft did not seem to accelerate, so the pilot closed the throttle and aborted the takeoff; however he was unable to stop and overan the end of the runway. The aircraft was severely damaged when it subsequently collided with a hedge. The pilot believes that the lack of acceleration might have been due to a possible combination of the soft grass surface and carburettor icing.

ACCIDENT

Aircraft Type and Registration:	Putzer Elster B, G-APVF
No & Type of Engines:	1 Continental Motors Corp O-200-A piston engine
Year of Manufacture:	1959 (Serial no: 6)
Date & Time (UTC):	27 June 2015 at 1500 hrs
Location:	Top Farm Airfield, Cambridgeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Landing gear struts and fuselage attachments
Commander's Licence:	Private Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	67 hours (of which 9 were on type) Last 90 days - not provided Last 28 days - not provided
Information Source:	Aircraft Accident Report Form submitted by the pilot

Whilst landing on Runway 24 at Top Farm Airfield, Cambridgeshire the aircraft touched down heavily, resulting in damage to the landing gear and their attachment points to the fuselage.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna F152, G-BFEK	
No & Type of Engines:	1 Lycoming O-235-L2C piston engine	
Year of Manufacture:	1977 (Serial no: 1442)	
Date & Time (UTC):	2 February 2016 at 1320 hrs	
Location:	Gloucestershire Airport	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Right wing tip, propeller and engine	
Commander's Licence:	Student pilot	
Commander's Age:	53 years	
Commander's Flying Experience:	27 hours (of which 26 were on type) Last 90 days - 14 hours Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

