CONTENTS

SPECIAL BULLETINS

None

COMMERCIAL AIR TRANSPORT

GENERAL AVIATION

CONTENTS (Continued)

SPORT AVIATION / BALLOONS

ADDENDA and CORRECTIONS

(ALL TIMES IN THIS BULLETIN ARE UTC)

INCIDENT

Aircraft Type and Registration:	ATR 42-300, EI-BYO
No & Type of Engines:	2 Pratt and Whitney PW120 turboprop engines
Year of Manufacture:	1989
Date & Time (UTC):	7 October 2008 at 1517 hrs
Location:	22 miles South West of Ronaldsway, Isle of Man
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 17
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:	14,038 hours (of which 2,150 were on type) Last 90 days - 39 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was en-route to the Isle of Man when smoke was detected in the toilet compartment at the rear of the aircraft. The cabin crew member carried out the fire fighting procedure and the smoke cleared. The flight crew advised ATC that they had received an indication of a fire in the cabin, assistance was provided by ATC and the emergency services and the aircraft landed successfully at the Isle of Man. The source of the smoke was found to have been a light fitting in the toilet compartment.

History of the flight

The flight was a scheduled service from Dublin to Ronaldsway, Isle of Man. Shortly after the aircraft started its initial descent from the cruise level, an AFT SMK warning was triggered on the flight deck. The flight crew carried out the '*AFT SMK*' Quick Reference Handbook (QRH) emergency procedure and the commander informed the cabin crew member, at the rear of the aircraft, about the problem.

The cabin crew member checked the area and found that the cargo bay was clear but that there was smoke in the toilet. She discharged one BCF extinguisher into the toilet compartment, closed the door, and reported back to the commander. After about two minutes she checked the toilet compartment again and found that the smoke had cleared. This was also reported back to the flight crew who noted that the AFT SMK warning on the flight deck had extinguished.

The commander contacted Ronaldsway ATC, advised them that a fire warning had activated in the cabin and requested a priority landing. ATC declared a full emergency, alerted both the Aerodrome Rescue and Fire Fighting Service (RFFS) and the external emergency services, and provided the aircraft with vectors for an ILS approach to Runway 26.

The aircraft completed a successful approach and landing on Runway 26, following which it was taxied to the ramp area with the RFFS in attendance. The passengers disembarked normally and the RFFS checked the aircraft for signs of fire. None were found.

The AFT SMK warning on the flight deck is linked to smoke detectors in the aft cargo area and the toilet compartment. Should either of these detectors activate, it will alert the flight crew to a possible fire but will not specify where. However, on the Flight Attendant Panel, located at the rear of the aircraft, the toilet and cargo smoke detectors are indentified with individual warning lights.

The aircraft's QRH has a generic *'SMOKE'* procedure. This includes a recall action for the flight crew to put on oxygen masks and further items to identify the source of the smoke. On another page there are separate procedures for FWD SMK and AFT SMK indications. On this occasion, in the absence of any smell of smoke, the flight crew went directly to the *'AFT SMK'* procedure.

An initial examination by maintenance personnel after the flight revealed that the cover on the illuminated RETURN TO SEAT sign in the toilet had overheated and the bulb filaments had failed. Further investigation took place which showed that the correct bulbs had been fitted and no cause of overheating could be found. The troubleshooting documentation and the unit were then sent to the manufacturer for examination; to date no apparent reason for the smoke has been determined.

ACCIDENT

Aircraft Type and Registration:	Cessna 310Q, N850KF
No & Type of Engines:	2 Continental IO-470-VO piston engines
Year of Manufacture:	1968
Date & Time (UTC):	10 May 2008 at 1030 hrs
Location:	Jersey Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Right wingtip, flap, aileron and propeller damaged
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	1,820 hours (of which 120 were on type) Last 90 days - 64 hours Last 28 days - 38 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent enquiries by the AAIB

Synopsis

The right main landing gear failed to lock down after the landing gear was selected down on the approach to land. This resulted in the failure of a component in the gear retraction/extension mechanism after landing, causing the right gear to partially retract. The right wingtip, flap, aileron and propeller contacted the runway and were damaged. The right gear was subsequently found to be stiff in operation; this was attributed to inadequate lubrication.

History of the flight

When the pilot selected the landing gear down approximately 3.5 miles out on an ILS/DME approach to Jersey Airport, the green gear down and locked light for the right main landing gear failed to illuminate. He initiated a go-around and when safe to do so, replaced the light bulb, but this made no difference. He then attempted to lower the landing gear using the normal and the emergency extension systems and tried sideslipping the aircraft in an attempt to lock the gear down, but these efforts were also unsuccessful. The green light for the right main gear remained off, leading the pilot to conclude that the gear had not locked down.

The pilot then made a visual approach to Runway 27, using full flap and reducing the speed to the blue-line figure. On rounding out, he held off until the stall warning occurred, to achieve a gentle touchdown. He held the aircraft straight, allowing it to slow down without applying the brakes, in the hope that the right main gear, even if not locked down, would continue to support the aircraft. As he moved the mixture controls towards the fully closed position, the right wing started to drop. He then turned off the fuel, electrics and magnetos and once the aircraft had come to a halt, he exited via the main door.

Subsequent examination revealed that a link securing the right leg in the extended position had suffered an overload failure. The damage was consistent with the effect of the component, designed to carry only retraction and extension loads, being subjected to the ground loads due to the failure of the landing gear to reach the locked position. During retraction and extension tests performed following subsequent repairs, considerable stiffness of operation of the right leg was noted. This was attributed to poor lubrication of the pivot bearings. It was concluded that the resulting stiffness in operation had prevented the leg from reaching the fully extended position.

ACCIDENT

Aircraft Type and Registration:	Fokker F27 Mk 500 Friendship, TC-MBG
No & Type of Engines:	2 Rolls-Royce Dart 532-7 turboprop engines
Year of Manufacture:	1971
Date & Time (UTC):	1 February 2008 at 2115 hrs
Location:	Stand 201, Edinburgh Airport
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller, engine and ground power unit severely damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	4,080 hours (of which 2,745 were on type) Last 90 days - 74 hours Last 28 days - 26 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was scheduled to operate a night cargo flight from Edinburgh to Coventry. The weather conditions at Edinburgh Airport were wintry with snowfall, which required the aircraft to be de-iced. Shortly after both engines had been started, the commander signalled to the marshaller to remove the Ground Power Unit (GPU) from the aircraft, which was facing nose out from its stand, down a slight slope. As the marshaller went to assist his colleague to remove the GPU to a safe distance prior to the aircraft taxiing off the stand, the aircraft started to move forward slowly, forcing them to run to safety. The flight crew, who were looking into the cockpit, were unaware that the aircraft was moving. It continued to move forward until its right propeller struck the GPU, causing substantial damage to the GPU, the propeller and the engine. The ground crew were uninjured. No cause as to why the aircraft moved could be positively identified.

History of the flight

TC-MBG was operating from Stand 201 on the North Cargo Apron, at Edinburgh Airport. Its operator had been subcontracted by another operator which regularly uses the airport.

The crew had flown the aircraft together the night before from Coventry to Edinburgh without incident. On that sector and the planned sector back to Coventry, the commander was line training the co-pilot. Due to forecast high winds at Edinburgh, the aircraft was repositioned by the handling agent to face into wind, after the crew had gone off duty. This placed the aircraft pointing nose out of the stand, facing down a slight slope.

Prior to the accident, the crew, which included a travelling company engineer, reported for duty at 1900 hrs for a scheduled departure time of 2050 hrs. A GPU was connected to the right side of the aircraft when they boarded, to provide electrical power prior to engine start. There were two ground handlers in attendance to oversee the departure, a marshaller, who supervised the start up and an assistant. It was dark at the time.

The aircraft was loaded and prepared for departure without event. De-icing was necessary due to falling snow and this caused a delay. When it was completed, the company engineer went outside to inspect the aircraft and collect the de-icing certificate. At approximately 2113 hrs, with the 'Pre-Flight' checklist completed, the co-pilot requested and received start clearance from ATC. The co-pilot then commenced the 'Before Start' checklist. As he called "Parking brake", expecting to hear the commander reply "Set" to confirm the parking brake was on, they were interrupted by the return of the company engineer, who verbally confirmed to the commander that the nosewheel was chocked. The co-pilot's parking brake call-out was not subsequently responded to by the commander. Using hand signals, the commander then requested and received clearance from the marshaller to start the aircraft's engines.

After start, with the engines stabilised, the commander noticed that the main and brake pneumatic system pressures had fallen to 1,600 psi. He advanced the engine power levers in a bid to restore the pressure to 1,800 psi. The commander then signalled to the marshaller to disconnect the GPU, by indicating a 'T' with his hands which he then pulled apart. The co-pilot then started to read out the 'After Start' checklist to the commander. Upon receiving the signal, the marshaller went to assist his colleague remove the GPU to a safe distance. As the marshaller reached the GPU, the aircraft started to move forward slowly. Noticing this, he shouted to his colleague, who was between the GPU and its tug. They both ran clear of the aircraft as it continued to move forward. The flight crew were still progressing through the 'After Start' checklist when they heard a loud 'bang' from the right side of the aircraft. The commander checked the engine instruments and noticed that the right engine had failed. He shut down the left engine and secured the aircraft by pulling both engine shutoff handles, before vacating the aircraft with the company engineer, followed shortly by the co-pilot. Once outside, the commander noticed that there were no chocks in the vicinity of the nosewheel.

The Airport Fire and Rescue Services (AFRS) were on scene within two minutes. Upon arrival they chocked the nosewheel, as no chocks were present and laid a blanket of foam beneath the right engine to cover the leaking fuel.

Edinburgh Airport Managing Director's Directive 04/07

Managing Director's Directive (MDD) 04/07, 'Aircraft Pushback and Powerback Procedures', was issued by Edinburgh Airport on 28 March 2007. It stated the following:

> *'Straight pushbacks are forbidden from any North Cargo Apron stand. If any aircraft on these stands has been previously repositioned to face out (e.g. because of prevailing wind conditions), such aircraft must be pulled off* ***stand and lined up on the taxiway centreline <u>before</u>*** *starting engines.'*

The airport operator commented that MDD's are sent out electronically to the general managers and station managers. They added that it is the responsibility of the handling agents to ensure that all applicable Airport Notices are brought to the attention of any new operator or airline company.

Commander's comments

The commander stated that when he had operated from Edinburgh on the two days before the accident, the aircraft was positioned in the same manner as when the accident happened, ie on the same stand and facing outwards, to avoid high tailwind conditions. On these previous occasions ATC had given clearance for the aircraft to taxi off the stand under its own power. He added that he had not received a copy of MDD 04/07 from his company until 25 February 2008, 24 days after the accident.

The commander stated that the brake pressure gauge was reading approximately 1,800 psi when he checked it during the 'Pre-Flight' checks and that he had checked that the parking brake was set during the 'Before Start' checklist. He added that throughout the 'After Start' checklist they were not aware of the aircraft moving prior to the impact with the GPU.

Marshaller's comments

The marshaller stated that he had supervised TC-MBG when it had operated from the North Cargo apron, facing nose out with the same operating crew, over the preceding two days. He added that on the night of the accident, the aircraft's nosewheel was chocked when he went to assist his colleague to remove the GPU. He stated that he had felt slightly under pressure to expedite the departure as there had been a delay due to the aircraft requiring de-icing.

ATC controller's comments

The ATC controller stated that at the time of the accident, he was working both Tower and Ground frequencies. When TC-MBG called for start clearance, he was initially unsure of its callsign due to the poor quality of the co-pilot's transmission. He was not aware that the aircraft was facing out of the stand and could not see it from his position in the control tower, due to the darkness and the distance involved.

Recorded data

The event was captured on the 30-minute Cockpit Voice Recorder (CVR). The recording indicated that the commander was providing instruction to the co-pilot. Although the flight was delayed awaiting de-icing services, the checklists were completed in an unhurried fashion. The number two engine was started, followed by the number one engine. Sound spectrum analysis of the recording showed that both engines stabilised at around 8,000 rpm. The commander then said "A LITTLE BIT MORE POWER TO CHARGE THE SYSTEM A LITTLE BIT", after which the engine speeds increased to around 8,600 rpm. Approximately 20 seconds later, whilst progressing through the 'After Start' check list, the sounds of the propeller striking the GPU were heard. This started with 0.7 second of propeller strike noise followed by a one second gap, a further one second period of propeller strike noise and then a louder mechanical sound, possibly associated with the engine breaking free of its mounting.

The aircraft is of an age when only a very limited number of parameters were required to be recorded by Flight Data Recorder (FDR). None of these would have assisted with this investigation. No data on the accident were recorded in any case, as the FDR start/stop logic had not yet triggered it to start recording.

The standards for more modern aircraft require more parameters to be recorded. Retrospectively increasing the number of parameters recorded by an FDR on older aircraft may be prohibitively expensive due to interfacing issues. However, current imaging technology potentially provides a cheaper alternative means of capturing a wide array of additional parameters via cockpit image recording. Minimum standards for such equipment have been specified in EUROCAE document ED-112. Work is currently underway to incorporate ED-112 into ICAO requirements and introduce cockpit image recorders. Once such recorders have become available and their associated costs are better understood, consideration should be given to reviewing the cost/safety benefit case for retrofitting them to aircraft with limited FDR parameter sets.

Examination of the accident site

A photograph of the accident scene, taken on the morning after the event, is shown at Figure 1. Chocks had been placed at all the wheels at this stage. According to the AFRS, no chocks were found in the vicinity of any of the wheels on their arrival and they chocked the wheels as a precaution, prior to applying foam. Two chocks were found in the wreckage of the GPU, with one of them being visible in Figure 1.

The power lead was found trailing on the ground between the GPU and the aircraft, although the ground power receptacle door on the aircraft had been closed. Following disconnection, the lead would normally be folded into one of the recessed trays that run the length of each side of the GPU's chassis and which are also

Figure 1

View of the accident site. Position of chock is indicated. The other is located within GPU debris in foreground used to store chocks. The tractor unit was not attached to the GPU; the ground handler was in the process of attaching it at the time of the occurrence. (Note: the handling agent had modified its GPUs in order to reduce the possibility of towing a unit away whilst connected, via its power cable, to the aircraft. As a result the GPU must first be unhitched from the tractor and the towbar raised to a near vertical position. The latter action applies the wheel brakes and operates a mechanical interlock which, by means of an associated relay, allows electrical power to be supplied to the aircraft.)

The GPU had sustained substantial damage as a result of being struck by the right propeller. The sliding portion of the cover, which was made from steel, had been torn from the chassis and thrown some 7-8 metres, landing in front of the outboard section of the aircraft's right wing. The control panel had also been removed from its mountings but had remained attached to the GPU by electrical cables. The roof of the tractor had suffered a glancing blow from a propeller blade and the rear window had received a number of impacts from flying debris.

As can be seen in the photograph, the aircraft's right engine nacelle had almost separated from the wing, remaining attached only by the exhaust duct and some conduits. The instability of the nacelle during the accident sequence and the close proximity of the fuselage had resulted in the propeller striking and breaking an adjacent window transparency.

Description of the aircraft pneumatic system

The F27 aircraft is equipped with a pneumatic system in which pressurised air is used to operate the brakes, nosewheel steering and landing gear. A schematic diagram is presented at Figure 2a and b. It consists of two separate systems, the main and alternate/emergency, each with an air storage bottle and an additional bottle for the main braking system. The entire system is charged by means of compressors, one driven from the accessory gearbox of each engine, or from a compressed air supply via a charging valve in the rear of each engine nacelle. The nominal working pressure is 3,000 psi. The aircraft manufacturer stated that, with both engines running at 10,000 rpm, the charging rate is around 20 minutes per 1,000 psi increase in pressure.

An isolating valve is incorporated within the system, which, as can be seen in Figure 2a, actually consists of two valves, both operated by a single control rod. The purpose of the valve is to preserve stored pressure in the event of a leak elsewhere in the system.

The Maintenance Manual noted that:

'...operational requirements allow a leakage of 100 psi per hour based on pneumatic system capability.'

Fokker F-27 expanded checklist

The operator of TC-MBG stated that they use the aircraft manufacturer's checklists, as published in the Airplane Flight Manual. The 'Pre-Flight' checklist pneumatic system check reads as follows:

'Pneumatic pressures…………………..Check

- *Min for take-off*

MAIN system	*1500 psi*
BRAKE system	*1500 psi*
ALTN system	*2500 psi'*

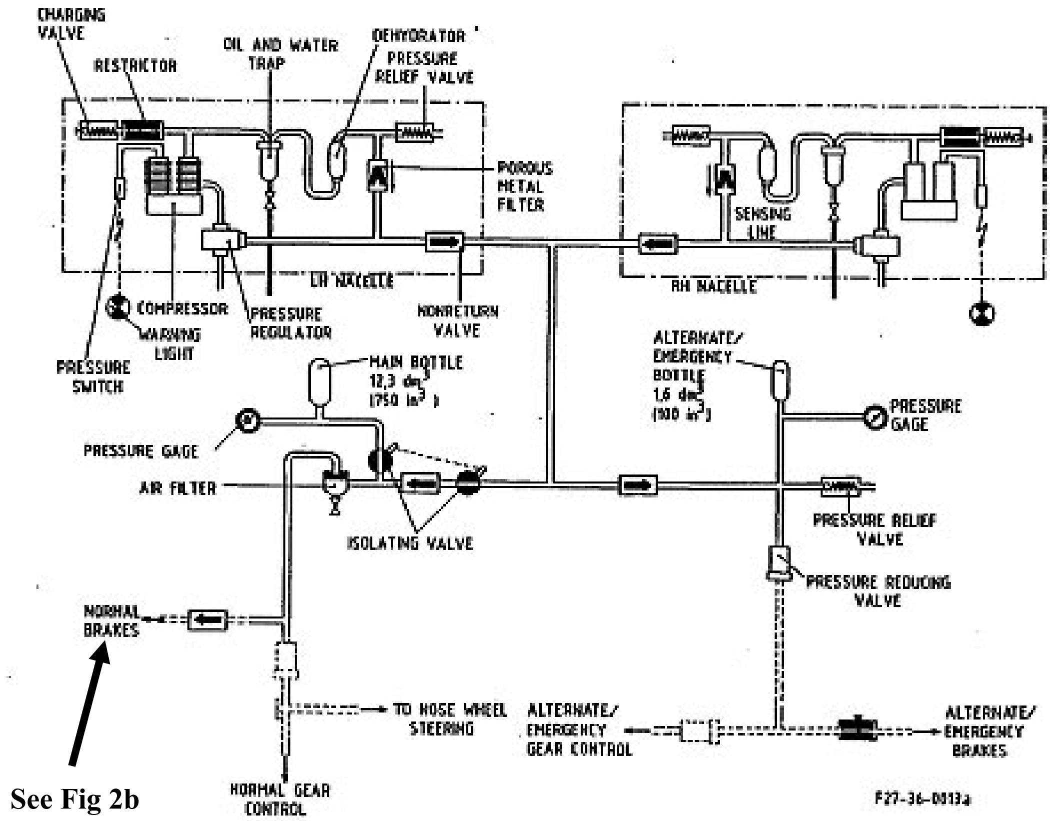


Figure 2a

Pneumatic system schematic diagram

Tests on the braking system

When the aircraft was first examined by the AAIB the brake pressure gauge was indicating close to zero. A charging trolley was obtained and the system was charged to approximately 2,000 psi, with the intention of attaching a tug to the aircraft in order to test the efficacy of the parking brake. However, a tug did not become available for approximately one and a half hours, during which time it was observed that the brake pressure had decayed to around 1,100 psi. Following the arrival of the tug, the system was recharged and, with the tug gently pulling and pushing the aircraft, satisfactory operation of the parking brake was demonstrated.

At a later date, it was decided to conduct a more accurate assessment of the leakage rate of the system. Accordingly, the pneumatic system was charged to 3,000 psi with the isolating valve open. The parking brake was set and the isolating valve closed. One hour later the pressure readings were observed as follows: main 2,800 psi, brakes 2,550 psi, alternate/emergency 3,000 psi. The isolating valve was then opened, thus connecting together the main and brake systems, with the pressure equalising at 2,700 psi; the alternate/ emergency system remained at 3,000 psi.

Forces acting on the aircraft

The accident occurred shortly after the engines were accelerated beyond 8,000 rpm. Information from the propeller manufacturer indicated that the propeller blades would remain at the zero angle pitch stop until around 13,000 engine rpm, with the result that the total thrust from both propellers in the prevailing conditions of 0°C and 6 kt headwind was only of the order of 55 kg force.

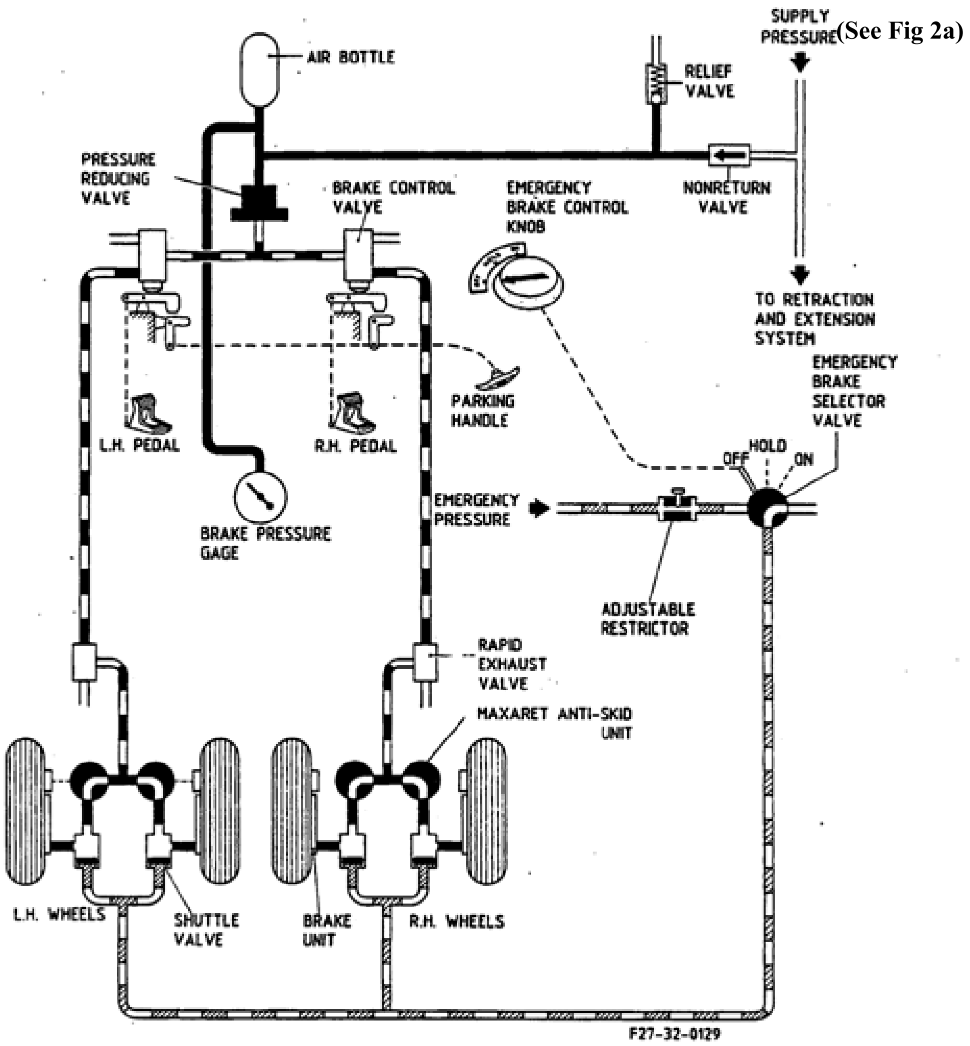


Figure 2b

Brake system schematic diagram

The slope of the hard standing where the aircraft was parked was approximately 1.5%. The aircraft was facing down the slope, with the result that the component of the aircraft weight of around 17.5 tonnes acting down the slope was some 260 kg force.

The only other force contributing to the forward movement of the aircraft was the exhaust efflux from the engines, but the aircraft manufacturer indicated that this force would have been "negligible".

Analysis

There are three unresolved issues surrounding this accident. The first concerns whether the aircraft was, in fact, chocked when it began to move. The commander stated that he signalled to the ground crew to remove the GPU and not the chocks and the marshaller stated he did not remove them at this time. According to the AFRS, no chocks were seen in the vicinity of the nosewheel when they arrived at the scene, although two were found in the wreckage of the GPU. The degree of interference with the debris following the accident cannot be established with certainty, so the reported absence of chocks does not necessarily mean that they were absent at the time of the event.

The second issue is whether the parking brake was set. The crew could be heard going through the 'Before Start' checklist on the CVR, but, as a result of an interruption from the travelling engineer, there was no verbal response to the challenge "Parking brake set". Nevertheless, the commander stated that he had set the brake correctly and no comment was heard on the CVR to indicate that the parking brake was not set, or reset, after the impact.

The third issue concerns the amount of leakage in the aircraft pneumatic system and the likely brake pressure available immediately prior to the accident. Subsequent tests showed that the leak rates for the brake and main systems were respectively 450 and 200 psi/hr. These values clearly exceeded the Maintenance Manual limit of 100 psi/hr, although it is possible that the pneumatic pipes within the right engine nacelle were subjected to a series of shocks and vibrations during the accident, resulting in the exacerbation of existing leaks or the generation of new ones.

Pneumatic system leaks can be expected on a 37-year-old aircraft such as this, but even with minimal leakage, the charging system (which is capable of generating 1,000 psi increase every 20 minutes at 10,000 rpm) could struggle to maintain adequate pressure in the event of a long taxi with frequent brake and steering applications. The alternate/emergency system is available for occasions when brake pressure falls below the minimum value, although it would not normally be used when starting the aircraft.

If it is assumed that the aircraft arrived on the stand earlier in the day with the system fully topped up at 3,000 psi, it is likely that this pressure would have almost entirely dissipated, with the as-found leak rate, during the 15 hours or so the aircraft was parked. Furthermore, the aircraft was moved once during the day, using a tug, in order to position it facing in the direction of forecast high winds. This would have involved at least one parking brake release/set cycle, which would have further reduced the stored pressure. The crew reported observing a brake pressure of 1,800 psi when they boarded the aircraft prior to the accident, which would suggest that the leak rate may have been considerably less than the subsequent tests indicated. However, if the pressure had been observed to be low, the crew had the option of summoning a charging trolley, and, moreover, would have had the time to do so whilst awaiting the de-icing vehicle. Despite the delay, the CVR indicated that the checklists were being worked through in an unhurried manner, with no evidence to suggest an intention to make up for lost time with a rushed departure. Thus, lack of system pressure is perhaps the least likely of the possible scenarios.

Of the forces acting on the aircraft causing it to move forward unexpectedly, gravity would have been the most significant, with a small contribution from the propeller thrust (assuming the propellers were at their ground fine settings) and a smaller contribution from the jet efflux from the engines.

The contracted operator and the subcontracted/aircraft operator had not received a copy of MDD 04/07 prior to the accident and the flight crew of TC-MBG had been given approval to self-manoeuvre the aircraft off the North Cargo Apron on several occasions prior to the accident, contrary to the instructions in the MDD. Had these instructions been followed, the accident is unlikely to have occurred. This is due to the fact that once the aircraft had been towed onto the taxiway centreline, the fall of the taxiway would have been laterally across the aircraft, so that the component of gravitational force would have acted sideways, instead of forwards. Even if the aircraft were not restrained with the brakes or chocks, it is unlikely to have moved.

Handling agent's actions

A representative for the handling agent stated that they have several procedures in place to audit the performance of their ground crew both internally and externally, covertly as well as overtly. These processes are formally recorded and actions are taken to address any deficiencies found.

The handling agent had assumed that the airport operator sent MDDs to operators directly, but this accident showed that this was clearly not the case. As a result, the handling agent is introducing a formal procedure to ensure that in future all MDDs are sent to aircraft operators.

Conclusion

The aircraft moved forward inadvertently after engine start, causing its right propeller to strike a GPU. Possible explanations include that the parking brake was not set, the chocks had slipped from the nosewheel, or the chocks were removed prematurely. There was insufficient evidence to determine which of these scenarios was the most likely.

Contributory factors were: the aircraft was facing down a slight downslope, the ramp was slippery due to the weather conditions and the flight crew increased engine speed to top up the pneumatic system pressure. The airport operator's instructions contained in MDD 04/07 required aircraft facing nose-out on North Cargo Apron stands to be towed onto the taxiway centreline, prior to starting engines. Had these instructions been complied with, the accident would probably have been avoided.

ACCIDENT

Aircraft Type and Registration:	Pilatus Britten Norman BN2A 26 Islander, VP-AAG
No & Type of Engines:	2 x Lycoming IO-540-E4C5 piston engines
Year of Manufacture:	1969
Date & Time (UTC):	2 February 2008 at 1420 hrs
Location:	Wallblake International Airport, Anguilla
Type of Flight:	Commercial Air Transport
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - 1 (Minor) Passengers - 2 (Minor)
Nature of Damage:	Substantial
Commander's Licence:	Air Transport Pilot's Licence issued by the FAA
Commander's Age:	41 years
Commander's Flying Experience:	4,217 hours (of which 693 were on type) Last 90 days - not reported Last 28 days - 17 hours
Information Source:	Aircraft Accident Report produced by the British Virgin Islands office of Air Safety Support International

Synopsis

The aileron gust lock was not removed prior to flight, resulting in loss of control after takeoff. Distracted by efforts to accommodate a non-revenue passenger on this cargo flight, the pilot did not complete a pre-flight check or check the full and free movement of the flight controls before takeoff.

History of the flight

The commander intended to fly the aircraft from Anguilla Wallblake International Airport (AXA) to the neighbouring island of St Maarten (SXM) to await cargo inbound on another flight. The cabin of the aircraft was configured for cargo operations with no passenger seats fitted, as the only other planned occupant was the operator's Chief Engineer, who would be sitting beside the commander in the right hand seat. However, the commander asked the operator if he could take a family member with him to SXM. The operator agreed and an extra seat was fitted. Witnesses stated that the commander appeared "rushed" prior to departure.

The commander stated that he partially carried out the normal pre-flight inspection. He then started the engines. Before taxiing he realised that the nose landing gear chocks were still in place so he shut down the left hand engine, removed and stowed the chocks and then restarted the left engine.

The aircraft took off from Runway 10 at 1415 hrs. At between 100 ft and 150 ft the commander initiated a left turn but after some initial movement the ailerons jammed. When he discovered that he was unable to straighten the ailerons he attempted to return to land on Runway 10. The other flight controls did not appear to be restricted.

With the ailerons jammed, the aircraft continued to turn to the left, losing altitude as it flew over a settlement to the north of the aerodrome, until pointed directly at the Air Traffic Control tower, causing the Air Traffic Control Officer (ATCO) to abandon the tower. The commander judged that the aircraft was too fast and high to attempt a landing and therefore initiated a go-around, applying full power. He continued the left turn, losing height and speed to position the aircraft for another approach but, as the aircraft descended over the northern edge of the runway, its left wing struck the perimeter fence.

On impact the aircraft spun about its vertical axis with its wings level and continued sliding sideways on its right side for approximately 80 ft before coming to rest facing north-west. The commander made a radio call to inform ATC that everyone on board was safe. The aircraft was substantially damaged but there was no fire or obvious fuel leakage and no serious injuries to the three occupants. On vacating the aircraft the commander noticed that the left aileron gust lock was still in place between the inboard section of the aileron and the fixed trailing edge of the wing.

Aircraft examination

Examination of the left aileron and trailing edge revealed damage that was inconsistent with the impact sequence, indicating that the aileron and trailing edge had been deformed by an external object. There were no indications of an internal defect that would have contributed to jamming of the aileron. A review of the technical logbook and previous aircraft scheduled maintenance work pack covering the previous 12 months did not reveal any irregularities.

Further inspection of the aileron gust lock revealed that it was not the type supplied by the aircraft manufacturer, which comprises two plates that clamp the aileron from above and below to prevent movement. The gust lock in use was a triangular metal cap positioned over the trailing edges of the wing and aileron and secured with a bungee cord. A hood on the opposite end of the bungee cord formed the pitot/static head cover. As the aileron gust lock had remained in place, so had the pitot/static cover, rendering the altitude, airspeed and rate of climb instruments unreliable. The aircraft manufacturer supplies a separate pitot/static cover.

Conclusions

The commander was probably distracted from his normal duties whilst arranging additional seating to accommodate the second passenger. He did not complete the requisite pre-flight check or the subsequent check of full and free movement of the flight controls, either of which would have revealed an obstruction to proper operation of the ailerons.

Overseas Territories Report

Please note that a more comprehensive report, produced for the Governor of Anguilla, by Air Safety Support International, is available from:

> Governor's Office, Old Ta, PO Box 60, The Valley,
> Anguilla AI-2640, West Indies

All accidents and serious incidents that occur in the United Kingdom Overseas Territories are now investigated directly by the AAIB and a full report published by the AAIB.

INCIDENT

Aircraft Type and Registration:	AS332L2 Super Puma, G-CHCF
No & Type of Engines:	2 Turbomeca MAKILA 1A2 turboshaft engines
Year of Manufacture:	2001
Date & Time (UTC):	20 November 2007 at 2057 hrs
Location:	Aberdeen Airport, Scotland
Type of Flight:	Training
Persons on Board:	Crew - 3 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50
Commander's Flying Experience:	13,199 hours (of which 2,040 were on type) Last 90 days - 118 hours Last 28 days - 37 hours
Information Source:	AAIB Field Investigation

Synopsis

A Training Captain was conducting an Operational Proficiency Check (OPC); the pilot under training was required to demonstrate a clear area rejected takeoff. The helicopter was equipped with a Training Idle System (TIS) which was in use to simulate a failure of the left engine. The helicopter took off along Runway 16 at Aberdeen; at about 28 kt the commander simulated a failure of the left engine and the takeoff was rejected. The pilot flared the helicopter to reduce speed and descended towards the runway. As the collective control lever was raised to reduce the rate of descent, the overspeed protection system shut down the right engine. Main rotor rpm (N_r) decayed rapidly and the helicopter touched down firmly before rrpm could be restored.

The right engine freewheel unit had failed causing that engine to overspeed; this was contained by the overspeed protection system shutting down the engine.

Four Safety Recommendations are made.

History of the flight

The purpose of the flight was to conduct standardisation training and OPCs on two pilots who had recently completed their type training and Licence Skills Test. The weather was good with a surface wind from 140° at 5 kt, visibility was in excess of 10 km with a few clouds at 3,700 ft, the temperature was +7°C and the QNH 1010 hPa. The intention was to commence the training by carrying out a maximum performance rejected takeoff. The flight had been fully briefed and the performance, weight and balance calculations had been completed prior to departure. The helicopter performance calculations were based on the training weights permitted in the Flight Manual Supplement relating to the engine TIS. The TIS allows the commander to simulate an engine failure on either engine by reducing its power to a training idle condition. The engine not selected to training idle powers the rotor system and is referred to in this report as the operating engine. Should the operating engine fail, the engine at training idle automatically accelerates to power the rotors.

Following a normal start on both engines a freewheel check was carried out and both freewheel units operated normally. The TIS was tested in accordance with the operator's Standard Operating Procedures (SOPs) and found to be fully serviceable. The helicopter was ground taxied to Runway 16, which is 1,829 m long, 46 m wide and has an asphalt surface. Following two demonstrations of an engine failure in the hover, using the TIS, the commander then demonstrated the rejected takeoff profile using a Takeoff Decision Point (TDP) of 60 kt. Following this demonstration, the helicopter stopped on the runway approximately half way along its length and was then ground taxied back to the threshold of Runway 16.

A rejected takeoff was then flown by one of the pilots under training using the same TDP and, as before, approximately half the length of the runway was used. Since there was sufficient runway length remaining, the pilot repeated the exercise. The helicopter was initially established in a 10 ft hover and then accelerated along the runway. As the airspeed passed through 28 kt at a height of 39 ft, the commander simulated a failure of the left engine using the TIS. The pilot lowered the collective control lever and pitched the nose up to 20° in order to reduce speed. As the speed decayed, the nose was lowered and the helicopter descended normally. The collective control lever was raised to cushion the landing, but at about 10 ft the crew heard the sound of an engine running up, accompanied by a loud bang and the sound of the low N_r warning. The commander took control of the helicopter, adopted the landing attitude and raised the collective control lever to its maximum limit. The helicopter continued to descend and touched down firmly with the left engine accelerating. The N_r which had decayed to 68% just prior to the touchdown began to increase and eventually stabilised at 90%.

The crew noted what appeared to be smoke or vaporised fuel on the right side of the helicopter and requested the attendance of the Airport Rescue and Fire Fighting Service (ARFFS). The crew identified from the cockpit indications that the right engine had suffered an overspeed condition and carried out the engine shutdown drill in accordance with the emergency checklist. Following confirmation from the ARFFS that there were no signs of fire, and noting that all other helicopter systems were normal, the commander taxied back to the operator's parking area. After a discussion with engineering control, the helicopter was shut down.

The helicopter was examined in accordance with the requirements of the engine overspeed inspection, after the removal of the right engine, at the operator's maintenance facility. The main rotor gearbox right freewheel shaft was found to rotate freely in both a clockwise and an anti-clockwise direction. The gearbox was removed for investigation.

Weight and balance

The maximum permitted takeoff training weight for the ambient conditions was 8,880 kg, with a maximum permitted landing weight of 8,450 kg. The actual takeoff weight at the commencement of the takeoff was 8,261 kg. The CG limits for the AS332L2 helicopter at this weight are 4.5 m to 4.95 m aft of the datum; the CG position of G-CHCF at the time of the incident was 4.67 m.

Main rotor gearbox

The AS332L2 is fitted with Makila 1A2 engines, which provide an additional 132 shp for single engine operation compared to the Makila 1A1 engine fitted to the AS332L1. Power from each of the engines is transmitted to the main rotor gearbox, which is common to all AS332 variants, through two input drive gearboxes fitted to the forward face of the main rotor gearbox. In the event that an engine fails or is shut down, a freewheel unit within the input drive gearbox prevents the engine being back driven through the gearbox by the remaining operating engine. The freewheel is a 'ramp and roller' unit, see Figure 1. The rollers are positioned on the engine driven 'ramped' freewheel shaft by a cage. As torque is applied to the freewheel shaft, the rollers are forced up the ramps locking the freewheel shaft to the gearbox input shaft allowing the engine to 'drive' the gearbox. In the event that engine torque is lost the rollers move down the ramps due to the relative rotation of the freewheel shaft and the gearbox drive shaft, disengaging the engine from the gearbox. The roller cage is fitted with a spring which holds the rollers towards the upper end of the ramps to minimise roller slip during engagement.

Engineering investigation

Main rotor gearbox

The main rotor gearbox was disassembled at the operator's overhaul facility under AAIB supervision and in the presence of the manufacturer's representative. No mechanical defects were found within the gearbox with the exception of the right engine freewheel unit which had been severely damaged. Examination of the freewheel unit showed that the roller cage had rotated to a point where the rollers had overridden the freewheel ramps, and moved into the adjacent 'trough' in the freewheel shaft disengaging the engine output shaft from the gearbox.

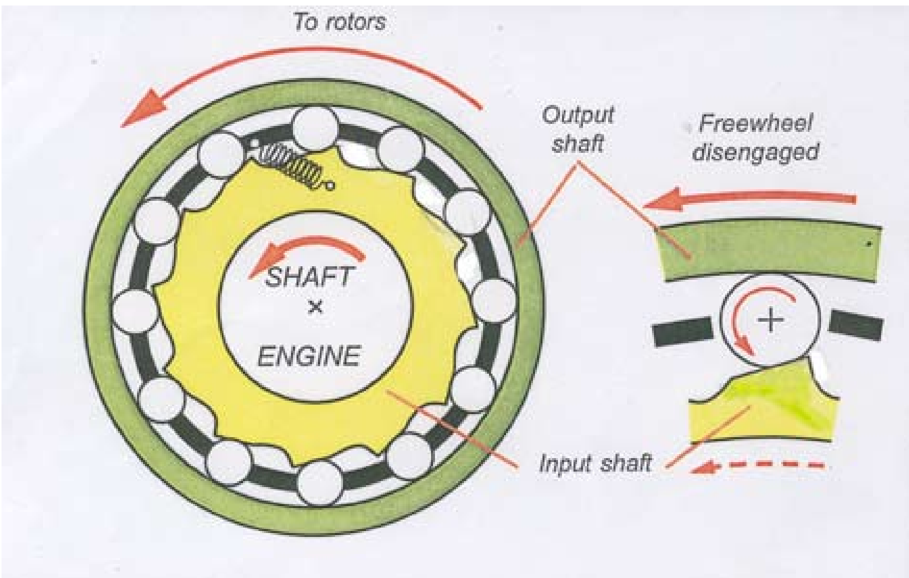


Figure 1

'Ramp and roller' freewheel unit

The freewheel anti-rotation stops had failed as a result of the roller cage rotating into them with significant force and all the rollers showed signs of deformation and mechanical damage. The shaft exhibited signs of significant mechanical wear on the ramps together with some burring of the ramp lips, produced when they had been 'over-ridden' by the rollers. Metallurgical examination confirmed that there were no material abnormalities within the freewheel shaft, the rollers or the roller cage. No evidence of a failure was identified during the inspection of the right engine which may have contributed to the failure of the right freewheel unit.

Manufacturer's experience and actions

Whilst there have been previous failures of the freewheel during engagement, the incident experienced by G-CHCF was the first failure of a fully engaged AS332 freewheel. Prior to February 2007, the allowable wear limits for the freewheel shaft ramps had been the same for both the AS332L1 and L2 gear boxes. During the overhaul of gearboxes, the manufacturer had identified that the wear rate of the AS332L2 freewheel assemblies was higher than that seen on the AS332L/L1 fleet and that the right freewheel shaft was subject to significantly higher wear rates than the left freewheel shaft. Whilst the reason for this higher rate of wear was not fully understood, it was believed to be due to variations in the torsional loading and rigidity within the rotor drive system. The increased wear rate of the L2 freewheel shafts had led to a significant increase in the number of shafts being scrapped due to excessive wear, with most right freewheel shafts being scrapped at the first exposure (3,000 hrs). In order to prevent an 'in service' freewheel failure due to excessive ramp wear, in February 2007 Eurocopter issued Repair Letter (RL) 214, which introduced tighter wear limits for the L2 freewheel shaft ramps. There was no requirement to re-inspect units overhauled prior to the release of RL 214.

As a result of this incident a review of the overhaul records of all AS332L2 main rotor gearboxes was completed by the manufacturer which identified those which may have been exposed to the potential of freewheel failure in operation. These units fell into two groups: those in which both freewheel units may have operated for at least 3,000 hours in the right input gearbox, and those where only one of the freewheel units had operated in that position for more than 3,000 hours. Those units within the first group were exposed to the potential of a double freewheel failure whilst those in the second were exposed to a single failure. On 20 December 2007 the manufacturer issued Alert Service Bulletin (ASB) 01.00.74 to require the removal and inspection of the first group of gearboxes within 40 hours or before 31 December 2007 (whichever was the earlier) and the second group within 100 hours and before 31 January 2008. This action was mandated by the publication of EASA Airworthiness Directive 2007-0312-E on 21 December 2007.

Maintenance records

The published overhaul life of the AS332L2 main rotor gearbox is 3,000 hours. The operator's records confirmed that the gearbox fitted to G-CHCF had operated for 2,644 hours since its last overhaul in November 2005. It was confirmed that the right freewheel shaft had been installed for a total of 8,942 flying hours and the left shaft for 5,652 hours at the time of the incident. A review of the records showed that the failed freewheel unit had been installed in the right input gearbox for 5,652 hours. They also confirmed that both the left and right freewheel shafts had been inspected and found within the published limitations applicable at the time of the last overhaul. Tooling calibration records confirmed that all the tooling used had been correctly calibrated at the time of this inspection.