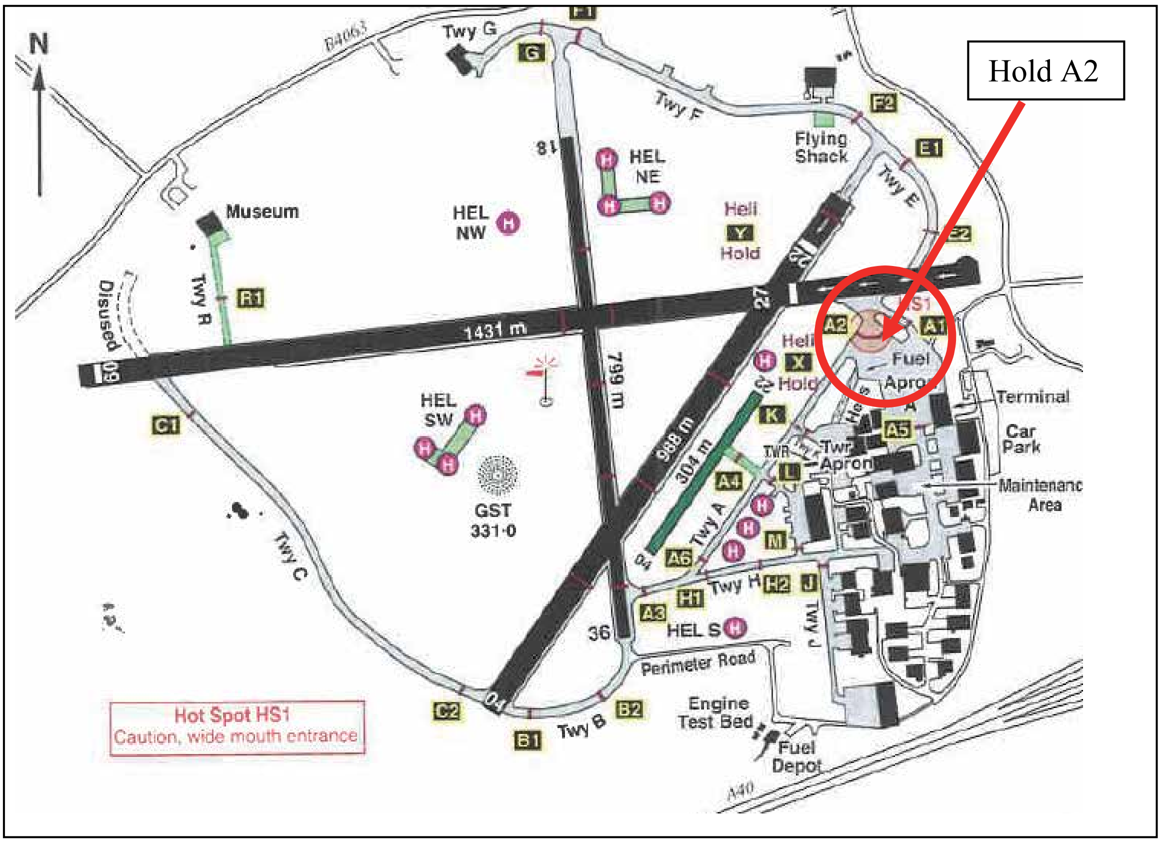
Synopsis

The student pilot of G-BFEK had been instructed to halt his aircraft at a holding point for Runway 27 at Gloucestershire Airport. After waiting for about two minutes, the aircraft suddenly tipped to the right, coming to rest on its right wing tip, right main wheel and propeller. An EC145 helicopter had completed a rotors-running refuel and, after obtaining ATC clearance, was hover taxiing behind the Cessna. Another helicopter, an R44, was on the ground at the nearby Avgas pumps, with rotors running. The EC145 pilot was aware of both the Cessna and R44 and followed a path that gave maximum clearance to both. It was estimated that he passed between two and three rotor diameters from the Cessna. It was concluded that the downwash from the EC145, perhaps exacerbated by the wind speed and direction, caused G-BFEK to tip over.

Circumstances

The pilot of G-BFEK, a Cessna F152, had recently conducted his first solo flight and subsequently had one session of consolidation solo circuits (dual to solo). On the day of the accident the pilot completed three dual circuits, which the instructor assessed were well executed in the slightly turbulent conditions. The wind was steady and at the time of the last landing was 270°/13 kt, which the instructor considered was suitable for solo flight. Accordingly he briefed the student to carry out up to three solo circuits.

After conducting power checks the pilot taxied the aircraft to the holding point at A2 (see Figure 1), to await clearance to enter Runway 27. He positioned the aircraft such that he had vision of any aircraft on final approach. He further stated that he held the flying controls in a position commensurate with the wind direction.



(Courtesy: Pooleys)

Figure 1

Airfield layout, showing location of incident

The pilot was informed of a delay to his takeoff clearance due to a Cessna Citation in the circuit. After approximately 2 minutes and without any warning, the aircraft started to tip, pivoting on its nose and right main wheels, causing the propeller and right wing tip to strike the ground. The pilot looked to his left and saw a yellow helicopter in a low hover immediately upwind of his holding point.

G-BFEK came to rest on the right wheel, wingtip and propeller spinner, following which the pilot transmitted a PAN call informing the tower of his situation. He then shut down the fuel and electrics and, because of the attitude of the aircraft, vacated via the passenger door. Figure 2 shows the aircraft after it had come to rest.

The pilot was in no doubt that his aircraft had been blown over by wake turbulence from a helicopter that had passed behind him. He estimated that the distance between his aircraft and the helicopter was around 20 m.

(Photo: Gloucestershire Airport Ltd)

Figure 2

View of aircraft after the incident

The investigation

The airfield operator conducted an investigation into the event, gathering information from the flying school and the helicopter operator. The ATC R/T recordings were also examined. The helicopter was a Eurocopter EC145, which has a main rotor diameter of 11 m and had just conducted a rotors-running refuel from a bowser, on the large 'H' sign at the refuelling point on the apron. This can be seen in the satellite image at Figure 3. This is located approximately 30 m southeast of the corner of the gasoline fuel pumps installation, which occupies a square area with sides of around 15 m; this can also be seen in Figure 3.