Recorded information

Flight Recorders

The helicopter was equipped with both a Combined Voice and Flight Data Recorder[1] (CVFDR) and a Health and Usage Monitoring System (HUMS). The CVFDR was capable of recording just over eight hours of data and 90 minutes of audio respectively. Parameters pertinent to this investigation were the main rotor speed, engine free power turbine speed (N_f), gas generator speed (N_g) and engine torque. A time history of the relevant parameters recorded during the incident is shown in Figure 2. The HUMS, and its associated data, is discussed later.

CVFDR Recorded Information

The CVFDR was removed from the helicopter and replayed at the AAIB. Data indicates that the right engine (No 2 engine) was started at 1909 hrs and the left engine (No 1 engine) five minutes later. Both the engine start and subsequent pre-flight checks were normal and the commander confirmed the TIS was operating correctly. At 1952 hrs the helicopter entered Runway 16 with the pilot in the first officer position (FO) as the handling pilot. The FO flew the helicopter into a 10 ft hover, before the commander simulated the failure of the left engine, using the TIS, and the helicopter slowly descended to the ground. This exercise was repeated from the same height, before the commander demonstrated a rejected takeoff, with the TIS being used to simulate the failure of the left engine as the helicopter approached 60 kt at a height of 40 ft.

About three minutes later, the helicopter was cleared to re-enter Runway 16, the FO flew the helicopter into the hover and the commander briefed him as to when he would activate the TIS. The helicopter then transitioned into the climb and at about 50 kt and 50 ft, the commander activated the TIS. The helicopter landed without incident and came to a stop on the runway. The commander confirmed that they would perform a further rejected takeoff.

During the transition, the commander activated the TIS to simulate the failure of the left engine when the helicopter was at 39 ft, at which time the airspeed was about 28 kt. Initially everything appeared normal, but at a height of about 10 ft, the right engine N_f speed rapidly increased to 115%, before the engine was automatically shutdown and the main rotor speed started to decay. (See points A and B, Figure 2). Almost immediately, the low rotor speed aural warning activated and the commander took control of the helicopter, just before it landed firmly. As the right engine had started to run down, the left engine responded with an increasing N_g speed. By the time the left engine had reached its normal operating speed, the helicopter had already landed. From the point at which the right engine had started to rundown, the left engine had taken about three seconds to increase from the TIS setting of 69% to 91% N_g. The main rotor speed had decayed from about 97% to about 73% in two seconds.

When the right engine had started to rundown, the engine torque indication had rapidly decreased and increased twice (See point C, Figure 2). The indications were later attributed to a misalignment of the torque sensing components, which had become misaligned as a result of the freewheel unit failure.

Analyses of the CVFDR data did not identify any abnormalities in either the operation of the helicopter or the characteristics of the freewheel unit. However, it did identify one defect in the recording of data from

Footnote

[1] Penny and Giles manufactured CVFDR, part number 900/51508, serial number 1030/10/93.

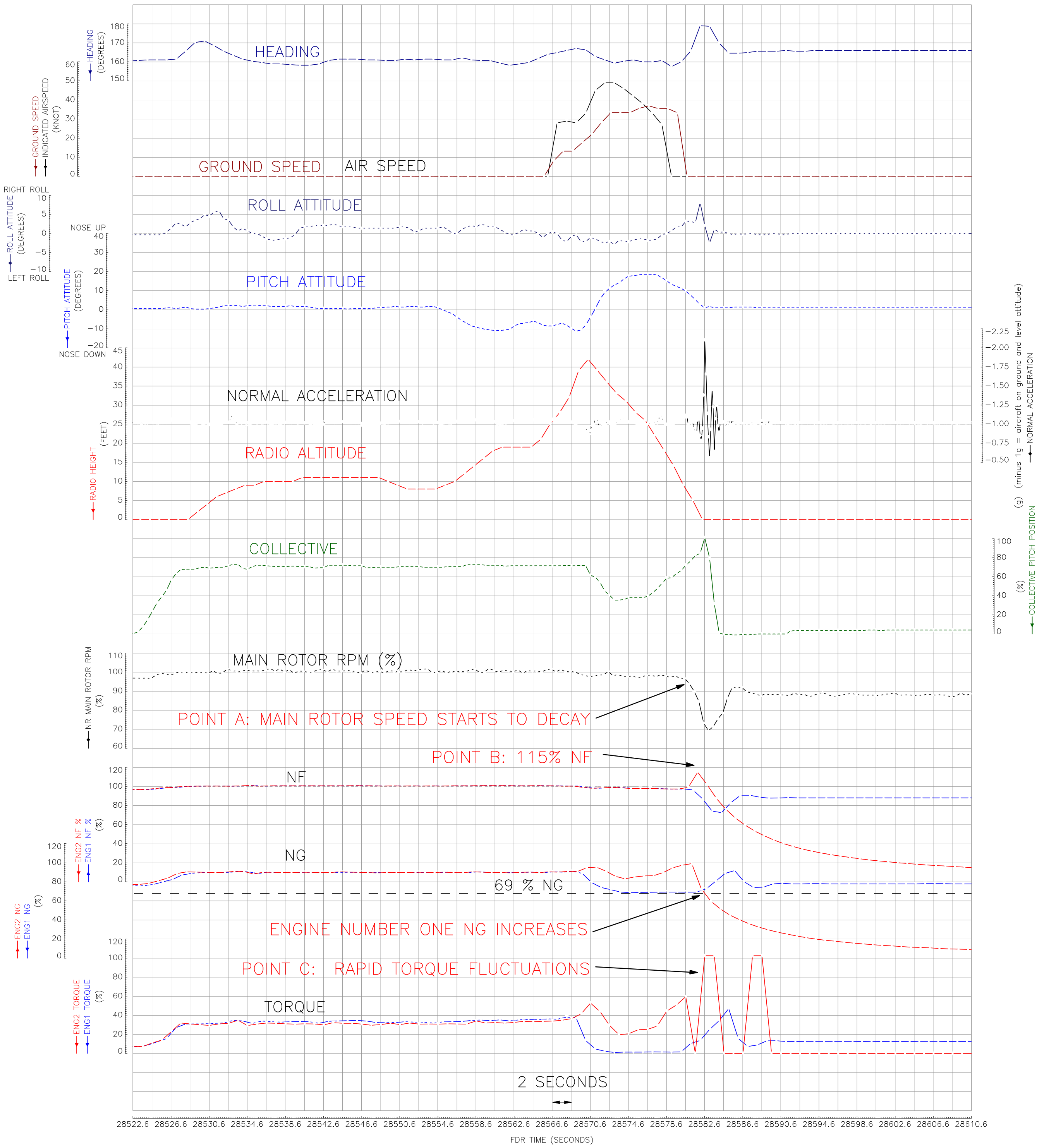


Figure 2

Salient FDR Parameters

the FDR systems mandatory tri-axial accelerometer[2]. The defect did not affect the operation of the HUMS or any other helicopter system. It was found that rather than the normal acceleration parameter quiescent value indicating +1g, it indicated -1g. A check by the operator on 27 November 2007 found that the tri-axial accelerometer had been incorrectly installed. Maintenance records indicated that the accelerometer had last been removed and replaced during July 2007. A fleet-wide check was carried out and no further helicopters were affected. The incorrect installation of the sensor had the effect of inverting the sense of the normal acceleration parameter and also reversing the operation of the lateral acceleration parameter. The operating range of the lateral acceleration parameter was not affected; however, that of the normal acceleration parameter was no longer compliant with the legislative requirement. Instead of having an operating range of between +9g to -3g, this was reversed to +3g to -9g. Although the Aircraft Maintenance Manual (AMM) installation procedure provided a diagram of the correct orientation of the sensor, there was no requirement to carry out a post-installation test. On this occasion, the incorrect installation of the tri-axial accelerometer did not result in a loss of information, although under different circumstances, information from a mandatory parameter could have been compromised. The helicopter manufacturer has responded to the installation error by confirming that it will be carrying out a review of the AMM procedure.

Footnote

[2] The FDR system is equipped with a dedicated tri-axial accelerometer, which provided normal, lateral and longitudinal acceleration data.

Health and Usage Monitoring System

Overview and system description

In accordance with legislation[3], the helicopter was equipped with a Health and Usage Monitoring System (HUMS). The system is designed to record vibration data from sensors that are strategically placed around the helicopter. Data can then be analysed to detect incipient defects in the major components of the helicopter, before they can become a hazard to flight. The system may also be used to improve the reliability of the airframe and its components by identifying sources of abnormal or increasing vibration. HUMS data trending is predicated on the comparison of data that has been obtained during as stable and as consistent a period of flight as practicable. For this reason, data is most typically recorded when either on the ground or in the cruise.

First generation systems, such as North Sea HUMS and Integrated HUMS (IHUMS), were developed in the late 1980s and early 1990s during North Sea helicopter operations. These early systems were installed, developed and supported by the helicopter operators and HUMS equipment manufacturers, with approval from the CAA. G-CHCF utilised a later generation system known as EUROHUMS. This differed from the first generation systems by being developed and supported by the helicopter manufacturer.

In common with the design philosophy of other rotary wing health monitoring systems, EUROHUMS does not record data continuously in flight. At pre-defined

Footnote

[3] The Civil Aviation Authority (CAA) issued AAD 001-05-99, which became effective on 7 June 1999. The AAD made the installation and use of health monitoring systems mandatory for United Kingdom registered helicopters issued with a Certificate of Airworthiness in the Transport Category (passenger), which had a maximum approved seating configuration of more than nine passengers.

time intervals, during either the ground or cruise phase, snapshots of vibration information specific to particular engine or drive train components are recorded. Components with high rotational speeds, such as the engine input shafts, would be recorded more frequently than lower speed components, such as those within the main gearbox. At the time of the incident, data pertaining to the engine input shafts were recorded once every 20 minutes when the helicopter was in the cruise phase. The engine input shafts were not recorded during any other phase of flight. Recording intervals for components had been refined over a number of years and had been demonstrated as providing suitable levels of detection by the helicopter manufacturer.

In accordance with UK legislative requirements, HUMS data is downloaded and analysed once per day. Data is downloaded into a ground-based analysis tool which detects any imbalance; misalignment; damaged, eccentric or cracked gears, or bearing wear within the main rotor gearbox and engines. An indication of the health of important components is thus provided and caution or warning indications can be provided if predefined limits are exceeded. If a caution or warning for a component is generated, or an adverse trend is identified, the ground-based system is able to provide the operator with details of corrective maintenance action. After maintenance, ongoing HUMS monitoring and in-service inspections are used to ensure that any corrective action was successful.

Although HUMS has demonstrated that it provides an effective means of monitoring, there are certain components, such as freewheel units, which may not exhibit any detectable levels of vibration during normal operation and, as such, cannot be monitored effectively by a vibration monitoring system.

HUMS data

Prior to the incident, the operator had been monitoring a progressive increase in the right engine input shaft vibration level. On the 18 November 2007, two days before the incident, the operator replaced the right engine. In the following two days, a small number of data points were recorded by the HUMS. These points indicated a reduction in vibration for the right engine input shaft. However, results from the subsequent stripdown did not identify any keys areas of damage and the operator and helicopter manufacturer discussed whether the increasing trend may have been due to wear of the freewheel unit.

The helicopter manufacturer reviewed the HUMS data and confirmed that a progressive increase in vibration levels relating to the right engine input shaft had been detected and that, following engine replacement, the vibration levels had reduced. They confirmed that vibration levels recorded prior to the engine replacement had been at a low level and that the subsequent stripdown findings were not unusual considering these low levels. Both the helicopter manufacturer and operator concluded that the increasing vibration trend had been as a result of normal wear within the engine or its coupling to the main rotor gearbox and was not related to vibration of the freewheel unit.

Operational aspects

Takeoff and landing profiles

The AS332L2 has takeoff and landing profiles for both clear area and helipad operations. These profiles ensure that the helicopter complies with Performance Class 1 requirements when operated at a weight appropriate for the ambient conditions.

In order to ensure that the helicopter can either land or fly away in the event of an engine failure the profiles have Takeoff Decision Points (TDPs). During a clear area takeoff the TDP is calculated on the distance available for landing should the helicopter have to abandon or reject the takeoff and/or the maximum weight, whichever is the more limiting. The TDP is based on Indicated Airspeed (IAS) and an associated height. The TDP may be varied between 20 kt and 60 kt at 10 kt increments and associated heights of 20 ft to 40 ft in 5 ft increments. The heavier the helicopter, the higher will be the IAS and height that define the TDP. With a limiting reject distance, the TDP IAS and height will be lower. If an engine fails prior to TDP the takeoff is rejected and the helicopter should stop within the pre-determined distance. Should an engine fail after the TDP, the helicopter can be flown away providing a target IAS is maintained and the correct power is set on the operating engine.

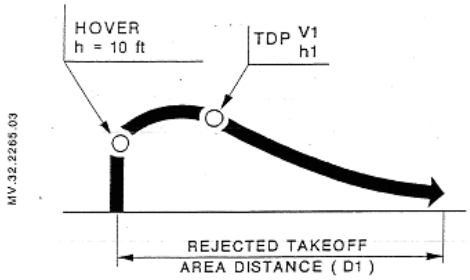
The Landing Decision Point (LDP) for a clear area landing profile is a fixed height of 100 ft and requires an IAS of 35 kt at that height with a rate of decent less than 400 fpm at the LDP. In the event of an engine failure before LDP the helicopter may continue to land or the pilot may go around and climb away. After LDP the helicopter must be landed and should stop within the promulgated landing distance.

When operating at a helipad the profile requires that the helipad must have a minimum diameter of 24 metres. The TDP is then a fixed point, 130 ft above the pad and with a horizontal back up distance from the pad of 125 m. LDP is the same as for a clear area but the approach is steeper. The takeoff, landing and rejected takeoff profiles are set out below.

Clear area profiles

Takeoff with Single-Engine Failure recognised at or before the TDP

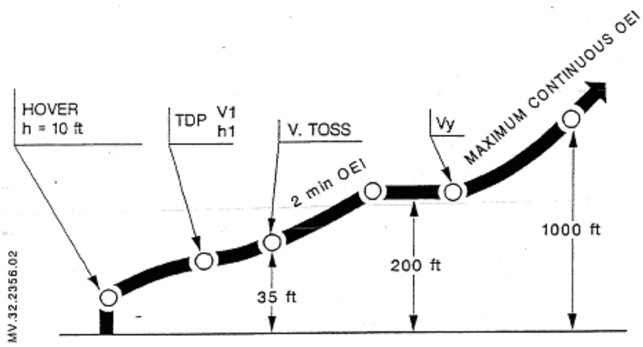
Abort takeoff as soon as engine failure occurs.



- Simultaneously reduce the collective pitch while maintaining a rotor speed of at least 250 rpm (94%), and adopt a nose-up attitude of 10° to 20°, allowing the aircraft to climb slightly.
- As aircraft begins to sink, control attitude and cushion touchdown.
- On the ground, reduce collective pitch to minimum and use wheel brakes to stop the aircraft.

Takeoff with Single-Engine Failure at or after the TDP

Continue the takeoff procedure.

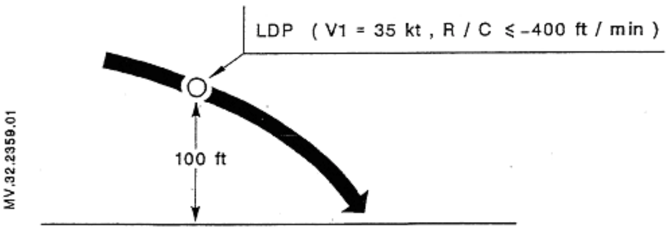


VI (IAS) = V.TOSS (IAS) - 10 kt [where V.TOSS is the Takeoff Safety Speed]

- Control N_r
- Accelerate to or maintain V.TOSS.
- At V.TOSS reduce collective pitch to 2-minute One Engine Inoperative (OEI) rating and simultaneously shift N_g stop to 2-minute OEI rating position.
- At a height of 200 ft, level off and accelerate from V.TOSS to V_y (best rate of climb airspeed).
- At 200 ft but no later than when the OEI LO caption flashes, adjust collective pitch to maximum continuous OEI rating.
- Retract landing gear and continue climbing at V_y.

NOTE: If landing gear is retracted below 60 kt, then red L/C caption will flash.

Normal Landing

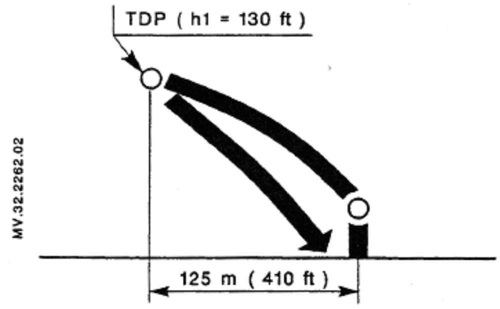


- After reaching LDP, proceed with a straight-in approach, reducing speed regularly to enter hover IGE at a height of 10 feet.
- Proceed with normal landing.

Helipad profiles

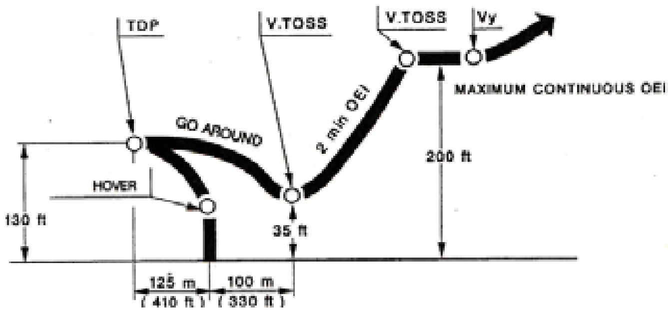
Takeoff with Single-Engine Failure at or before the TDP (before aircraft rotation)

Abort takeoff as soon as engine failure occurs.



Takeoff with Single-Engine Failure at or after the TDP (aircraft rotation started)

Continue flight



Training idle system

The maximum OEI limits cannot be used unless an actual engine failure occurs. The TIS enables OEI flight training to be conducted using non-damaging power levels, provided that the helicopter weight has been reduced to the associated training limit.

A guarded switch, associated with each engine, is provided on the overhead control unit. This switch is used to perform the following actions simultaneously:

1. Simulation of an engine failure by reducing the power of that engine to idle rating, with N_f being governed at a value slightly lower

than 245 rpm, equivalent to 92.5% Main Rotor Rotation Speed (N_r).

2. De-rating the OEI stops of the other engine by approximately 1665 rpm (5%) in order to limit the N_g to a value not exceeding the takeoff power rating.

The Flight Manual Supplement contains the following information regarding safety devices associated with the TIS:

> *'Function Safety Devices*
>
> *In addition to limiting the power to non-damaging ratings, the following safety devices are provided when using the TRAINING function:*
>
> - *In the event of an incorrect training manoeuvre or an actual failure of the engine supplying the power, the required power can be obtained from the idling engine simply by pulling the collective pitch lever. The principle is as follows: as soon as the NR drops below 240 rpm (90.5%) the idling engine supplies the amount of power required until the actual 30-second OEI rating is reached (at NR = 220 rpm (83%)), using static droop effect.*
> - *There is no risk of a false manoeuvre with the fuel flow control levers, since these levers remain in flight position; the OEI is simulated using specific controls.*
> - *In the event of unintentional action on more than one TRAINING IDLE control, the function is inhibited and a minor governing fault is indicated. The function will be re-established after landing, shutting down both engines and re-starting the engines according to the standard procedure.*
> - *Should the engine running in TRAINING IDLE mode fail, the procedure can be continued at the actual OEI rating (i.e. with a larger power margin) by setting the TRAINING IDLE control forward (switch guard down).*
> - *Return to twin-engine flight is possible at any time by setting the TRAINING IDLE control forward (switch guard down).'*

The Engine Monitoring Display (EMD) for the operating engine changes to the indications that the pilot would read in true engine failure condition. A letter 'T' appears in an inverted triangle to indicate to the pilot that the training mode is in operation.

Helicopter certification

The initial certification of the helicopter was carried out by the French, Direction Generale de l'Aviation Civile (DGAC). The UK CAA conducted a validation of that certification in 1991/92. No specific requirements were in place to establish the helicopter performance with the TIS selected and a subsequent failure of the operating engine. A requirement was in place which ensured that any 'Option' such as the TIS should not introduce an increased hazard.

Prior to the introduction of the TIS, the only method of simulating a single engine failure was to retard a Fuel Flow Control Lever (FFCL). In the event of the operating engine failing that FFCL would then have to be advanced to reinstate the power available from that engine. This would have to be combined with a lowering of the collective control to prevent loss of N_r. If the FFCL were advanced too rapidly, the possibility of engine surge, flame-out or an overspeed shutdown of that engine was possible.

By introducing the TIS both FFCLs remained in the flight position and the decaying N_r, resulting from a failure of the operating engine, was used to trigger the acceleration of the engine at idle. The Digital Engine Control Unit (DECU) optimised the acceleration to restore safe flight.

There was no record or data available of any tests carried out during development by the manufacturer or certification authorities to simulate the failure of an operating engine whilst the TIS was in use. The UK validation did not call for any testing of a failure of the operating engine but satisfactory flight tests of the TIS in operation were conducted.

Operator's safety actions

General

Following the incident involving G-CHCF, the operator ceased training and testing on the AS332L2 using the TIS. This was followed by a ban on using the TIS, which was imposed by the UK CAA for all operators.

Tests and evaluation

In order to understand the potential hazards which may arise when using the TIS the operator evaluated a number of test conditions in the AS332L2 flight simulator based in Marseille, France. The test points were identified within the takeoff and landing profiles for both clear area and helipad operations. The tests were based on the operating engine failing whilst the other engine was in the training idle mode. The test pilot then attempted to preserve N_r and safe flight whilst the other engine accelerated to the extent that the helicopter could either be landed or flown away.

The Flight Simulator

The flight simulator was a level D Synthetic Training Device (STD) with motion and visual display. The data on which the simulator was modelled was derived from the manufacturer's AS332L2 flight test and certification programme. The certification programme confirmed the helicopter performance when using OEI 30-second power but a failure of the operating engine, with the other engine in the training idle mode, was not carried out. Although the modelling of the TIS was not derived from flight test data, it was considered that the simulator offered a reasonable indication of the likely outcome of the event being simulated.

Test conditions

The simulator was representative of the operator's standard AS332L2 configuration. The conditions were set to sea level standard (1013 hPa, +15°C) with no wind. The runway at Hong Kong was used as it is at sea level and the model database gave good visual cues throughout the tests. Helicopter mass was set at 8,600 kg for the clear area work and 7,500 kg for the helipad exercises. These weights were representative training mass values (maximum training mass for the conditions would have been 8,900 kg and 7,600 kg respectively).

Tests made

Failures of the operating engine were investigated before and after TDP, and before LDP on a clear area, as well as before TDP on a helipad. Failures were initiated by selecting the left engine to training idle, at the target speed, using the TIS, followed one second later by injecting a failure into the operating engine. The operating engine was initially failed by introducing an N_f overspeed condition, but there was a marked delay in the left engine accelerating. By using the FFCL to stop the right engine the time delay was reduced. The right engine failure was activated as the pilot flying (PF) was commencing the required recovery manoeuvre. The inherent delays in the simulation and the inertia of the helicopter meant that the actual failure of the operating engine during the takeoff exercises occurred at between 5 kt and 10 kt above the target speed. Each test point was recorded and the relevant data (N_r, N_g and radio height) could be noted.

Findings

The behaviour of the simulator was considered against the Flight Manual Supplement (FMS), Supp 3 (One Engine Inoperative (OEI) Flight Training Procedures), which contains the limitations, procedures and performance data for use of the TIS. It makes the following statement:

> *'In the event of an incorrect training manoeuvre or an actual failure of the engine supplying the power, the required power can be obtained from the idling engine simply by pulling the collective pitch lever. The principal is as follows: as soon as the* NR *drops below 240 rpm (90.5%), the idling engine supplies the amount of power required until the actual 30-second OEI rating is reached (at* NR *=220 rpm (83%)), using the static droop effect.'*

The tests revealed inconsistencies in the simulator modelling, not only in the response to low N_r and variation of collective movement, but also in the different responses depending on how the engine failure was initiated. The low N_r trigger at 220 rpm and removal of the training idle stop (release of real OEI 30-second power) were consistent, and appeared to be in accordance with FMS Supp 3 if the failure was introduced using the FFCL, but inconsistent if the failure was introduced via the N_f overspeed. This could be assessed in the helicopter without going to the actual OEI; it would be sufficient to see the release of the real OEI rating and an N_g increase through 90% in response to N_r decay.

It was evident from the tests performed in the simulator that clear area rejected takeoffs, with failure of the operating engine during the reject (ie failures before TDP), could be recovered and the helicopter could be landed safely; this was the case relating to the incident with G-CHCF. It was also evident that failures just after TDP (with the intention to continue the takeoff) would result at best in a rejected takeoff, depending on the distance of suitable landing surface remaining. Any failure of the operating engine in the first segment (ie below 200 ft) would result in the helicopter either making a forced landing or descending to or below 35 ft in the flyaway. A similar conclusion could be drawn for failures before LDP, because the failure simulated at 150 ft resulted in a controlled forced landing with insufficient height to recover N_r or N_g to the extent that a safe go-around could be considered. It is probable that at least 200 ft would be required (possibly more because the helicopter is already descending at the moment of failure). Furthermore, real intervention times are likely to be greater and this can only have a detrimental effect on the potential outcome.

Conclusions

From the simulator tests, the Flight Manual Supplement, Supp 3, statement set out above does not accurately reflect the behaviour of the helicopter or the technique that the pilot should adopt. Simply pulling the collective lever did not restore N_r but caused it to decay into an over-pitching condition unless the collective lever was first lowered positively to prevent this. The helicopter also touched down beyond the rejected takeoff distance following a failure of the operating engine after TDP and in the undershoot with the operating engine failing just before LDP. It was not possible to land or fly away safely during the helipad profile.

Recommendations

On the basis of the simulator test results, the operator considered that the TIS should not be used to simulate engine failures in the following cases:

- On clear areas during continued takeoffs in the first segment (ie below 200 ft)
- On clear areas during landing not below a height agreed with, and authorised by, the authorities
- On helipads at any time

This restriction would remain in force until a risk assessment of engine failure training on the AS332L2 had been carried out.

Analysis

Engineering

Excessive wear to the freewheel shaft ramps resulted in the freewheel rollers overriding the ramps, disengaging the engine from the main rotor gearbox. No metallurgical defects were identified within the freewheel unit. The gearbox had been overhauled in November 2005, prior to the release of Eurocopter RL 214, in accordance with the applicable limitations and procedures in force at that time. The possibility of an in-service freewheel failure has been significantly reduced by the introduction of RL 214. Eurocopter, in Alert Service Bulletin 01.00.74, identified all the AS332L2 main rotor gearboxes which were exposed to a potential freewheel failure with a defined timescale for removal and this was mandated by the publication of EASA Airworthiness Directive 2007-0312-E on 21 December 2007. All of the affected gear boxes were removed from service and are now compliant with EASA AD 2007-0312-E.

Operations

The crew were properly qualified to conduct the flight and the helicopter was being operated within the weight and the C of G envelope for the manoeuvre being flown. The training exercise had been fully briefed.

The failure of the operating engine freewheel unit, as the collective control was being raised, occurred in an area of the takeoff profile where recovery was possible, and this was achieved through the prompt action of the helicopter commander in taking control and performing a safe landing. From the evidence provided by the FDR, the helicopter touched down before the left engine accelerated. Once on the ground the N_r was restored. There was no test data from the flight test or certification programme with which the TIS operation could be compared to establish whether it had operated correctly.

The test points carried out in the simulator flying the clear area profile with a failure of the operating engine at or just before TDP showed that a rejected takeoff could be performed successfully. This relied on the prompt reaction of the pilot and demonstrated the need for the pilot to lower the collective control, if possible, to assist with restoring N_r. This action, combined with flaring the helicopter, would assist in reducing N_r decay and providing the accelerating engine with the best conditions for restoring N_r. It also showed that the action required in the Flight Manual Supplement, Supp 3, that '*the required power can be obtained from simply by pulling the collective pitch lever'* is incorrect.

If an operating engine failure occurs at or after TDP, or just before LDP, attempting to fly away using the technique described in the Flight Manual Supplement, Supp 3, could result in significant over-pitching with the associated build-up in the rate of descent. The simulator modelling was not sufficiently reliable in the scenario being tested to identify an exact outcome. It is, however, probable that the helicopter would touch down or descend below the 35 ft minimum height required. The point of touchdown may be beyond the rejected takeoff distance available.

Using the helipad profile, with an operating engine failure before or just after TDP or just before LDP the loss of N_r and high rate of descent may make the situation irrecoverable. The point of touchdown would be short of the pad in the early stages of the profile and beyond the pad if positive airspeed was achieved. It was considered highly unlikely a successful safe landing on the pad would be achieved.

Conclusions

The safe outcome of this incident was dependant upon a combination of the point at which the failure of the freewheel unit occurred and the prompt corrective action taken by the commander. The information presented in the Flight Manual Supplement, Supp 3, does not appear to accurately reflect the behaviour of the helicopter or the technique to be employed following a failure of the operating engine and may provide a false sense of security if using the TIS. The principle of having a system to accelerate an engine from a training idle position, following a failure of the operating engine, is a positive safety enhancement and avoids a rapid movement of the FFCL introducing an overspeed shutdown. However, the Flight Manual Supplement, Supp 3, should alert the pilot to the limitations of the system and in particular the technique to be used should the operating engine fail. Therefore:

Safety Recommendation 2009-003

It is recommended that Eurocopter should review the operation of the Training Idle System on the AS332L2 helicopter in the event of the failure of the operating engine. Eurocopter should ensure that the behaviour of the helicopter in terms of N_r recovery and any height loss are included in the Flight Manual Supplement, Supp 3. The correct pilot technique for managing such an event should also be included. This information should be based on flight test data.

Furthermore, the AS332L2 is one of a number of helicopters fitted with a Training Idle System, or similar system. As no certification requirements are stipulated for such systems, there may be other helicopters where the operation of the TIS is not accurately documented. Therefore:

Safety Recommendation 2009-004

It is recommended that the European Aviation Safety Agency should review the accuracy of Flight Manual information covering Training Idle Systems fitted to all helicopter types or models. They should ensure that the information on the system, the behaviour of the helicopter and the correct pilot technique to be employed in the event of the operating engine failing are correctly documented.

Moreover, there is no current requirement within the certification process for the Training Idle System to be evaluated with a failure of the operating engine. Data derived from such tests would ensure that the correct information was included in the Flight Manual and that accurate data was used for the modelling of flight simulators. Therefore, the following two Safety Recommendations are made:

Safety Recommendation 2009-005

It is recommended that the European Aviation Safety Agency should require that when a helicopter is fitted with a Training Idle System, or similar system, the effects of a failure of the operating engine are determined during the flight test and certification process.

Safety Recommendation 2009-006

It is recommended that the European Aviation Safety Agency should ensure that where a Training Idle System is fitted to a flight simulator the handling qualities and performance of the helicopter, following the failure of the operating engine, are accurately modelled.

ACCIDENT

Aircraft Type and Registration:	Avions Fairey SA Tipsy Junior, G-AMVP
No & Type of Engines:	1 Walter Mikron 2 piston engine
Year of Manufacture:	1952
Date & Time (UTC):	15 September 2008 at 1250 hrs
Location:	Sandown Airport, Isle of Wight
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - None
Nature of Damage:	Wooden propeller broken; engine cowling dented; port aileron underside scuffed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	82 years
Commander's Flying Experience:	5,500 hours (of which 273 were on type) Last 90 days - 11 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and occurrence reports submitted by airport operations staff

Synopsis

The aircraft was landing on Runway 05 at Sandown, in good weather conditions and with a surface wind from the north at 5 to 8 kt. The pilot reported that, as the aircraft was just above the runway prior to making a 'three-point' landing, the port wing stalled and struck the ground. Operations staff at the airfield reported that the wing drop occurred shortly after the aircraft had bounced on landing, following which the propeller struck the ground. The aircraft came to rest in a nose-low attitude and the uninjured pilot, who was wearing a full harness, vacated the open cockpit.

ACCIDENT

Aircraft Type and Registration:	Beech H35 (Modified) Bonanza, G-ASJL
No & Type of Engines:	1 Continental Motors Corp IO-520-BA12B piston engine
Year of Manufacture:	1957
Date & Time (UTC):	10 June 2008 at 1350 hrs
Location:	Compton Abbas Airfield, Dorset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to nose and main landing gear, propeller and engine
Commander's Licence:	Private Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	195 hours (of which 37 were on type) Last 90 days - 13 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Following a normal touchdown, the aircraft was approximately halfway along the runway during the roll-out when, without warning, the landing gear collapsed. The aircraft slewed to the left and came to a halt, blocking the runway. The pilot turned off the fuel and electrical services and both occupants vacated the aircraft without injury. The pilot reflected that it was possible he had inadvertently selected the landing gear switch to UP, having intended to retract the flaps. The aircraft was equipped with a weight-on-wheels microswitch that should have prevented landing gear retraction. However, it is possible that the slightly undulating nature of the runway may have caused the microswitch to open at some point during the roll out, allowing the gear to retract.

ACCIDENT

Aircraft Type and Registration:	CAP 232, G-GSGZ
No & Type of Engines:	1 Lycoming AEIO-540-L1B5 piston engine
Year of Manufacture:	1996
Date & Time (UTC):	2 September 2008 at 0940 hrs
Location:	Near Llay, 3 nm South of Hawarden Airport
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Major damage to fuselage, tail and landing gear
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	957 hours (of which 689 were on type) Last 90 days - 34 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot reported that he misjudged a pre-flight visual inspection of the aircraft's fuel quantity and the engine stopped due to fuel exhaustion during flight. The ensuing forced landing resulted in the aircraft pitching forward onto its back. This trapped the pilot who required external assistance to vacate the aircraft.

History of the flight

In preparation for a local aerobatic flight, the owner of the aircraft carried out the normal pre-flight checks, including a physical check of the fuel on board. The aircraft was fitted with a centre tank and a tank in each wing, with aerobatics only permitted with the wing tanks empty. The pilot confirmed the wing tanks were empty and on checking the centre tank, could see fuel and assessed the tank to be full. He did not use a dip stick. He estimated that there was sufficient fuel for at least half an hour's flying depending on the amount of time that aerobatics were flown.

The pilot strapped in and noted that the centre tank fuel gauge indicated 7/8ths full. This gauge is positioned in such a way that the pilot must move his leg to see it once strapped in.

After a normal start and power checks, he took off from Hawarden Airfield and flew for approximately six minutes to reach the area in which he planned to perform the aerobatics. He completed his pre-aerobatic checks which included another check of the fuel and flew a series of aerobatic manoeuvres lasting approximately seven minutes. The last manoeuvre was a stall turn during which the engine stopped for approximately 2-3 seconds before restarting. After recovering from the stall turn and with the aircraft level, another check of the fuel revealed the centre tank gauge indicating zero. The pilot started to return to the airfield, setting economical cruise and making a PAN call to inform ATC of his fuel state.

Approximately 3 nm from the airfield the engine stopped and could not be restarted. As he was unable to glide to the airfield, the pilot conducted a forced landing in a freshly cultivated field. He reported that one reason for selecting this field was that there was a tractor working in it which might be of assistance after landing. The pilot described flying a satisfactorary approach but the roll out after touchdown was rough and bouncy. As the aircraft slowed, the nose pitched down and the aircraft flipped over onto its back, partly breaking the canopy. The pilot, who was wearing a full harness, had his head forced onto his chest by the earth which made breathing difficult. The driver of the tractor witnessed the accident and was able to lift the wing of the aircraft using the plough attached to the tractor. This allowed him sufficient room to dig away the soft earth and break the remaining canopy using a hammer. The pilot undid his harness and was able to escape from under the aircraft.

Analysis

The pilot considered the engine stopped approximately 15 minutes into the flight due to fuel starvation. He was not aware of any fuel leaks and despite his initial fuel checks indicating the centre tank was nearly full, he believes he misjudged the quantity and that it was more likely to have been only half full. The pilot reported that the fuel gauge did not move in a linear fashion and was therefore not an accurate method of assessing the quantity on board. In addition, due to the position of the gauge, it was not easy to continually monitor during flight. He commented that he would now fill a tank to the top as he considered this the only way to be sure of the fuel quantity it contained.

The pilot did not routinely wear a parachute and had no option other than to carry out a forced landing. He reported that the accident had made him reconsider this and that he would now wear a parachute, only attempting a forced landing if there was a prepared surface on which to land. He believed this type of aircraft was likely to pitch forward onto its back on any other sort of surface, as on this occasion, and he considered himself lucky not to have suffocated or suffered a serious or fatal head injury. In this event, his situation would have been considerably more serious had it not been for the soft earth and the timely intervention of the tractor driver.

SERIOUS INCIDENT

Aircraft Type and Registration:	CEA DR400/2+2, Dauphin, G-GAOM
No & Type of Engines:	1 Lycoming O-235-H2C piston engine
Year of Manufacture:	1977
Date & Time (UTC):	19 September 2008 at 0840 hrs
Location:	Runway 12, RNAS Culdrose, Cornwall
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Main landing gear tyres burst
Commander's Licence:	Private Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	189 hours (of which 19 were on type) Last 90 days - 8 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, ATC recordings and further enquires by the AAIB

Synopsis

During a visual circuit at Royal Naval Air Station (RNAS) Culdrose, Cornwall, G-GAOM was cleared, by ATC, to "CONTINUE" as another aircraft had just landed. G-GAOM subsequently landed without clearance with the other aircraft still on the runway. As a result, G-GAOM braked very hard after landing, to avoid the other aircraft, and burst both tyres on the main landing gear.

History of the flight

G-GAOM was visiting RNAS Culdrose, Cornwall, from its base at Bodmin Airfield, with approximately 30 other light aircraft for a joint civil and military safety day. All visiting aircraft had been given a runway landing slot by ATC. When G-GAOM joined the circuit it contained three other aircraft and there were other aircraft joining behind.

G-GAOM positioned right-hand downwind and the pilot was advised that he was number two in the landing sequence. As the aircraft turned onto right base, the pilot transmitted "TURNING RIGHT BASE BEHIND NUMBER ONE." ATC replied "CONTINUE" because the aircraft ahead had just landed; the pilot did not acknowledge this clearance.

G-GAOM subseqently landed on Runway 12 with the other light aircraft still on the runway. During the landing roll both main landing gear tyres burst before the aircraft stopped about 400 m behind the now vacating aircraft. G-GAOM was unable to vacate Runway 12 until additional assistance arrived several minutes later.

Pilot's comments

The pilot commented that he did not hear the "CONTINUE" clearance transmitted by ATC. Although he saw the aircraft ahead on the runway, he considered that it would have vacated the runway before he landed.

He added that he was concentrating hard on flying his aircraft, as it was high and fast on the approach, and he failed to ensure the runway was clear before he landed. He also felt compelled to land due to runway slot time pressures and the other aircraft joining. After landing he applied maximum braking to stop his aircraft before reaching the other aircraft. In hindsight he believes he should have flown a go-around.

Safety actions

As a result of this incident ATC at RNAS Culdrose is reportedly ensuring that all visiting civilian flying clubs are pre-briefed on the circuit procedures and are establishing several Visual Reporting Points to aid the sequencing of arriving VFR traffic.

ACCIDENT

Aircraft Type and Registration:	Cessna 182F Skylane, G-WARP	
No & Type of Engines:	1 Continental Motors Corp O-470-R piston engine	
Year of Manufacture:	1963	
Date & Time (UTC):	15 October 2008 at 1100 hrs	
Location:	Caernarfon Aerodrome, Gwynedd, Wales	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to propeller and engine shock-loaded	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	60 years	
Commander's Flying Experience:	416 hours (of which 76 were on type) Last 90 days - 18 hours Last 28 days - 12 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

During the takeoff ground roll a gust of wind from the left lifted the left wing despite the pilot having held full into-wind aileron. The aircraft then pitched nose-down and the propeller struck the runway. The pilot taxied the aircraft off the runway and then shut down the engine.

ACCIDENT

Aircraft Type and Registration:	Cessna F172H Skyhawk, G-AWUX
No & Type of Engines:	1 Continental Motors Corp O-300-D piston engine
Year of Manufacture:	1968
Date & Time (UTC):	27 September 2008 at 1550 hrs
Location:	Dowland Farm Strip, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left wing strut and cowling dented
Commander's Licence:	Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	305 hours (of which 242 were on type) Last 90 days - 5 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After an uneventful approach to Runway 27 with 40° flap selected, the aircraft touched down at 58 kt. The pilot reported that he then commenced normal braking, but encountered an area of "damp green grass", as a result of which the aircraft started to skid slightly. He was unable to stop completely and, just before reaching the end of the runway, he steered to the right in an unsuccessful attempt to avoid a low hedge and retaining wall beyond. The aircraft struck both at slow speed, estimated at less than 10 kt, and was brought to rest. Afterwards, both occupants were able to evacuate without difficulty through their respective cabin doors.

ACCIDENT

Aircraft Type and Registration:	DA40 D Diamond Star, G-CCHA
No & Type of Engines:	1 Thielert TAE 125-02-99 piston diesel engine
Year of Manufacture:	2003
Date & Time (UTC):	30 August 2008 at 1510 hrs
Location:	Retford (Gamston Airport), Nottinghamshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to right wing tip and propeller
Commander's Licence:	Student
Commander's Age:	34 years
Commander's Flying Experience:	17 hours (of which all were on type) Last 90 days - 9 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The student pilot had just landed from a solo flight and was taxiing back to parking. After making a left turn he became distracted during a radio call and did not notice that the aircraft was still rolling towards Hangar No 3. He tried to turn away but the aircraft's right wing tip hit the side of the hangar; this caused the aircraft to pivot to the right and the propeller struck the hangar door. The pilot shut down the engine and vacated the aircraft.

ACCIDENT

Aircraft Type and Registration:	Europa XS, G-CHOX
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2007
Date & Time (UTC):	10 August 2008 at 1500 hrs
Location:	Near Sherburn-in-Elmet, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nosewheel damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	176 hours (of which 5 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent telephone enquiries by the AAIB

Synopsis

The pilot made a successful forced landing in a field following an engine failure due to oil starvation caused by the engine oil filter working loose. The reason why the filter worked loose could not be determined.

History of the flight

During the climb after takeoff from Sherburn-in-Elmet, when approaching 2,000 ft, the passenger commented that he could smell burning. This was followed almost immediately by smoke in the cockpit. The electrics were checked, but did not appear to be the cause. Oil could then be seen on the windscreen. The pilot turned back towards the airfield and transmitted an emergency call, just before, the engine stopped. He turned the aircraft into wind and selected a suitable field for a forced landing. A glide approach was made, followed by a successful landing in a field of unharvested wheat.

Inspection of the engine revealed that the oil filter had worked loose, allowing oil to escape under pressure. When strip examined, the engine was found to have suffered seizure of a connecting rod big end. This had caused extensive secondary internal damage, rendering the engine beyond economic repair. It was deduced that the seizure was the result of oil starvation.

Discussion

The oil filter is screwed on and does not have any locking device. Detailed fitting instructions are provided in the engine maintenance manual. The UK distributor of the engine is aware of only one other case of an oil filter working loose on this engine type. On that engine there was evidence that the threads had been damaged when installing the filter.

ACCIDENT

Aircraft Type and Registration:	Evans VP-1 Volksplane, G-BFJJ
No & Type of Engines:	1 Volkswagen 1800 piston engine
Year of Manufacture:	1979
Date & Time (UTC):	20 April 2008 at 1810 hrs
Location:	Near Farley Farm Airfield, Winchester
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft sustained substantial damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	467 hours (of which 4 were on type) Last 90 days - 5 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft took off from a farm strip at its maximum authorised weight. It then flew over a small valley and encountered a downdraught. The pilot considered that the aircraft might not clear the far side of the valley so he commenced a forced landing. During the forced landing the right undercarriage leg collapsed and the right wing came into contact with the ground. The aircraft structure failed where the pilot's shoulder harness was attached to the airframe and the pilot sustained minor head injuries.

One Safety Recommendation has been made.