Around the time of the incident a Robinson R44 helicopter was parked on the southwestern corner of the square, after refuelling, and had just started its engine. At 13:18:49 the Tower controller cleared the EC145 to air taxi to its hangar on the southern side of the airfield via Taxiway A. The R44 had also requested clearance to lift from the pumps for departure to the south. The controller observed the EC145 pass to the west of the fuel pumps and turn south and, at 13:19:48 instructed the R44 to follow it. At 13:20:05 the Cessna Citation pilot reported he was going around Runway 27 and additionally reported "AIRCRAFT ON ITS NOSE AT THE HOLDING POINT". At around this time the Approach controller had observed G-BFEK in its predicament and alerted the Tower controller; a ground incident was then declared.

The R44 was on a training detail and at the time the EC145 was requesting taxi clearance, the instructor was focussed on her student's actions. Her aircraft was facing west and, although she was unable to see the EC145, she was aware that it was somewhere behind her. She observed the helicopter pass to the right of her aircraft, north of the fuel pumps, with the main rotor blade tips possibly over the concrete square. She later commented that she was relieved that her own main rotors were up at operating rpm, as the downwash from the EC145 may have caused problems. She was unaware of the incident involving G-BFEK until she heard a radio message from the Tower referring to it.

The EC145 pilot was aware of both G-BFEK and the R44 and maximised his separation from them by taxiing close to the north side of the pumps. He observed no adverse effects on either aircraft and received no information from ATC on the event. He commented that there was a strong westerly wind at the time with gusts of around 25-30 kt.

The approximate track of the EC145 is shown in Figure 3; this was based on an Internet-based Flight Tracking application. Whilst the accuracy cannot be guaranteed it accorded with the reports from all three pilots involved. From this it was concluded that the EC145 had, whilst hover taxiing, passed between two and three rotor diameters from G-BFEK. The Civil Aviation Authority (CAA) Safety Sense Leaflet 15, version C, notes that:

> *'Helicopters with rotors turning create a blast of air outwards in all directions, the strongest effect being downwind. This effect is not so significant when the helicopter with rotors turning is on the ground. It is most severe during hovering and hover taxiing, when the rotors are generating enough lift to support the full weight of the helicopter, and this creates the greatest downwash, out to a distance of approximately three times the rotor diameter.'*