History of the flight

The owner had planned to take the aircraft for a short flight to practise circuits. The weight of the aircraft, including the pilot and sufficient fuel for 40 minutes flight, was 340 kg, its maximum for takeoff. The weather conditions were good with a northerly wind of 10 kt, the temperature was 18ºC and the QFE was 1020 hPa.

Runway 06 was the runway in use at Farley Farm. This was a grass strip 665 m in length. The threshold of Runway 06 was 431 ft amsl and the threshold of reciprocal Runway 24 was 481 ft amsl; there was thus an upslope of approximately 2.25% when using Runway 06.

The aircraft's takeoff was described as normal, with the aircraft getting airborne well before a marker that is used by local pilots as an acceleration indicator. Once safely airborne, the aircraft turned to the left to join the circuit pattern and, in doing so, flew over a small valley. The pilot reported that the aircraft encountered a significant downdraught whilst crossing the valley and started to descend, despite the airspeed being 70 kt and the engine operating normally at full power. The pilot assessed that he would not be able to clear the far side of the valley safely and commenced a forced landing into a nearby field. During the landing the right main landing gear collapsed and the right wing tip dug into the ground, spinning the aircraft around. As a result of the impact, the top of the bulkhead, which included the rear wing strut carry-through-structure and the attachment for the pilot's restraint harness shoulder straps, failed and detached from the fuselage. The pilot was no longer restrained at the shoulders and, as a consequence, received minor head injuries but he was able to vacate the aircraft normally.

Aircraft description

G-BFJJ is a single engine, low wing monoplane, with two steel bracing struts on each wing (Figure 1). One end of each strut is fixed to the structure of the wing and the other end is connected to the fuselage. The front two bracing struts are connected to a carry-through-structure, which goes through the front of the cockpit, and to which the instrument panel is attached. The rear two bracing struts are connected to an extended bulkhead containing a carry-through-structure, which forms the rear face of the cockpit compartment. The shoulder straps of the pilot's restraint harness are attached to the rear carry-through-structure at the top of this bulkhead.

The aircraft was built from a kit in 1979 and flown regularly until its Permit to Fly expired in 1996. In December 2007, after a change of ownership, the aircraft's Permit to Fly was renewed.

Figure 1

Bracing strut orientation

Comment

Whilst not in place when the aircraft was originally issued with its Permit to Fly, the current design code used for the assessment of new aircraft of this category is CS-VLA. The criteria for emergency landing conditions are described in CS-VLA 561 General, and includes the following:

> *'(a) The aeroplane, although it may be damaged in emergency landing conditions, must be designed as prescribed in this paragraph to protect each occupant under those conditions.*
>
> *(b) The structure must be designed to give each occupant reasonable chances of escaping injury in a minor crash landing when*
>
> *(1) Proper use is made of seat belts and shoulder harnesses; and*
>
> *(2) The occupant experiences the ultimate inertia forces listed below –*
>
> *Ultimate Inertia Load Factors; Upward 3·0 g, Forward 9·0 g, Sideward 1·5 g.'*

The aircraft was damaged in the emergency landing. It was not possible to accurately determine the inertia loads experienced by the pilot, who was wearing a seat belt and shoulder harness, but it is unlikely they exceeded the specified limits. Due to the failure of the bulkhead to which the shoulder harness was attached, the pilot was no longer restrained at the shoulders, and, as a result, received minor head injuries. Accordingly the following Safety Recommendation is made:

Safety Recommendation 2009-001

It is recommended that the Civil Aviation Authority, in conjunction with the Light Aircraft Association, review the design of the shoulder harness attachment on the Evans VP-1 to ensure that the pilot is adequately restrained in the event of an accident.

Response to Safety Recommendation

The Light Aircraft Association, in consultation with the Civil Aviation Authority, reviewed the design of shoulder harness attachment on the Evans VP-1 and provided the following response:

> *'The Light Aircraft Association have reviewed the design of the shoulder harness attachment on the VP-1 but do not consider that a mandatory design change is appropriate because:*
>
> *1. As a permit to fly aircraft, full compliance with a design code is not required.*
>
> *2. The aircraft type has accommodated a substantial history of successful in-service experience, including in the UK, and shoulder harness issues have not previously been a significant safety issue in influencing the outcome of accidents, when they have occurred.*
>
> *3. In an aircraft of this class and configuration, occupant protection in an accident is inevitably poorer than in a conventional aircraft by virtue of the exposed cockpit and lack of turn-over protection, plus the proximity of the instrument panel to the pilot's face. Due to the latter, even if the shoulder harness had not failed it is considered likely that*

the pilot's harness will inevitably allow forward head motion as the harness 'takes up the slack'. Furthermore, there is a risk that a more effective shoulder harness in conjunction with the rather minimum turn-over protection could actually increase the danger of a head injury in a turn-over accident. A Tipsy Nipper pilot died a few years ago when his head struck the ground in a gentle turn-over accident when he might well have survived if he had been able to slump forward as the aircraft pitched over.

4. *The CS-VLA requirements do not specify that the harness attachments must remain intact following an accident in which major airframe disruption occurs, as in this case. It is common with light aircraft to use the attachments for wing and tail as the harness attachments, on the assumption that normally the airframe is still essentially intact at the instant that the shoulder harness is required to contain the pilot at initial impact.'*

ACCIDENT

Aircraft Type and Registration:	Extra EA 300/L, G-ZEXL
No & Type of Engines:	1 Lycoming AEIO-540-L1B5 piston engine
Year of Manufacture:	2006
Date & Time (UTC):	14 November 2008 at 1547 hrs
Location:	Sywell Aerodrome, Northamptonshire
Type of Flight:	Formation Aerobatic Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Shattered canopy and minor damage to the tail plane and rudder
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	4,755 hours (of which 615 were on type) Last 90 days - 119 hours Last 28 days - 14 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

An unsecured fuselage panel detached during a maximum energy manoeuvre. The panel struck and destroyed the canopy and caused damage to the aircraft. The pilot was protected effectively by the use of a helmet.

History of the flight

The aircraft was on its seventh flight following a 150 hr maintenance inspection. The previous six flights, flown over a nine-day period, had involved relatively low energy manoeuvring. Three 'A' checks as well as pilot pre-flight walkrounds had been conducted in this period with no relevant defects being noted. The incident flight, conducted over the aircraft's base airfield with ground safety precautions in place, was a formation display practice. As the aircraft conducted a maximum performance 'break', a three-foot square section of the forward fuselage detached. This fuselage section impacted the canopy, causing it to shatter, before the panel struck the rear fuselage and tail. The pilot immediately terminated the display and landed safely.

Loss of fuselage panel

Following the incident, the operator established that there was no damage to the holes for four screws that secured the front horizontal edge of the fuselage panel, known as the 'turtle deck'. A review by the operator found photographs from before the fourth flight following maintenance (the first on the day of the incident); the four screws appear to be missing in this photograph. It is therefore likely that the screws were either not correctly replaced following maintenance or were removed for unknown reasons at some point prior to the photograph being taken.

Maintenance action

The missing four screws secure a composite panel. The maintenance organisation stated that the correct technique for securing this panel was to replace the screws to "finger tight", then after adjusting the panel's positioning, torque the screws to the required value. As part of their release to service, the maintenance organisation conducts a final inspection which includes touching every panel and the inspector running their hand along screw lines. The maintenance organisation considers that the flexibility of the panel could have resulted in no screw head protrusion, even if torque to the screws had not been correctly applied.

Use of protective headgear

The pilot, who was occupying the rear of the two tandem seats, was wearing a full 'bone dome' style helmet. Following the incident, the helmet had witness marks from contact with the Perspex canopy as it shattered. It is likely that the use of this helmet protected the pilot from a significant head injury.

ACCIDENT

Aircraft Type and Registration:	Jodel D9 Bebe, G-BGFJ
No & Type of Engines:	1 Volkswagen 1600 (Peacock) piston engine
Year of Manufacture:	1982
Date & Time (UTC):	31 May 2008 at 1039 hrs
Location:	Tyndrain Farm, Trawsfynydd, Gwynedd
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Minor) Passengers - None
Nature of Damage:	Minor damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	72 years
Commander's Flying Experience:	351 hours (of which 15 were on type) Last 90 days - 3 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

During an approach to land at a farm strip, the engine reportedly lost power, resulting in the aircraft landing short in 'soggy' ground. The undercarriage became bogged down and the aircraft overturned, sustaining minor damage in the region of the cockpit aft bulkhead. On examining the engine, the pilot discovered a small crack in the right cylinder head, which he presumed had caused the power loss.

ACCIDENT

Aircraft Type and Registration:	1) Luscombe 8E Silvaire Deluxe, G-AKUI 2) Pacific Aerospace PAC 750XL, ZK-KAY
No & Type of Engines:	1) 1 Continental Motors Corp O-200-A piston engine 2) 1 Pratt and Whitney PT6A-34 turboprop engine
Year of Manufacture:	1) 1947 2) 2004
Date & Time (UTC):	16 December 2007 at 1158 hrs
Location:	Rectory Farm, near Rugeley, Staffordshire
Type of Flight:	1) Private 2) Private
Persons on Board:	1) Crew - 1 Passengers - 1 2) Crew - 1 Passengers - 2
Injuries:	1) Crew - 1 (Fatal) Passengers - 1 (Fatal) 2) Crew - None Passengers - None
Nature of Damage:	1) Aircraft destroyed 2) Left main landing gear separated, minor damage to nose landing gear and underside of fuselage and left wing
Commander's Licence:	1) Private Pilot's Licence 2) Private Pilot's Licence
Commander's Age:	1) 59 years 2) 39 years
Commander's Flying Experience:	1) 670 hours (of which 130 were on type) Last 90 days - Not known Last 28 days - Not known 2) 2,037 hours (of which 730 were on type) Last 90 days - 50 hours Last 28 days - 3 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot of ZK-KAY was flying under Visual Flight Rules (VFR) on a cross-country flight, tracking south-east, close to Blithfield Reservoir. The pilot and passenger of G-AKUI were on a local flight from their base near the reservoir. G-AKUI entered a turn to the right shortly prior to the collision, possibly to avoid a third aircraft which later radar analysis showed was near. Following the turn, with G-AKUI now on an easterly heading, the two aircraft collided. The weather was benign, with good visibility below a layer of cloud and a little haze. ZK-KAY sustained damage in the collision but landed safely at East Midlands Airport. G-AKUI sustained severe damage and was rendered incapable of flight; it fell to the ground and there was a fierce fire. Both occupants of G-AKUI died in the impact.

The investigation identified factors which may account for the failure of the 'see and avoid' principle.

History of the flights

ZK-KAY

ZK-KAY, a Pacific Aerospace PAC 750, departed from its base at Cark airfield, Cumbria, on a VFR flight to Cranfield, where it was to receive routine maintenance. The aircraft was flown by its owner, who occupied the left front seat. An acquaintance sat on a temporary seat at the very front of the passenger cabin and the acquaintance's child sat in the front right seat. ZK-KAY was fitted with strobe lights on each wingtip, and equipped with a Mode C transponder. At the beginning of the flight the pilot switched the transponder ON (Mode C) and selected the conspicuity code (7000).

Approaching the Manchester Control Zone, the pilot established radio contact with the Manchester approach controller. The pilot did not ask for, nor was he offered, a radar service. Nonetheless, the controller observed a secondary radar return which he believed to be ZK-KAY and he kept a mental note of its position as it tracked towards his airspace.

After flying down the Manchester Low Level Route, the pilot climbed to 2,000 ft and turned towards the destination; the aircraft's speed was approximately 160 kt. A short while later, the controller observed that the aircraft was now outside his area of responsibility, and suggested to the pilot that he might like to change frequency to another ATC unit. The pilot informed the controller that he wished to remain on the Manchester frequency for a little longer.

As the aircraft neared Blithfield Reservoir, the pilot glanced down at his map, and then heard a 'thud'. Thinking that his engine had failed, he immediately banked the aircraft to the left to look for a landing site. Having turned, he saw burning wreckage on the ground, and concluded that there may have been a collision. He examined the engine instruments, which all showed normal readings. He transmitted a 'MAYDAY' call to Manchester approach.

The pilot was aware that he was only a short distance west of Tatenhill aerodrome. He set course for Tatenhill, established communication with the air/ground radio operator and stated that he wished to land. As the aircraft flew towards Tatenhill, the pilot briefed his passengers for an emergency landing and evacuation.

The pilot established the aircraft on the approach, but the air/ground radio operator observed that the aircraft's left main landing gear was absent, and informed the pilot of this. The pilot broke off his approach and diverted to East Midlands Airport, where he believed the fire and rescue facilities better suited an emergency landing.

The pilot contacted ATC at East Midlands and informed them of his situation. The aircraft was identified on radar and then directed to the final approach for Runway 09. The Aerodrome Fire and Rescue Service (AFRS) were deployed for the aircraft's emergency landing. The aircraft touched down normally on its right and nose landing gear, and the pilot endeavoured to prevent it settling onto its left wingtip for as long as possible. When it did eventually settle, friction between the wingtip and runway surface caused the aircraft to yaw to the left. The aircraft came to a standstill, and all occupants vacated without injury. AFRS personnel observed a small fuel leak from the left wing fuel tank, and sprayed the aircraft with Aqueous film-forming foam (AFFF). There was no fire.

G-AKUI

This aircraft, a Luscombe 8E Silvaire, was owned by an individual who was not a pilot, but an engineer. He had purchased the aircraft some years previously, and had restored it to a very good condition. He had established an informal arrangement with the pilot (who had previously owned a similar aircraft) and the two often flew together in the aircraft. Passengers who had flown with the pilot commented that he was circumspect, and took care to look out in the direction of a turn before manoeuvring.

On the day of the accident, the owner and pilot went to the aircraft's base at Abbots Bromley, intending to have a short flight. They mentioned in conversation before departure that they did not intend to land away.

The aircraft was not fitted with a transponder. A GPS receiver, capable of recording the aircraft's flight, was on board but was destroyed in the accident. Therefore, no definite information exists as to the altitudes at which the aircraft was flown.

Radar information indicates that the aircraft took off from Abbots Bromley at about 1150 hrs. At 1155 hrs, the aircraft was flying on a southerly track in the vicinity of Blithfield Reservoir. Radar information shows that another aircraft, not ZK-KAY, with a relatively lower groundspeed and giving a smaller radar return, was flying on a north-westerly track, to the south-east of G-AKUI. Thus, the two aircraft were flying towards each other, until, more or less simultaneously, the other aircraft commenced a turn to the left, and G-AKUI commenced a turn to the right.

G-AKUI's turn continued until the aircraft was on a roughly easterly heading; the other aircraft had continued its left turn during this time. G-AKUI and ZK-KAY then collided. In the collision, the left wing of G-AKUI was substantially damaged, and the aircraft was rendered incapable of further flight. The aircraft, missing some pieces of the left wing, fell to the ground and caught fire. The impact with the ground was not survivable. Fragments of the left wing structure and covering fell to the ground to the west of the main wreckage site.

History of the flight – the third aircraft

Further examination of radar data, and investigation at local airfields, identified the third aircraft. It was found to be a microlight, which was on an instructional flight from its base in the Lichfield area. Both the instructor and student were interviewed; they had been on a flight during which the instructor was teaching the student to conduct turning manoeuvres.

As the aircraft neared Blithfield Reservoir it had climbed to approximately 1,800 ft. Both on board remembered flying near the reservoir but neither had seen any other aircraft during the flight.

Recorded flight data

Neither of the aircraft involved in the collision were required to be equipped with a flight recorder. ZK-KAY was equipped with GPS navigation equipment, but this equipment was not capable of recording track data. The GPS device on board G-AKUI was capable of recording track data, but was destroyed in the fire. The third aircraft was equipped with a handheld GPS device capable of recording track data, but this was not switched on during the flight.

Investigation by NATS (the provider of enroute air navigation services in the UK) showed that the collision was not recorded by any of the NATS enroute radars. However, AAIB investigation identified that a radar 'feed', provided commercially by Birmingham ATC to a third party, was recorded. The quality of the recording was adequate for some analysis of the collision and is shown as Figure 1.

Figure 1

Images of radar recording at 24 second intervals

The Birmingham radar recording showed all three aircraft involved, until the time of the collision. At the moment of collision the radar returns of ZK-KAY and G-AKUI merged, and after this moment only the primary return of ZK-KAY was recorded (the SSR antenna on ZK-KAY was broken off in the collision, and SSR transmissions from the aircraft ceased).

Figure 1 shows images of the radar recording at intervals of 24 seconds, immediately prior to and including the collision; the time is shown in the bottom left corner of each image. Figure 2 shows an overview of the collision and debris field, relative to ground features.

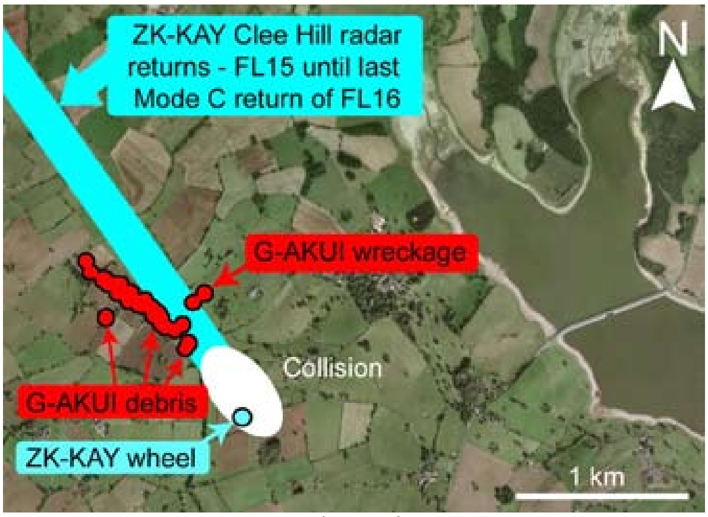


Figure 2

Collision overview

(Note: Radar FL figures are QNH corrected)

Google Earth ™ mapping service / Image © 2008 Infoterra Ltd & Bluesky

Aircraft information

Luscombe Silvaire 8E, G-AKUI (Figure 3)

G-AKUI was a single-engine, two-seat monoplane with a tailwheel landing gear and a high wing; it was manufactured in 1947. The aircraft was of all metal construction, with the exception of the wings which comprised a metal structure covered with fabric.

Figure 3

Luscombe Silvaire 8E, G-AKUI

G-AKUI was predominantly medium blue in colour with silver markings, and was equipped with a white anti-collision beacon mounted on the top of the fuselage. The windows comprised a wrap-around front windscreen, a side window in each cabin door, a small rear quarter window on each side and a rectangular skylight window in the cabin roof. It was known to be carrying a radio, but was not believed to be equipped with an ATC transponder.

The aircraft held a current Permit to Fly, valid until 30 March 2008.

Pacific Aerospace Limited PAC 750XL, ZK-KAY (Figure 4)

ZK-KAY was an all-metal, low-wing utility aircraft with a fixed tricycle landing gear. This type of aircraft is powered by a single 750 horsepower PT6A-34 turboshaft engine mounted in the nose, driving a 106-inch diameter, three-bladed, constant-speed propeller. Air is supplied to the engine via a chin-mounted intake duct and a fibreglass oil cooler outlet duct is mounted immediately behind the nose landing gear. ZK-KAY was configured for skydiving operation and as such was equipped with only two seats; one on the left side of the cockpit for the pilot and another on the right side for a front passenger. The windows comprised a wrap-around windscreen, a single large window on each side of the cockpit and several windows along the length of the cabin.

The fuselage was predominantly dark blue with yellow stripes and the wings were yellow with dark blue stripes. The aircraft was equipped with a radio and an ATC transponder, the antenna for the latter being mounted on the belly of the fuselage. The external lighting included navigation and anti-collision strobe lights mounted on each wingtip and a forward facing landing light located in the outer leading edge of each wing.

The aircraft had a valid, non-terminating Certificate of Airworthiness, issued by the Civil Aviation Authority of New Zealand on 8 June 2004.

Figure 4

Pacific Aerospace Corporation PAC 750XL, ZK-KA

Aircraft wreckage

G-AKUI

G-AKUI crashed on farmland approximately 2.5 miles north of Rugeley and one mile west of Blithfield Reservoir in Staffordshire. At the point of impact the aircraft was travelling at high speed, in a steep nose-down attitude and yawed slightly nose to the right. The forward fuselage and cabin area were largely destroyed by the impact and post-crash fire. The outer 9 feet of the left wing could not be accounted for at the crash site.

ZK-KAY

ZK-KAY exhibited several areas of obvious collision-related damage.

One of the propeller blades was missing the tip, and chordwise blue paint transfer marks and leading edge impact damage were present on the outer two-thirds of the blade span. A section of one of the internal bracing rods from G-AKUI's left wing was wrapped around the blade.

Scrape marks and paint transfer from G-AKUI were visible on the lower surface of the chin intake and along the lower right side of the fuselage, stopping short of the wing (Figure 5). The marks were angled approximately 30° to the aircraft's longitudinal axis.

The ATC transponder antenna and oil cooler outlet duct were missing and a 16 inch longitudinal gash was visible in the fuselage belly skin aft of the nose gear.

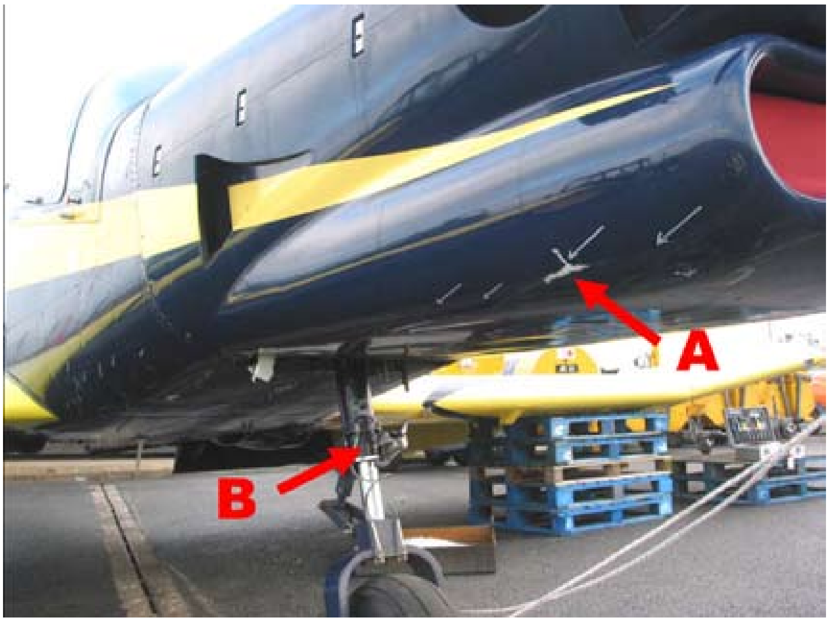


Figure 5

ZK-KAY nose view
Showing scrape marks (A) and nose gear shimmy damper damage (B)

Impact damage and deformation was visible on the nose gear strut and shimmy damper mechanism. The direction of the deformation was consistent with impact forces acting from right to left and front to rear relative to ZK-KAY's direction of travel. The entire left landing gear was missing, having been forcibly detached from its mountings.

The leading edge of the left wing was punctured immediately outboard of the leading edge root fairing, causing a minor fuel leak from the integral fuel tank.

Collision debris

A search of the surrounding countryside revealed numerous fragments of wreckage distributed over a ½ mile trail running from northwest to southeast, the centre of which was located approximately ¼ mile to the west of the crash site of G-AKUI, shown in Figure 2. The debris consisted of parts of G-AKUI's left outer wing and included the wingtip, pieces of wing structure, fabric and large fragments of the left aileron, one of which had a piece of ZK-KAY's oil cooler duct trapped in it.

One piece of wing leading edge fabric was found with an impression of a tyre tread on it, with accompanying rubber transfer on the fabric outer surface.

ZK-KAY's left landing gear was found approximately ⅓ mile beyond the southern end of the G-AKUI debris field, on the extended axis of the wreckage trail. Scrape marks and blue paint transfer were visible on the lower part of the landing gear and on the brake unit.

Engineering analysis

Collision parameters

The left wing of G-AKUI was reconstructed (Figure 6) to enable the pattern of damage to be compared with that of ZK-KAY, in order to deduce the dynamics of the collision.

The position and pattern of the scrape marks on ZK-KAY's chin intake and fuselage indicated that

G-AKUI approached from ZK-KAY's right side and that the outer 9 feet of its left wing was in collision with the lower right side of ZK-KAY's fuselage, with G-AKUI in an approximately wings-level attitude and slightly below ZK-KAY. G-AKUI's precise pitch attitude could not be determined, but it was not extreme. Assuming that ZK-KAY was travelling around twice the speed of G-AKUI, the direction of the scrape marks suggests that G-AKUI was tracking approximately at right angles to ZK-KAY at the point of collision.

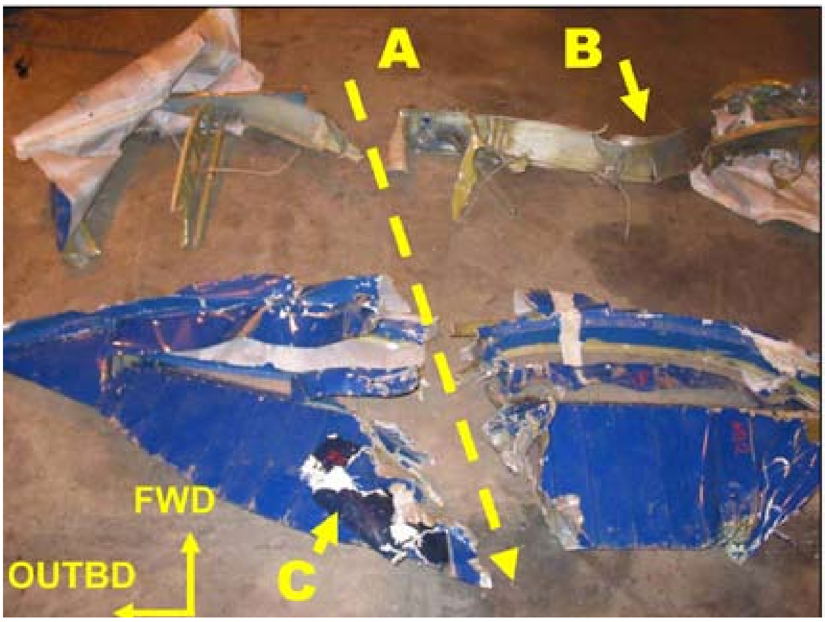


Figure 6

G-AKUI left outer wing

Showing damage caused by ZK-KAY nose gear (A), left main gear (B) and fragment of ZK-KAY oil cooler duct trapped in aileron (C)

The patterns and locations of the damage observed on both aircraft are consistent with G-AKUI's left wing having been in contact with ZK-KAY's propeller blade and nose landing gear. G-AKUI passed under ZK-KAY with the latter's nose gear cutting a swathe of damage through the outer part of G-AKUI's left wing, transecting the aileron and causing ZK-KAY's oil cooler duct to be torn off, a part of which became trapped in the aileron (Figure 6).

The impact between G-AKUI's left wing and ZK-KAY's nose gear caused G-AKUI to yaw to the left so that the flight paths of the two aircraft became more parallel. ZK-KAY's left tyre then struck the leading edge of G-AKUI's left wing slightly inboard of the first swathe of damage, causing ZK-KAY's left landing gear to be torn from its mounts and inflicting further, significant damage to G-AKUI's wing. Structural items from this area of the wing were found, with deformation matching the curvature of ZK-KAY's tyre. The piece of wing fabric with the tyre impression was also identified as being from this area. The longitudinal gash in ZK-KAY's fuselage belly skin and the puncture in the left wing leading edge were consistent with contact with the disrupted structure of G-AKUI's left wing.

It is probable that the damage sustained by the left wing of G-AKUI would have rendered this aircraft uncontrollable.

Visibility from the pilot's position

AAIB investigators took photographs from the forward end of the passenger cabin in ZK-KAY (Figure 7), and the approximate pilot's eye position in an aircraft similar to G-AKUI (Figure 8).

Eyewitness information

No eyewitnesses saw the collision take place. One person saw the wreckage of G-AKUI falling to the ground, whilst others saw ZK-KAY in flight after the collision had taken place.

Figure 7

View from cabin of ZK-KAY

Note - view from the pilot's eye position (left and lower) is compromised by the windscreen strut and engine cowling

Figure 8

View from pilot's position in an aircraft similar to G-AKUI.

Note - the view left and above is compromised by the aircraft wing, door pillar, and strut. G-AKUI was not fitted with the semi-transparent sun blind

Limitations of lookout

The AAIB investigation into a collision between a Cessna 152 aircraft and an Aerotechnik Eurostar on 18 December 2005[1] examined visual flight, collision avoidance, and lookout, in some detail. It noted that:

> *'there are limitations in the human visual system that serve to make collision avoidance difficult by visual means alone.'*

and that:

> *'small targets may be hidden behind aircraft structure, such as the engine cowlings, canopy arches, wings, or struts, until very late.'*

For these reasons some pilots use special techniques with the aim of improving their lookout. When interviewed, the pilot of ZK-KAY stated that he had not been taught a particular lookout technique.

A pilot who perceives an urgent need to avoid a collision with another aircraft is likely to manoeuvre his aircraft solely to avoid the immediate threat and is unlikely to carry out a specific lookout in his intended direction of turn. The probability of encountering another aircraft during avoiding action is, generally, slight.

Meteorological information

An aftercast from the Met Office indicated that the weather conditions across the UK were influenced by a large area of high pressure centred over Denmark. The resultant airflow was a south easterly polar continental air mass across the United Kingdom and the accident site. A marked inversion trapped a layer of sub-zero stratocumulus cloud across the greater area over and around the accident site. It was estimated that there were 7 or 8 oktas of stratocumulus cloud at the accident site with a base between 2,000 and 2,500 ft. Surface visibility was estimated to be between 7 and 10 km.

Footnote

[1] AAIB Bulletin 11/2006, EW/C2005/12/01.

A number of pilots who were airborne in the area at the time of the accident, or shortly afterwards, were interviewed. Most gave accounts of visibility ranging from 7 to 10 km, and all spoke of cloudbase somewhat above 2,000 ft. Only one spoke of a difference between the visibility 'into-sun' and 'down-sun', stating that 'into-sun' the in flight visibility was as little as 3 km, and 'down-sun it was about 7 km.

Medical and pathological information

The pilot of ZK-KAY was tested for alcohol after the accident; the test was negative. Otherwise, he was not medically examined.

The pathology reports on the pilot and passenger of G-AKUI did not reveal any abnormalities.

Rules of the Air

The Rules of the Air Regulations require aircraft in VFR flight at more than 140 kt, below 3,000 ft amsl, in Class G airspace, to remain clear of cloud, in sight of the surface, and in a flight visibility of at least 5 km.

It is possible (discussed in Analysis, below) that the occupants of G-AKUI spotted the '3rd aircraft' identified in Figure 1. Regarding avoidance of collision, and in respect of powered aircraft, the Rules state:

> *'When two aircraft are approaching head-on or approximately so in the air and there is danger of collision, each shall alter its course to the right.'*

Radar services

The UK IAIP (International Aeronautical Information Publication) gives details of the Lower Airspace Radar Service (LARS), which makes a Radar Advisory Service or a Radar Information Service available to pilots flying up to and at FL95[2] in certain areas. Blithfield Reservoir is theoretically within the range of Shawbury LARS, but the service is not available at a weekend.

ATC at Birmingham do not promulgate the availability of a LARS, although, subject to workload, the controllers there will endeavour to provide a service if a pilot requests it. Such provision will be the lowest of their ATC priorities, and the service may be limited, in accordance with the instructions published in the Manual of Air Traffic Services.

Visual conspicuity

The RAF Institute of Aviation Medicine published two unclassified reports on aircraft conspicuity[3]. The first examined the possible benefits of powerful forward-facing lights and the use of black paint on aircraft. The report concluded that both gave *'statistically significant advantages'* in terms of conspicuity, over aircraft without lights and those painted grey, respectively. The second report concluded that:

> *'Matt black paint schemes are in general more conspicuous than grey/green disruptive pattern[4], dark sea grey, and red, white and blue.'*

Another study[5] found that an aircraft with a black underside was more conspicuous than a white one, and that reflective tape applied to an aircraft's wings also aided conspicuity.

Footnote

[2] Military Middle Airspace Radar Service is available above FL95.

[3] IAM Report 723 *'A trial to assess aids to conspicuity'* and Report 747 *'Aircraft conspicuity and paint schemes'*.

[4] camouflage.

[5] Cranfield University *'Glider conspicuity trials held at RAF Bicester'*.

Electronic conspicuity and collision prevention

Electronic conspicuity involves the carriage and operation of devices such as transponders and 'FLARM' (a device developed initially for gliders). These devices make aircraft 'electronically conspicuous' to other aircraft which are equipped with the means of detection of, or interaction with, the equipment on the subject aircraft. These systems require electric power and the fitting of wiring and antennae, which demand spare capacity from the aircraft's power sources; they also add weight to the aircraft.

Aircraft owners may fit equipment such as TCAS, transponder proximity receivers, and FLARM, which assist their pilots in gaining awareness of other aircraft around them, and, in the case of TCAS, provide guidance to assist in avoiding collisions. Some lightweight devices are available, including some which carry their own battery power supplies.

TCAS is in very limited use in recreational aircraft, transponder proximity receivers are used by a small number of pilots, and FLARM, although gaining popularity amongst glider pilots, is finding less widespread acceptance outside gliding. It is widely accepted that the introduction of TCAS in commercial air transport aircraft has markedly reduced the probability of collision involving a TCAS-equipped aircraft and another transponding aircraft.

Mode S transponders and mandatory carriage

Following a previous mid-air collision, a CAA working group reviewed the recent history of mid-air collisions between recreational aircraft. The review determined that UK-registered aircraft had been involved in a total of 30 mid-air collisions in the period 1995 to 2004, resulting in 27 fatalities from 14 fatal accidents. Thus, collisions averaged three per year, and roughly half of the collisions involve at least one fatality.

Following the accident to G-AKUI and ZK-KAY, AAIB investigators discussed mid-air collisions involving recreational aircraft, and electronic conspicuity, with staff at the CAA's Directorate of Airspace Policy. The Directorate staff explained that, although they perceived a widespread concern about mid-air collisions amongst participants in recreational aviation, they were also aware of strong opposition from aircraft owners to mandatory requirements to fit transponders, on the grounds of complexity, cost, and weight. For these reasons, proposals to mandate widespread carriage of Mode S transponders had been withdrawn, and more limited proposals had been put forward for consultation. These proposals did not amount to an effort to reduce the collision risk between recreational aircraft, but only to protect aircraft operating inside controlled airspace from collision with recreational aircraft. The consultation was still under way at the time of this report's publication.

Any airborne collision avoidance system will only be effective provided that virtually all aircraft carry the necessary equipment. While few aircraft do so, there is relatively little benefit to those aircraft owners who do choose to fit it.

Analysis

Until the collision, the flights of both ZK-KAY and G-AKUI were unremarkable. The aircraft were airworthy, the pilots qualified and experienced, and the weather was appropriate for the flights. In particular, it is clear that the weather conditions satisfied the relevant legal requirements for VFR flight.

The radar data showed that the collision occurred whilst ZK-KAY was in straight and level flight, but very soon after G-AKUI had completed a turn to the right. The turn executed by G-AKUI's pilot may have been carried out in the normal course of his flight, not prompted by any particular cause. However, radar evidence showed that this turn began as G-AKUI flew towards the third aircraft at short, and decreasing, range. The absence of information about the altitude at which G-AKUI began the turn is unhelpful. The collision occurred at approximately 2,000 ft, and the third aircraft's crew reported that it was at 1,800 ft in the area where the collision occurred. It is possible that G-AKUI was at about 1,800 ft, and its pilot saw the third aircraft coming towards him and decided to take action to avoid it. In these circumstances, a turn to the right would have been the correct action. The fact that the third aircraft then turned to the left, effectively increasing the duration of its encounter with G-AKUI, could explain the relatively tight nature of the turn by the pilot of G-AKUI, and the fact that it continued through perhaps as much as 300°.

When a pilot takes avoiding action, he is less likely than normal to look out prior to manoeuvring his aircraft. In this circumstance, his priority lies in avoiding a seen 'threat', and the presumption, at least in the short term, that no other 'threat' exists in the direction of the turn, is normal.

The dynamic situation in which the two aircraft collided may also have been critical: G-AKUI was to the right of ZK-KAY's path, and thus less visible to the pilot of ZK-KAY than if it had been to the left. In particular, if G-AKUI was climbing slightly following an encounter with the third aircraft at about 1,800 ft, this would place G-AKUI below and to the right of the nose of ZK-KAY, probably obscured by ZK-KAY's engine cowling. In a high-wing aircraft such as G-AKUI, lookout in the direction of any turn is impeded severely by the aircraft structure.

The collision occurred as the pilot of ZK-KAY glanced at his map, a natural part of the navigation task. There is insufficient evidence to determine whether this was a contributory factor in this accident.

Studies have shown that dark coloured aircraft are more conspicuous than light coloured ones. Both aircraft involved were relatively dark in predominant colour, although the areas of yellow paint on ZK-KAY may have had the effect of breaking up the areas of dark blue paint, and reducing the benefit of the darker colour scheme. It is probable that both aircraft were more visually conspicuous than white aircraft, which are considerably more common.

It is possible that collision might have been avoided by ATC intervention, as all three aircraft were visible, on radar, at Birmingham. However, Birmingham ATC is not normally able to provide a LARS, and it is understandable that pilots do not routinely request a radar service from them.

In summary, technology would appear to offer a robust means of reducing the risk of mid-air collisions, but this depends upon the widespread fitting of airborne devices. Proposals for mandatory carriage of Mode S transponders[6] outside controlled airspace met with widespread opposition from the recreational flying community; the CAA has withdrawn those proposals and no Safety Recommendation is made in this regard.

Footnote

[6] Summary of Responses Document for the Consultation on a proposal to amend of The Air Navigation Order 2005 For The Purpose Of Improving The Technical Interoperability Of All Aircraft in UK Airspace (http://www.caa.co.uk/docs/810/Summary%20of%20Responses%20Document.pdf)

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-140 Cherokee, G-BOSR
No & Type of Engines:	1 Lycoming O-320-E2A piston engine
Year of Manufacture:	1966
Date & Time (UTC):	1 July 2008 at 1235 hrs
Location:	Old Sarum Airfield, Wiltshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Student pilot
Commander's Age:	31 years
Commander's Flying Experience:	50 hours (of which 37 were on type) Last 90 days - 22 hours Last 28 days - 22 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent telephone enquiries

Synopsis

The accident occurred whilst the solo student pilot was attempting to take off with a significant crosswind. He lost directional control of the aircraft, causing it to depart the runway and strike a fence.

History of the flight

The accident occurred at Old Sarum Airfield which has a single grass runway, oriented 06/24. Runway 24 was in use at the time.

On the morning of the accident the student flew 17 circuits, 13 of which were solo. He had completed his first solo flight the day before. Following a lunch break he flew two further circuits with the instructor, who then authorised him for a further hour of solo circuit flying.

The solo student commenced the takeoff roll and as the aircraft accelerated along the runway, it veered to the left. He reportedly applied right rudder, but the aircraft did not respond. He retarded the throttle and attempted to stop, but was unable to prevent the aircraft from departing the left side of the runway and colliding with a hedge and fence situated around 50 metres from the left edge of Runway 24. There was no fire. The ATC operator sounded the crash alarm and the airfield emergency services attended the scene.

ATC records reportedly showed that the surface wind had been close to 90° to the runway for most of the day. At the time of G-BOSR's takeoff for the dual flight in the afternoon, the indicated windspeed was 15 kt, occasionally gusting to 25 kt. When the student pilot commenced his solo takeoff, the gusts had apparently died away. The surface wind registered at the time was 160° at 15 kt and this was passed to the pilot. The Flight Manual for the aircraft type states that:

> *'The maximum crosswind component in which the aeroplane has been demonstrated to be safe for take-off and landing is 17 knots at a tower height of 33 feet.'*

Based on the indicated wind, the crosswind component would have been only around 2 kt below the demonstrated maximum value.

The ATC operator reported that when he returned to the control tower around 20 minutes after attending the accident, the maximum windspeed indicator registered 32 kt. The time at which this gust had occurred was not recorded.

The aircraft suffered impact damage to both wing leading edges, the propeller and the engine cowling and was beyond economic repair. Wheel tracks from the aircraft found by the airfield authorities reportedly curved smoothly away from the runway heading. An eyewitness reported that the veer to the left started before the aircraft reached the midpoint of the runway, at an estimated ground speed of 45-50 kt, and that none of its wheels left the ground. He considered that the aircraft appeared somewhat nose-low during the ground run. With this type of aircraft, excessive load on the nosewheel due to insufficient back pressure on the control yoke can cause a reduction in directional controllability.

Difficulties were experienced in obtaining full information on the circumstances of the accident from either the student or the instructor, but it appeared that the crosswind and pilot's lack of experience in such wind conditions were significant contributory factors to the accident. The reasons for the student having been authorised to fly solo in such conditions could not be established.

ACCIDENT

Aircraft Type and Registration:	Piper PA-30 Twin Comanche, N230MJ
No & Type of Engines:	2 Lycoming 10-320-B piston engines
Year of Manufacture:	1967
Date & Time (UTC):	10 July 2008 at 1330 hrs
Location:	Runway 21, Lydd Airport, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Two bent propellers and damage to the underside of the aircraft
Commander's Licence:	Private Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	873 hours (of which 22 were on type) Last 90 days - 10 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft inadvertently landed with the gear retracted, following a circuit breaker 'pop' in the landing gear electrical system.

History of the flight

Returning to Lydd Airport after a local flight, the pilot reports that he first performed a successful touch-and-go landing on Runway 21 and, for the final landing, he decided to practise an asymmetric approach. He recalls selecting the landing gear down at the start of the descent on this final approach.

Just before touchdown, ATC noticed that the aircraft's landing gear was still retracted and issued a go-around instruction. The pilot applied power on both engines, resulting in an asymmetric condition and a developing roll, so he retarded both throttles and landed the aircraft, which remained upright but then veered onto the grass at the right side of the runway, striking a runway light. After coming to a stop on the grass, the pilot secured the aircraft and he and his passenger were able to leave normally by the cabin door, assisted by the airport fire crew.

It was later found that the circuit breaker for the landing gear motor had 'popped', resulting in the landing gear legs remaining in the 'up and locked' position. The maintenance organisation confirmed that this had occurred before on this aircraft. The pilot considers that he did not detect that the landing gear had not extended on being selected down partly because were that the absence of the normal pitch change was masked by the start of the descent and partly because the single 'gear down' light in this aircraft was dim and was further masked by bright sunlight.

There were two sets of propeller strike marks identified on the runway surface. The pilot considers that the first was very close to the point where the 'go-around' was called. He considers it likely that the thrust asymmetry was at least partly due to the propeller damage, confirming the decision to retard the throttles and accept the landing.

ACCIDENT

Aircraft Type and Registration:	Spitfire Mk 26 (scale replica), G-CENI
No & Type of Engines:	1 Jabiru piston engine
Year of Manufacture:	2007
Date & Time (UTC):	5 May 2008 at 0945 hrs
Location:	Approximately 1.5 miles west of Aboyne Airfield, Aberdeenshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to front cowling and propeller
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	17,643 hours (of which 1 was on type) Last 90 days - 6 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was on its second flight after construction when, at 2,000 ft after an uneventful takeoff and climb, the engine oil temperature increased into the caution range. During the precautionary return to the airfield, and as the landing gear was lowered and locked down, the pilot heard a "bang". As the aircraft descended in the overhead the pilot became aware that throttle movements were having no effect on engine thrust and on base leg he became aware that the propeller was missing. He subsequently carried out a safe glide approach and landing.