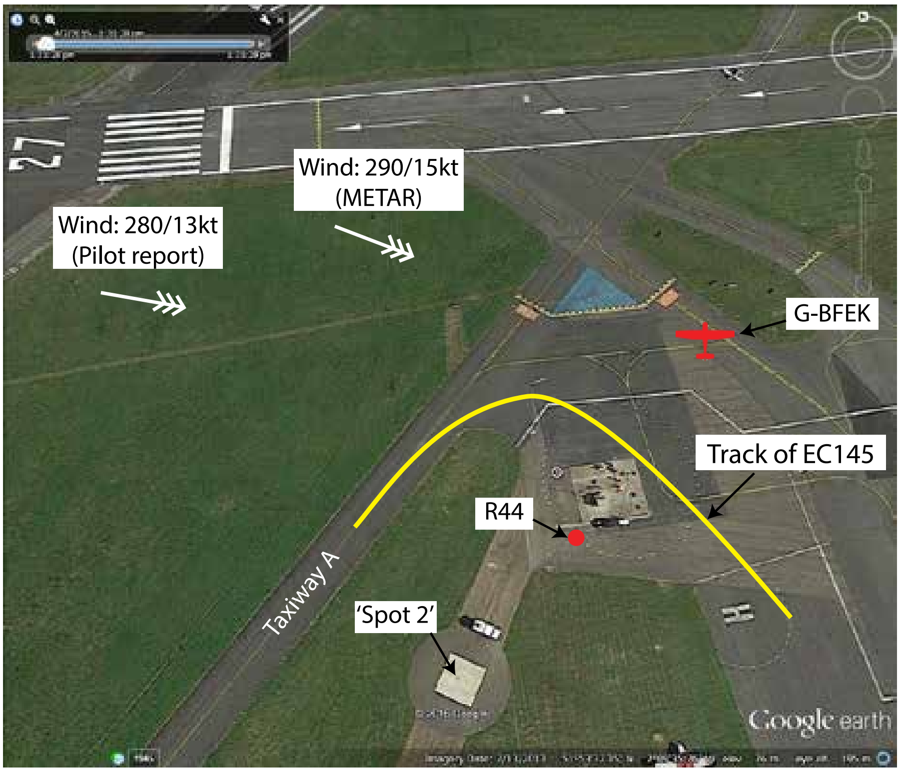


Figure 3

Satellite image showing approximate track of EC145 and positions of Cessna 152, G-BFEK, and the Robinson R44

The airfield operator's report also commented that the position of G-BFEK was typical of many aircraft when, having been given clearance to proceed to A2, they actually stop well short of the holding point.

Weather

The pilot of G-BFEK stated that the wind was 280°/13 kt at the time he reported ready for takeoff, and this is shown in Figure 3. However the METAR for the airfield at 1320 (the time of the accident) gave the wind as 290° at 15 kt (also shown in Figure 3),gusting 25 kt, with a strong wind warning in force. The METARS additionally showed that during the period 1020 to 1420 the wind veered from 240 to 300°.

Safety actions

The incident occurred in a congested part of the airfield that had already been identified as a 'Hot Spot', and is marked as such in Figure 1. The apron and taxiways are used by rotary and fixed wing traffic and, in addition to the two helicopter refuelling points that featured in this event, there are other frequently used helicopter landing sites nearby, including 'Spot 2', shown in Figure 3, and 'Spot 5', which is located just off to the right edge of the image in Figure 3, approximately 55 m from G-BFEK's holding point.

> The airfield operator has implemented a number of changes, including not conducting rotors-running refuelling operations on the large 'H'. Restrictions on the use of Spots 2 and 5 include the stipulation that Spot 5 can only be utilised if there are no fixed wing aircraft holding at A2. There is likely to be a reduction in rotors-running refuelling operations as a result of these measures. Finally, fixed-wing operators will be encouraged to 'move up' at holding points in order to generate increased separation from nearby rotary traffic.

Discussion

The Cessna 152 was tipped over, most probably as a result of the main rotor downwash generated by the EC145 helicopter hover taxiing behind it at a distance of between two and three rotor diameters. The effects of the downwash may have been exacerbated by the wind speed and direction. The METAR indicated that the wind strength had increased during the elapsed time between the pilot's previous landing and the incident, with the direction having veered by around 10°. The gusts increased in strength during this period, although, with reference to Figure 3, the change in the average wind direction would have tended to direct the helicopter downwash to the rear of G-BFEK.

The EC145 helicopter pilot was aware of both G-BFEK and the R44 at the fuel pumps and, after being given clearance to taxi, manoeuvred his own aircraft such that he remained approximately equidistant from the other two. However, G-BEFK was holding short of the stop line at A2 and it could be argued that there was scope for 'moving up' a few metres closer, which would have given increased separation from the EC145. Whether this would have affected the outcome is debatable and would tend to counter the advice given by flying schools to their student pilots, in that attempting to halt on the stop line runs the risk of overshooting it, thus potentially exposing the aircraft to the greater risk of a runway incursion.

If such relatively small distances do have an effect on the incidence of occurrences such as this, it serves to illustrate the problems of mixing rotary and fixed wing operations in a confined area.

The measures adopted by the airfield operator include reducing congestion by restricting or stopping rotors-running refuelling operations from some of the currently used sites. This may have the effect of dispersing such operations to other sites on the airfield and perhaps reducing the overall number. Potential issues here include the reluctance of helicopter operators to significantly increase the number of turbine cycles that would result from shutting down for refuelling, and that RFFS facilities should be within a reasonable distance of sites where rotors-running refuelling is conducted.