History of the flight

The accident flight was the second flight after the aircraft's construction. All the pre-flight checks were completed and the takeoff, the 'after takeoff' checks and the climb to 2,000 ft were uneventful. The pilot levelled the aircraft at 2,000 ft, accelerated to 130 kt and reduced the power to 23 inches of manifold pressure and 2,300 rpm. He felt a slight vibration but nothing that alarmed him. He noticed that the cylinder head temperature was normal but the engine oil temperature had started to rise into the 'caution' range and he decided to initiate a return to the airfield, reducing the power to idle. At about 1,000 ft and 80 kt he lowered the landing gear. As the landing gear locked in the DOWN position there was a "bang (not loud)". As this was the first time that the landing gear had been lowered in the air the pilot double-checked that all the indications were satisfactory for a continued approach, which they were. He did not notice any unusual vibration or engine noise. When the aircraft was overhead the airfield the pilot became aware that there was no change in engine parameters in response to throttle movement, that the engine had stopped, and on base leg he became aware that the propeller was missing. A successful glide approach and landing were carried out.

Engineering examination

Examination of the aircraft revealed that the propeller, together with the 'propeller to engine' adaptor flange and 'adaptor flange to crankshaft' attachment bolts, were missing. There was impact damage to the forward right side of the engine cowling. The propeller assembly has not been recovered.

The engine was transported to the manufacturer's UK agent for examination. It was seen that, of the twelve threaded holes in the crankshaft flange, only two showed evidence of distressed threads. The only evidence of 'Loctite' (a proprietary locking compound used in assembly) was at the bottom of the threaded holes and it had the appearance of the grade of 'Loctite' used by the engine manufacturer. There was no evidence of locking compound within the upper threads of any of these holes.

Other information

In this combination, once the propeller is fitted to the 'propeller to engine' adaptor flange it is not possible to inspect the 'adaptor flange to crankshaft' attachment bolts.

Light Aircraft Association (LAA) safety actions

The LAA have published an article as a 'Safetyspot' in the Engineering Matters section of their August 2008 edition of the magazine '*Light Aviation*', highlighting the problem of inspecting the security of the attachment bolts between propeller adaptor flanges and engine crankshafts when propellers are fitted. The LAA propose to incorporate an item in their Inspectors' Notes (SPARS) highlighting this potential problem area.

ACCIDENT

Aircraft Type and Registration:	Starduster Too, G-BTGS
No & Type of Engines:	1 Lycoming HIO-360-E1AD piston engine
Year of Manufacture:	1978
Date & Time (UTC):	12 October 2008 at 1552 hrs
Location:	Runway 20, Shoreham Airport, Sussex
Type of Flight:	Unknown
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Landing gear collapsed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	321 hours (of which 150 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was returning to Shoreham after a short local flight. Following a normal approach, it touched down briefly, bounced and finally landed, whereupon the left landing gear began to collapse. The aircraft veered off the left side of the runway and the right landing gear collapsed before the aircraft came to rest after a ground roll of approximately 50 m. The pilot judged the landing had not been particularly firm, despite the bounce.

It was found that part of the underside of the tubular steel fuselage framework, to which the landing gear had been attached, had failed at a weld joint. Part of the fracture surface appeared darker than elsewhere, indicating that that a crack in the weld had been present for some time. This area had been repaired following a previous accident at Staverton on 15 October 1986, when registered as G-AYMA.

ACCIDENT

Aircraft Type and Registration:	Tri-R Kis Cruiser, G-BYZD
No & Type of Engines:	1 Lycoming IO-360-A1B6 piston engine
Year of Manufacture:	2001
Date & Time (UTC):	4 July 2008 at 1035 hrs
Location:	Near Upfield Farm, Whitson, Gwent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	340 hours (of which 18 were on type) Last 90 days - 16 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After a precautionary touchdown at his departure airstrip, due to suspicions about engine performance, the pilot decided to continue into a rolling takeoff. During initial climbout the engine suffered a loss of power and, in the subsequent forced landing, the aircraft hit a tree before impacting the ground. The pilot and passenger were uninjured but the aircraft was destroyed by fire.

History of the flight

The pilot intended to fly to Filton airfield, Bristol. On the morning of the flight he conducted a comprehensive check of the aircraft, including fuel drains and physically checking fuel contents. The gauge readings of 65 litres (right tank) and 55 litres (left tank) agreed with the visual check. The internal checks were all normal, the engine temperatures and pressures were within the normal operating range and the propeller was cycled. An uneventful takeoff with one stage of flap was executed.

However, on the climbout, the pilot sensed that the aircraft was climbing somewhat slower than usual and, since he would be crossing the Bristol Channel, he decided it would be prudent to return to the airstrip for further investigation even though all engine parameters were normal. A normal approach and line-up on Runway 23 was carried out, followed by a successful touchdown. During the extended ground roll the pilot decided to do a go-around with one stage of flap selected. The pilot reports that during the climbout there was a significant loss of power and the aircraft descended. In order to avoid the hangars and other buildings, the pilot took avoiding action which resulted in the left wing hitting a tree, spinning the aircraft through 180° as it fell to the ground tail-first. Despite the fact that the aircraft burst into flames immediately, the pilot and passenger were able to evacuate without injury but the aircraft was consumed by fire. Because of the severity of the fire, no attempt has been made to diagnose the reason for the loss of power.

ACCIDENT

Aircraft Type and Registration:	Eurocopter AS350B2 Squirrel, G-CBHL
No & Type of Engines:	1 Turbomeca Arriel 1D1 turboshaft engine
Year of Manufacture:	1992
Date & Time (UTC):	15 September 2007 at 1505 hrs
Location:	Lanark, Scotland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 3
Injuries:	Crew - 1 (Fatal) Passengers - 3 (Fatal)
Nature of Damage:	Helicopter destroyed
Commander's Licence:	See text
Commander's Age:	39 years
Commander's Flying Experience:	965 hours (of which 490 were on type) Last 90 days - 50 hours estimated Last 28 days - 15 hours estimated
Information Source:	AAIB Field Investigation

Synopsis

The helicopter crashed in a wooded valley while manoeuvring at high speed and low height. It was intact prior to impact, and the available evidence indicated that the engine was delivering power. The cause of the accident was not positively determined. Although no technical reason was found to explain the accident, a technical fault could not be ruled out entirely. However, it is more likely that the pilot attempted a turning manoeuvre at low height, during which the helicopter deviated from his intended flight path. This may have been due to the pilot encountering handling difficulties, misjudgement, spatial disorientation, distraction or a combination of factors. There were indications that the pilot had started a recovery but, with insufficient height in which to complete it, the helicopter struck trees in the valley and crashed, killing all four occupants. Four Safety Recommendations are made.

History of the flight

The accident occurred towards the end of a short flight, about 150 metres from the point of intended landing. The helicopter crashed at high speed in a wooded valley that ran adjacent to the pilot's home, where a dedicated helicopter pad and hangar were situated.

Earlier in the day, the pilot had arranged to visit a friend at a farm complex near Larkhall, 8 nm from his home in Lanark. The pilot regularly flew G-CBHL for business and domestic purposes, so it was not unusual when he decided to use it for the short return journey.

He had spent the first part of the day at home with two male friends, one of whom accompanied him in the helicopter. Also on board were two children: the pilot's five year old son and a friend, aged six years.

There were no surviving witnesses to the pilot's pre-flight preparations, although the adult passenger had a camcorder on which he recorded part of the pilot's cockpit checks prior to takeoff, along with portions of the two flights (see '*Recorded information*'). When the helicopter took off, at about 1400 hrs, the pilot occupied the front right (pilot's) seat, the adult passenger was in the front left seat and the two children sat in two of the three rear seats. The outbound flight took about six minutes. The helicopter was on the ground at the destination for just less than an hour. The pilot was reported as being his normal self during this period and said nothing relating to the helicopter.

The helicopter took off again at 1500 hrs for the short return flight. Apart from an automotive gearbox, which had been loaded into the rear compartment, the aircraft and passenger configuration was unchanged. A number of witnesses, including several in the Lanark area, saw the helicopter during the flight. It approached Lanark from the west, before turning and descending into the Mouse Water valley, which ran past the north side of the town and the pilot's home. When last seen, the helicopter was generally described as flying faster than expected, in a banked, nose-low attitude. There were no witnesses to the accident itself, which occurred in the valley, and in which all four occupants suffered fatal injuries. There was an extensive post-crash fire that consumed a large part of the aircraft structure.

Accident site details

The aircraft had crashed into steeply sloping, heavily wooded ground on the south bank of the Mouse Water valley, approximately 1.5 nm north of Lanark, Figure 1. The initial impact, which was on a track of about 110°(M), had occurred with the upper branches of two substantial trees: the left side of the rotor disc had impacted the trunk of a fir about 30 ft from its top, with the fuselage and the rest of the rotor disc striking an oak tree, dislodging a large bough together with several smaller branches. The damage to the rotor head resulted in a complete main rotor blade being released, which then flew above the tree tops, landing in a field approximately 150 m beyond the initial impact point. The main gearbox was torn from its mountings on impact with the trees and fell to the ground nearby.

The tail boom had separated into two major sections at the initial impact. The remainder of the aircraft, comprising the cabin section and engine struck the rising ground of the valley side among smaller trees and saplings, before nosing over into an inverted attitude about 45 metres from the initial impact point. A severe fire developed, which destroyed most of the cabin structure, interior furnishings and the instruments. The engine lay close to the furthest edge of the burned area and had remained attached to the cabin structure by its control cables.

The aft section of the tail boom, including the tail rotor assembly and horizontal stabiliser, had remained lodged in the upper branches of a tree immediately down track from the fir tree that was struck in the initial impact. Fragments from the windscreen and the transparencies in the lower part of the nose were also found in this area, most probably resulting from the impact of the fuselage with the oak tree.

A closer examination of the fir tree at the initial impact revealed that the trunk bore evidence of a broad, horizontal, scar with a number of small branches that had surrounded

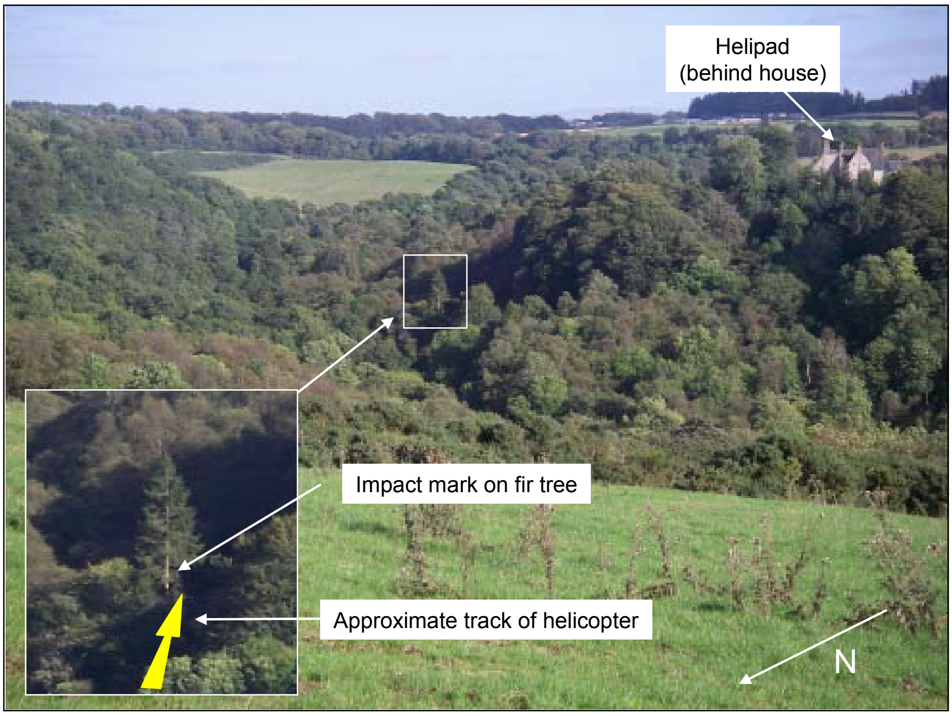


Figure 1

Accident location, looking along approximate track at impact

it having been broken off. It was concluded that the scar had been made by a single strike of a main rotor blade, only one of which exhibited any evidence of significant leading edge impact damage. This had resulted in the liberation of the outboard 0.6 m of the blade, which was subsequently located north of the river.

The orientation of the scar on the tree, together with the general disposition of the wreckage, suggested that the helicopter had struck the trees in an upright attitude, with no significant bank angle. The pitch angle was estimated to be nominally level. However, it is possible that the nose was pitched above the horizontal as this would have increased the exposure of the tail boom and horizontal stabiliser to the tree branches and may have resulted in the detachment of the boom. The main impact area was at an elevation of about 550 ft above mean sea level (amsl). This was approximately the same elevation as the initial tree strike, which suggests an almost level trajectory. This, together with the high degree of airframe break-up, indicated a relatively high impact speed. The front portion of the right hand skid was found embedded in the ground before the burned area of wreckage, together with larger pieces of the cabin doors and one of the steps that had been attached to the skid structure. However, there were no significant marks that enabled the aircraft ground impact attitude to be established with any degree of accuracy.

Witness information

Twenty witnesses reported seeing G-CBHL during the accident flight. Of these, two had some experience of helicopters in the Army and off-shore oil industry, while several in the Lanark area were familiar with G-CBHL and its normal manoeuvres in the area of the helipad.

The first sighting was about 1 nm from the helicopter's departure point, when it was seen to climb steeply out of a narrow wooded valley, immediately west of Larkhall. Witnesses described it as an unusual manoeuvre, which gave them cause for concern. Witnesses in the Clyde valley described the helicopter flying across the valley from west to east, descending quite low as it did so, before flying a hard right turn and continuing in the direction of Lanark. Other witnesses along the helicopter's route generally described it as flying quite low, but did not describe anything to suggest it was in difficulty.

There were 12 witnesses in and around the town of Lanark, who saw the helicopter for a brief period, only seconds before the accident. No-one saw the accident itself, although several people heard it, and some saw the airborne main rotor blade that was released in the initial impact. The locations of these witnesses are shown at Figure 2, together with an indication of the flight path they described. From their combined accounts, the helicopter approached the area from the west, initially flying across the Mouse Water valley in the general direction of the helipad. It then made a brief right turn before banking steeply to the left and descending into the valley. It adopted a marked nose-low, banked attitude as it descended, and was generally described as flying much faster than normal. The arcs of view shown in Figure 2 are of two witnesses who described seeing the helicopter in the steep left bank when it went out of view.

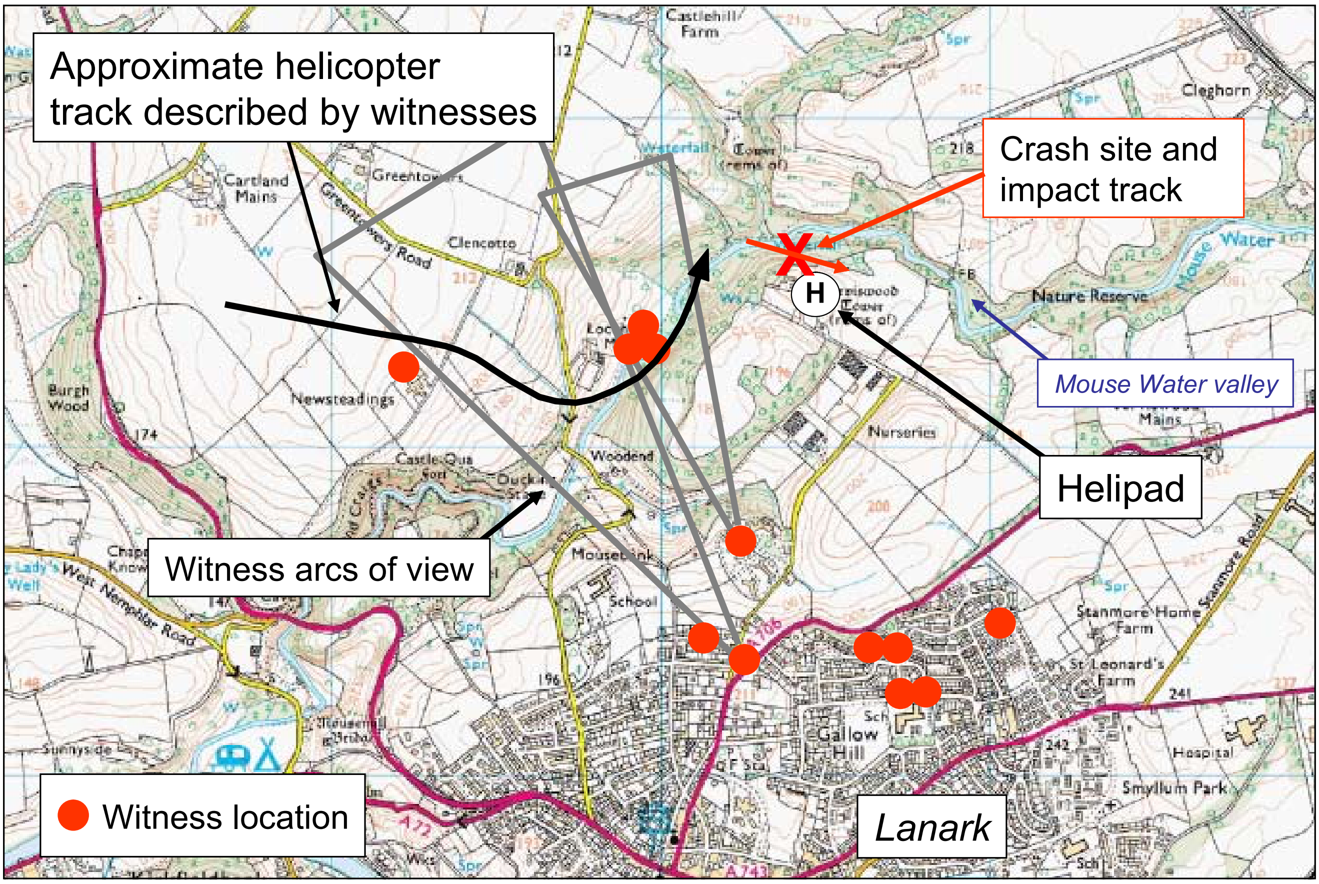


Figure 2
Witness information

The helicopter was a common sight locally, so most witnesses could compare what they saw with its normal flight path and manoeuvres. The helicopter's final flight path and speed was generally described as unusual and even alarming, as it normally flew to the east of the helipad before making a slow, controlled descent to land. However, two witnesses described seeing the helicopter perform a similar manoeuvre before, and therefore were not concerned on this occasion. The helicopter was not described as being in obvious difficulty, other than may have been suggested by its descending flight path and unusually high speed. No-one reported smoke or flames from the helicopter and nothing was seen to fall from it, or to strike it.

Of the witnesses who described the sound of the helicopter, the majority reported it as normal or unremarkable. These included two of the closest witnesses: the first was serving in the Army and very familiar with helicopter operations; the second was a local farmer, who was directly under the flight path, and regularly saw and heard the helicopter flying close to his farm. Although there were some reports of the helicopter making an unusual noise, or sounding 'high revving', some who described this attributed it to the helicopter's high speed.

None of the witnesses who saw the helicopter descend into the valley saw it emerge again, although two of them did see the airborne rotor blade, and several saw smoke rising from the site soon afterwards.

Meteorological information

According to the Met Office, a warm front would have been about 35 nm west of the area. This would have produced dry, cloudy weather until about the time of the accident, with light or moderate rain after. Visibility would have been between 15 and 30 km outside any showers. An automated weather station 4 nm south of the accident site reported a scattered cloud base at 3,200 ft amsl, which was considered representative of conditions at the accident site.

Satellite imagery showed some evidence of mountain wave activity. Detailed analysis of the data produced an estimated vertical wind velocity of about 200 ft min, which was below the 500 ft/min threshold that would warrant inclusion as a caution note on aviation forecast charts. Winds at the accident site were estimated using an isobaric analysis and the reported wind from the nearby weather station. The wind at 500 ft above the accident site (ie about 1,000 ft amsl) was estimated as between 23 kt and 28 kt from 240º, increasing at 1,000 ft to between 25 kt and 30 kt from 250º. Mean sea level pressure was 1017 HPa and the 500 ft temperature was 13ºC.

Witness and video evidence supported the assessment of generally good flying conditions. The wind was universally reported as the main feature of the weather, described as brisk to strong by ground observers. Pilots of the emergency service helicopters - on scene 25 minutes after the accident - reported a gusty wind in the valley area with some turbulence, though it was not excessive or severe.

Recorded information

Radar data

The majority of the flight was captured by the Lowther Hill radar (19 nm south of the accident site), but the track was lost shortly before the helicopter reached the accident site. This was probably due to terrain obscuring the line of sight between the radar facility and the helicopter as it descended. The transponder on the helicopter was not set to Mode C (altitude reporting), so the recorded track did not provide altitude data. Although the helicopter's groundspeed was derived from the radar data, such radar-derived ground speeds are not very accurate when calculated between data points a short time apart. This is due to limitations of radar positioning and the possibility that the track may not be a straight line between the data points. Radar-derived ground speeds are more accurate when averaged over longer periods in straight and level flight.

Figure 3 shows an overview of the outbound flight (white track) and the inbound accident flight (yellow track). It also shows the last six recorded radar points, together with a graph of the derived speed data of the whole accident flight. The coverage from Lowther Hill radar was good, and recorded positional data for the whole flight until less than 20 seconds before the accident.

The radar track of the accident flight started at 1500:29 hrs and ended at 1504:32 hrs. The average ground speed at the start of the track was between 90 kt and 100 kt, subsequently increasing to between 120 kt and 130 kt. In the second half of the flight, the average ground speed fluctuated between 100 kt and 120 kt, with the average speed over the last 30 seconds of data having increased to 122 kt.

Video recording

The only form of flight recording recovered from the helicopter was the video recording taken during the two flights; the helicopter was not fitted with, and was not required to be fitted with, an accident data or cockpit voice recorder.

The adult passenger's camcorder had recorded a total of 5.3 minutes of video and sound track from the two flights. The video was all taken from his seat within the cabin, and ended about 55 seconds before the accident. Cabin noise levels prevented the microphone from recording normal conversation, although louder comments and exclamations were audible.

A short segment, recorded before takeoff from the helipad, showed what appeared to be a normal pre-flight process. The pilot appeared relaxed as he went about his pre-takeoff checks and the mood in the aircraft was jovial, with the adult passenger providing some commentary. Fuel contents were 50%, sufficient for about 1 hour 40 minutes flying. All engine and system indications were normal, and flight instruments appeared serviceable. Based on later observations, the altimeter pressure setting was not changed before or during flight, so an approximate 100 ft error before takeoff was assumed to exist throughout the recording period. In this report, height calculations based on observed altimeter indications have been adjusted accordingly.