ACCIDENT

Aircraft Type and Registration:	Stewart S-51D Mustang, G-CGOI	
No & Type of Engines:	1 Chevrolet V8 ‘Big Block’ piston engine	
Year of Manufacture:	2005 (Serial no: 144)	
Date & Time (UTC):	2 August 2015 at 1515 hrs	
Location:	Benwick, Cambridgeshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Extensive	
Commander’s Licence:	National Private Pilot’s Licence	
Commander’s Age:	72 years	
Commander’s Flying Experience:	1,247 hours (hours on type not declared) Last 90 days - 6 hours Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot and report submitted by witness/aircraft engineer	

Synopsis

The pilot lost directional control of the aircraft shortly after commencing the takeoff run. The aircraft left the side of the runway and became airborne for a short while before rolling to the left. The left wing tip struck the ground and the aircraft yawed left, coming to rest extensively damaged but in an upright attitude. The pilot sustained minor injuries.

History of the flight

The pilot, who was the owner of the aircraft, reported that he was attempting a takeoff from a private grass runway when the accident occurred. The weather was fine, with a light south-westerly wind. The pilot completed his pre-flight checks and lined up for takeoff in a southerly direction. The grass runway was described as being firm, flat and dry, about 800 m long by 30 m wide. The fields to each side of the runway were laid to potato crops, standing about 1 m high.

After the aircraft had travelled about 140 m on its takeoff roll, the pilot realised it was drifting to the left so retarded the throttle to idle and commenced braking. As the aircraft slowed, he applied right rudder to correct the track but the aircraft failed to respond. It struck an earth bank at the left side of the runway and became airborne. It rolled to the left and the left wing struck the ground, causing the aircraft to rotate such that it came to rest in an upright attitude but facing north. In the accident sequence, the engine detached from the firewall and passed down the right side of the aircraft, coming to rest between the wing trailing edge and the horizontal tailplane.

Aircraft information

The aircraft was an all-metal 70% scale replica of the North American P51 Mustang. It was powered by a 500 horsepower (hp) Chevrolet engine and was fitted with a large four-bladed metal variable pitch propeller. It was fitted with electric flaps and trim and a hydraulically powered retractable undercarriage.

The aircraft was imported from the USA by the pilot before being reassembled. A Light Aircraft Association (LAA) Inspector was designated to be the engineer responsible for overseeing the reassembly, and for detailed inspections and flight release. The Permit to Fly was issued in October 2014.

Witness information

The accident was witnessed by the same LAA Inspector who had overseen the application process for the aircraft's Permit to Fly. He had subsequently also had responsibility for supervising maintenance work done by the pilot and for 'signing off' the work. He understood that the aircraft had been flown on several occasions in 2015 but only once before by the pilot owner, that being in the Spring. He understood that, prior to the accident, the aircraft had been flight tested by a pilot experienced on similar complex aircraft. The witness believed that the aircraft was fit for flight and that no unauthorised work had been carried out or faults reported which might have rendered it unfit.

The witness described how, prior to the takeoff attempt, the pilot had reported difficulties turning the aircraft to the right during taxi. Together, they inspected the aircraft but could not identify a reason for the steering issue, which was thought might have been due to surface conditions. The pilot carried out a taxi test and the problem did not seem to occur again.

There was a further delay before takeoff while issues with the communications and navigation equipment were resolved. After this the pilot taxied the aircraft for takeoff, having said that he intended to fly direct to Little Gransden Airfield, 20 nm to the south. The witness saw the aircraft start its takeoff run, but as the tail came up the aircraft swung in yaw and the throttle was cut. The aircraft came to a stop before turning and taxiing back to the start of the runway.

A further takeoff attempt was made. There was an audible rapid application of power and the tail appeared to come up almost immediately after acceleration had begun. The aircraft swung again to the left and, although the swing was stopped, it left the aircraft tracking about 30° to the runway centreline and directly towards the witness's position. The aircraft was then seen to climb at a steep angle (estimated at about 45°) until the nose of the aircraft was at about 30 or 40 ft, at which point it appeared to stall and roll, followed by the left wing striking the ground.

The witness ran to the crash site and alerted the emergency services. He was joined at the site soon after by nearby farm workers, and subsequently by an air ambulance and the other emergency services. The pilot, who was injured but remained conscious, was taken to hospital by the air ambulance.

The witness provided observations he had made of the ground marks left on the runway after the accident. He stated that the tyre marks for the aircraft, which was considerably heavier than other types using the airfield that day, could be identified for both takeoff attempts. The tracks believed to have been associated with the accident were seen to curve toward the left side of the runway but stopped before the edge. The witness concluded from this that the aircraft had either left the ground at this point or was producing sufficient lift to avoid leaving tracks. The first sign of impact in the crops was some 75 m from the last visible tyre tracks.

ACCIDENT

Aircraft Type and Registration:	EV-97 Teameurostar UK, G-CEHL
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2006 (Serial no: 2928)
Date & Time (UTC):	14 February 2016 at 1347 hrs
Location:	Gloucestershire Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose landing gear (NLG) collapsed, damage to propeller and lower fuselage
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	112 hours (of which 107 were on type) Last 90 days - 1 hour Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was taking off from Runway 04 for a local flight. The wind was 050°/14 kt, gusting up to 20 kt. The aircraft was configured with takeoff trim and flaps and full power was applied. It started to lift off at a speed between 55 and 60 mph, but the pilot maintained a flat attitude to gain airspeed. At a height of 20 to 30 ft, the aircraft pitched nose-down suddenly and the nosewheel struck the runway. It bounced back into the air in a nose-high attitude, which the pilot tried to correct by checking forwards on the control column and maintaining full power. This was repeated twice more but, on the third bounce, the aircraft veered to the left off the runway and, on the fourth, the NLG collapsed. It came to a halt on the grass with no injury to the pilot.

The pilot discussed the incident with his Chief Flying Instructor who, although not having witnessed the event, considered that the pilot had probably stalled the aircraft when just out of ground effect. He thought that he had taken off at too low an airspeed for the gusty wind conditions.

ACCIDENT

Aircraft Type and Registration:	Skyranger 582(1), G-CCDW	
No & Type of Engines:	1 Rotax 582/48-2V piston engine	
Year of Manufacture:	2003 (Serial no: BMAA/HB/268)	
Date & Time (UTC):	11 February 2016 at 1124 hrs	
Location:	Old Warden Aerodrome, Bedfordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Minor)	Passengers - 1 (Minor)
Nature of Damage:	Damage to right wing, landing gear, engine and propeller	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	52 years	
Commander's Flying Experience:	67 hours (of which 67 were on type) Last 90 days - 3 hours Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB	

The pilot intended to complete three circuits before flying in the local area.

The first circuit was uneventful but the second landing was fast and heavy and the aircraft bounced twice. The pilot decided to go around but reported that the aircraft would not turn left in response to his control column inputs. He was able to turn right and climbed to avoid trees that were in his path; the standard pattern for Runway 21 is a left circuit.

With speed decreasing and limited roll control the pilot decided to land in a field that was perpendicular to the runway. The right wheel clipped a wall on the approach, spinning the aircraft through 180°. The aircraft was extensively damaged but the pilot and his passenger were able to exit through the doors.

The cause of the control difficulties was not established. The pilot reported that the aircraft had been cut during recovery and was in the process of disposal, thereby precluding the possibility of detailed inspection. He reported that the aircraft had flown normally prior to the heavy landing. Neither the BMAA nor the UK importer were aware of any previous similar occurrences.

Miscellaneous

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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