Airborne cockpit indications were normal throughout the recorded period, with the exception of the chronometer, which was not running. Indicated Air Speed (IAS) generally varied between 110 and 115 kt, which would be a typical cruise speed. The main radio was tuned to 119.875 MHz, which was an appropriate Scottish Area Control Centre frequency. However, there was no requirement for the pilot to contact Air Traffic Control during either flight, and no such contact was made. The pilot remained in full control of the helicopter, and the manner in which he flew the aircraft suggested that he had no concerns about its serviceability or continued airworthiness.

The helicopter's autopilot remained in its normal flight mode, although the yaw channel was disengaged throughout. The autopilot was equipped with a self-monitoring function.

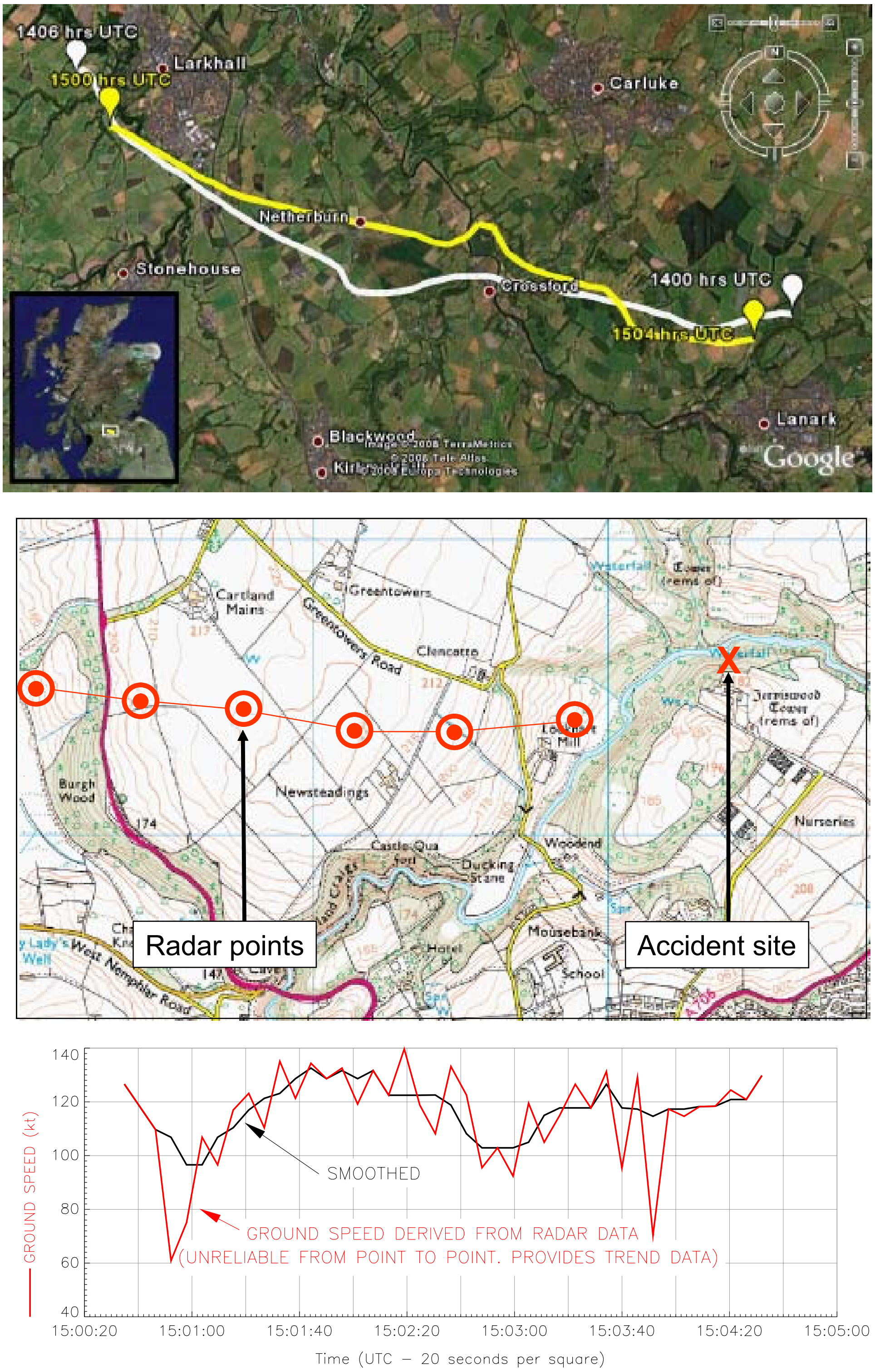


Figure 3

Radar derived parameters

Google Earth ™ mapping service / Image © 2008 TerraMetrics / © 2008 Tele Atlas / © 2008 Europa Technologies

Dual flight controls were fitted, but the recording showed that the adult passenger, although of large stature, was able to sit without interfering with them. A flight guide booklet on a map shelf was the only observable loose article, assuming that the passenger retained adequate restraint of the camcorder. During much of the recording, and particularly whilst the helicopter was manoeuvring, the passengers were vocal in expressing apparent enjoyment of the experience.

During the periods of flight captured on the video recording, the helicopter did not fly above 500 ft agl, and it was considerably lower for most of the time. Other aspects of the pilot's handling of the aircraft were noteworthy: these included instances of very low flying, valley flying and other manoeuvres, as described below.

On the outbound flight the helicopter flew as low as 155 ft over open farmland, as indicated by the altimeter and, at one point, it flew over farm buildings at a height estimated from the video to be 275 ft. The pilot then rolled the helicopter rapidly into a brief but steeply banked right turn, before reversing the turn to the left, at which point a true indicated height of 335 ft was recorded.[1]

When the helicopter departed from the farm on the accident fight, the pilot flew a 'zoom' climb[2], before descending into a narrow, steep-sided valley, next to the town of Larkhall. The valley is about 250 ft deep, and densely packed with trees along its length. This section of the recording showed the helicopter flying over trees at the valley's edge at speed, with a separation from the trees estimated from the video footage at between 20 ft and 30 ft. It then pitched nose-down and descended into the valley, coming into similar proximity to trees on each side and below. The pilot then flew a further zoom climb out of the valley, which was seen by witnesses on the ground. The passengers appeared to enjoy the manoeuvre, with laughs and shouts audible on the video. Figures 4a and 4b show full screen images from the video, of the helicopter approaching the valley, and in the valley just prior to the zoom climb.

The next recorded segment showed the helicopter in a steep right turn, at low level, over the Clyde valley. The helicopter then stabilised at a moderate height, flying towards its destination, about 2.8 nm away.

The final recorded segment lasted 8 seconds, the first frame of which is shown at Figure 4c. The helicopter was flying at 110 kt in a steep (about 60º angle of bank) turn to the right, at about 440 ft above a shallow valley floor. It appears to have just started a climb, with a pitch attitude at 10º and greater than normal cruise power applied. The helicopter then rolled left, reaching an approximately upright attitude as the recording ended. Again, the video and accompanying audio appeared to show that the passengers were enjoying the experience.

History of the aircraft

The helicopter was initially delivered to Japan; subsequently it operated in Canada. It was first registered in the UK in January 2002 and appeared in the subject pilot's log book in November 2003.

The current Technical Log (covering 28 May 2007 onwards), which recorded each flight together with any defects, was not recovered and was presumed lost in the post-impact fire. Consequently the exact number

Footnote

1 Rule 5 of the *Rules of the Air Regulations 2007* prohibits any aircraft from being flown closer than 500 ft to any person, vessel, vehicle or structure.

2 A steep climb, in which aircraft speed is exchanged for height.

Figure 4
Still images from the recorded video

of flight hours at the time of the accident is not known. The maintenance company provided documentation, including the engine and airframe log books and work-packs, which listed the maintenance activity carried out on the helicopter. The most recent work was an Annual Inspection carried out on 7 June 2007 at 4,158.8 flight hours. The previous Annual Inspection was on 1 June 2006 at 4,084.5 hours and the 12 Year Inspection was signed off on 25 April 2005 at 3,939.5 hours.

The documentation included a European Aviation Safety Agency (EASA) Standard Certificate of Airworthiness, which was valid to 1 May 2008.

Detailed examination of the wreckage

General

The recovery of the wreckage included a fingertip search of the site, which was conducted by the police. In addition, the top layer of earth in the main wreckage area, which contained significant quantities of ash and burned debris, was also taken away for subsequent sifting. All the wreckage was recovered to the AAIB facility at Farnborough, where the detailed examination was assisted by representatives from the engine and airframe manufacturers, and from the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'Aviation Civile, the French air accident investigation authority.

Structure

All the extremities of the aircraft were accounted for and there was no evidence of any pre-impact failure or detachment. All the failures in the structure, the rotor head and the main rotor blade attachments were consistent with violent impacts with the trees and/or the ground.

Engine

The engine had been extensively damaged in the accident, with the rotating components having seized as a result of distortion of the engine casing. In the case of the free turbine, the blades had broken at their approximate mid-span points due to tip contact with the shroud. Evidence of rotation of the gas generator part of the engine was provided by rotational score marks on the intake 'bullet' on the first stage of the compressor.

Disassembly of the free turbine module revealed that the drive nut had slipped rotationally relative to the turbine shaft. The direction of slippage indicated that the shaft was being driven, i.e. the engine was delivering power at the time of the impact.

Elsewhere on the engine, the magnetic plugs were clear of metallic particles and the oil filter clogging indicator was in its normal, recessed position.

Hydraulic system

This aircraft type is equipped with a hydraulic system, which comprised a pump, filter, pressure regulator and a reservoir. Its function is to provide hydraulic power for the flying control servos. The pump is mounted on a housing attached to the rear of the main rotor gearbox and is driven via a Kevlar belt from the tail rotor drive shaft.

The pump was found separated from its mounting on the drive shaft housing. However, it had remained intact and the pump mechanism still functioned when the input wheel was rotated. The drive belt was also recovered and was found to have snapped cleanly, with no evidence of fraying or other signs of in-service deterioration. It was concluded that the belt had failed in overload when the tail rotor drive shaft parted from the main gearbox during the impact sequence. The hydraulic reservoir had remained attached to its mounting on the main gearbox and although it had been holed during the impact, approximately 50% of the fluid contents remained when examined on the accident site. The pressure regulator was tested at Eurocopter's hydraulic test facility in Marignane, France; this was witnessed by the AAIB. It was found that a full production test could not be conducted due to the pressure inlet fitting having been torn out during the accident but it was possible to test the regulatory function. It was noted that a seal fitted to the unit at manufacture was still intact, indicating that it had never been adjusted. Under test, at a representative flow rate of 6 lt/min, the regulated pressure was found to be between 44 and 45 bar, which compared favourably with the specified figure of 43 ± 1 bar. At the end of the test, an internal filter was removed and was found to be free from contamination. The regulator was fitted with an electrically operated valve, which, when operated by the Hydraulic Test button on the cockpit pedestal, depressurises the system. This valve was also tested and found to operate correctly.

Flying controls

The flight controls on this type of helicopter are conventional in that the cyclic and collective levers are connected to the main rotor swashplate by push-pull rods and bellcranks, with the yaw pedals connected to the tail rotor servo by similar means. It is usual in most aircraft for the rods and bellcranks to be connected together using nuts and bolts, and secured with split-pins. However, in the AS350 model series, aluminium alloy rivets, secured by deformable collars, were used in place of steel nuts and bolts on all aircraft built up to the year 2000, when a problem on the assembly line resulted in a change to nuts and bolts being used on all subsequent aircraft. This process was covered by Modification No 07-3103, which was approved by the manufacturer in October 2001.

Any maintenance activity on an in-service aircraft requiring disconnection of the flying controls would necessarily involve drilling out the rivet. Since few, if any, maintenance organisations would possess the specialised riveting tool, the subsequent reconnection would be achieved using a nut, bolt and split pin. There would be no need to record which specific control rod connections had been changed, unless all the rivets had been replaced with nuts and bolts, in which case the aircraft would be deemed to have complied with Modification 07-3103. This had not been accomplished on G-CBHL, although it was clear from the wreckage that some of the flying controls were connected by nuts and bolts.

Although most of the flying controls components located under the floor of the forward cabin area had remained connected, much of the remainder had been severely affected by the post-impact fire. Most of the push-pull rods had been fabricated from aluminium alloy tubes with steel end fittings and as a result, the tubes had largely been consumed in the fire, leaving just the end fittings. It was not possible to identify the specific airframe locations of many of these items. Where rivets had been used in component connections, these generally appeared as solidified molten beads, although the joints had remained intact. The one exception was the lower end of the forward servo operating rod, where it had been attached to a bellcrank mounted on the transmission deck immediately in front of the main rotor gearbox. The bellcrank had been constructed from sheet alloy and was not recovered and identified. The rod, which had remained attached at its upper end to the forward servo on the gearbox, had not been exposed to the fire and the lower eye end was in near pristine condition, as can be seen in Figure 5. Figure 6 shows the bellcrank installation in an intact aircraft; this happened to have a steel nut and bolt assembly connecting it to the servo operating rod, with a rivet attaching it to the control linkage at the opposite end.

Any mechanical linkage that has been subjected to a violent impact would be expected to display evidence of overloading at the component connections. In the case of forks or eye ends, this could take the form of elongation of the bolt/rivet holes, or the components could separate as a result of the bolt or rivet pulling through the material surrounding the holes. Thus an apparently undamaged eye end, such as that seen on the servo operating rod, might suggest that the bolt or rivet was missing at the time of the impact. However, a steel bolt is inherently stronger than an aluminium alloy rivet, with the attendant possibility that a rivet could fail without causing significant damage to the eye end.

As noted earlier, the main rotor gearbox had been torn from its mountings on the initial impact with the trees. Thus, as the airframe continued on its trajectory, the servo operating rods would have been exposed to predominantly tensile loads, which had led to failures in two of the three rods. Both these rods had been attached to bellcranks located beneath the transmission deck and there was evidence to suggest that the failures had occurred partly as a result of a guillotining effect at the point where they emerged from their respective apertures in the transmission deck. The third rod, with the undamaged eye end, had remained attached to the servo input linkage on the gearbox and was in good condition, apart from a slight bend. This was probably caused as a result of the rod becoming trapped beneath the gearbox as it rolled along the ground.

In view of the apparent lack of damage to the servo rod eye end, additional investigation was conducted on this component in order to determine whether a bolt or rivet had been present at the time of the impact.

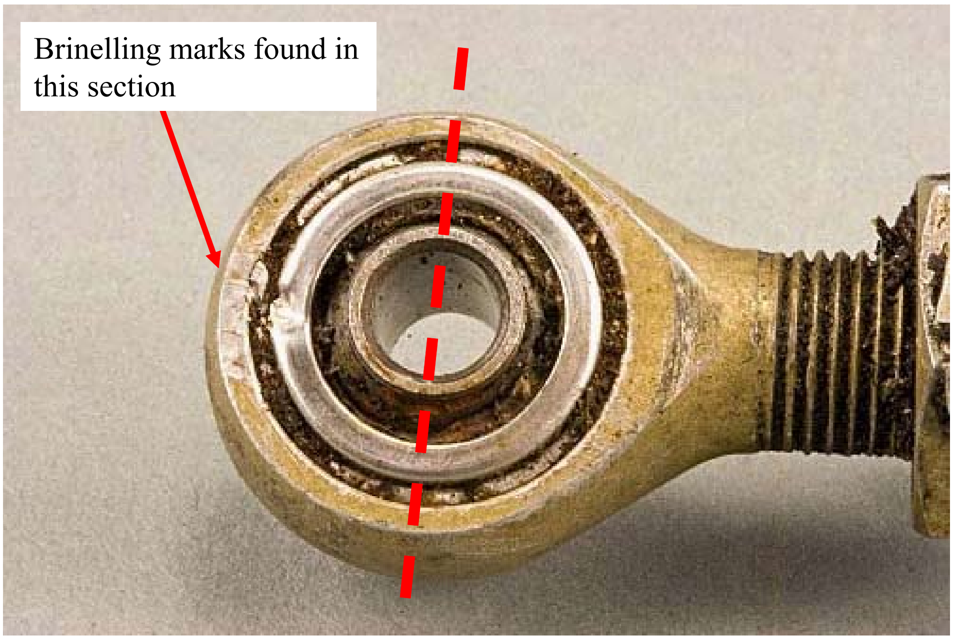


Figure 5

Forward servo rod eye end from G-CBHL

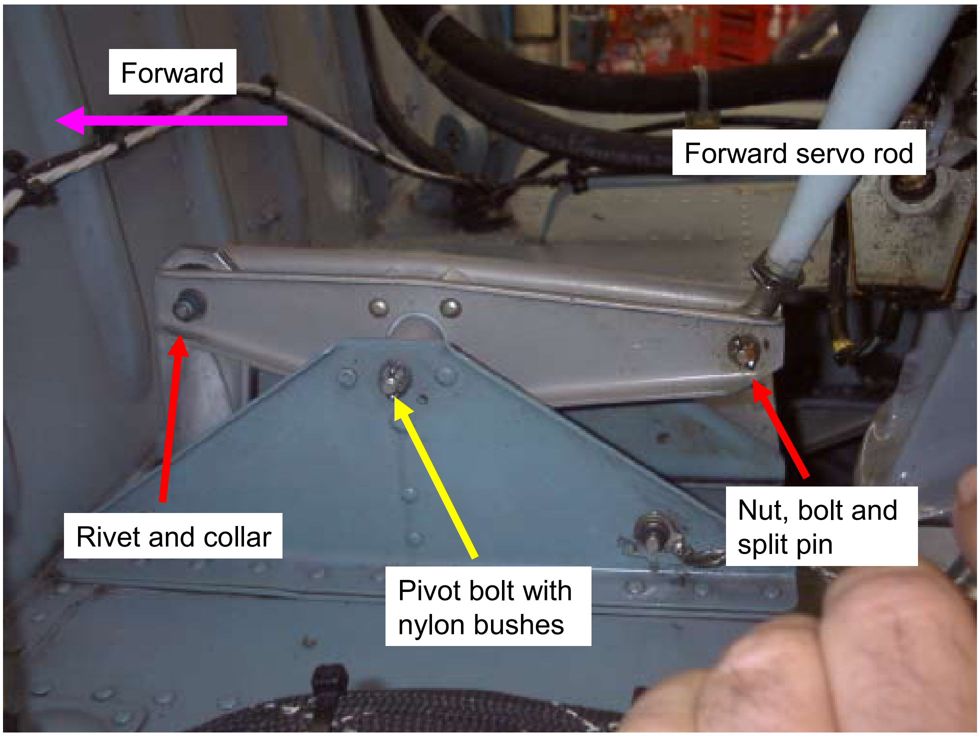


Figure 6

The bellcrank on the transmission deck of an intact aircraft, showing bolted and riveted connections

Investigation of servo operating rod eye end

It was not apparent, from the maintenance documentation, whether the original aluminium rivet had been changed to a steel nut and bolt at some point in the life of the aircraft. However, it was noted that a nut and bolt was installed at the upper end of the rod where it attached to the servo input linkage. This was not considered surprising, in view of the periodic requirement to remove and replace the servo and/or gearbox.

The documentation indicated that the flying controls in the area of interest were last disturbed in April 2005 during the 12 year inspection. An Additional Worksheet item raised the requirement to: *'replace fore/aft servo input bellcrank bushes on transmission deck'*. The worksheet bore the signature of the technician who carried out the work, together with the stamps of the licensed engineers who conducted the subsequent dual inspection. Also listed was the Part and Batch Numbers of the replacement bushes. There was no record of what components were disturbed in order to access the bellcrank bushes and in fact it was not clear, from a visual inspection of the area on an intact aircraft, whether it was even necessary to disconnect any of the adjacent linkages. Furthermore, the Maintenance Manual did not provide a procedure for performing the task.

The technician who replaced the bushes still worked for the maintenance organisation that conducted the inspection and he stated that he recalled carrying out the task. At the time of the work, the main rotor gearbox had been removed from the airframe, with the upper end of the servo rod having been disconnected from the servo. This greatly facilitated access to the push-fit nylon bushes which was accomplished simply by removing the bellcrank pivot bolt (arrowed in Figure 6) and lifting the bellcrank clear of its mounting. This meant that it was thus not necessary to disconnect additional flying control components. However, the technician could not recall whether there was a bolt or a rivet in the attachment to the servo rod, which was understandable given the elapsed time between carrying out the work and the accident.

The servo input eye end shown in Figure 5 comprised a central bearing that was able to swivel, by means of a double row of ball bearings, within an outer eye. The latter was cut open along the axis indicated which allowed inspection of the bearing outer race. Brinelling[3] marks were evident around that portion of the circumference that would have been loaded as a result of a tensile interaction between the servo input rod and the attaching bellcrank. These marks are shown in Figure 7 and it can be seen that they are elongated in nature, as opposed to circular dimples that might be expected from the individual balls.

In parallel with this examination, the aircraft manufacturer conducted a tensile test using representative rod end and bellcrank components which were attached with a rivet. Whilst the test machine could not replicate the dynamic nature of the accident, it did provide an indication of the failure load and mode of the rivet. The eye end, both in the test and on the helicopter, is located in the fork formed by the two sides of the bellcrank so that the rivet is loaded in double shear. The results of the test are shown in Figure 8, where it can be seen that the rivet failed in two positions along its shank, either side of the eye end. The fracture faces did not exhibit any significant burrs, so that the central portion of the rivet was not retained within the hole in the eye end. The failures,

Footnote

3 Brinelling is a form of mechanical damage typified by permanent deformation of the bearing surfaces where the rollers (or balls) contact the races; it is generally the result of excessive load or impact.

Figure 7

Brinelling marks on the forward servo input rod lower eye end

which were actually the result of a combination of bending and shear, were not exactly simultaneous; this had led to the central portion of the eye end twisting on its ball bearings during the failure process, which in turn had caused the balls to mark the outer race surface in a similar manner to that seen on the accident aircraft. The bore of the central, eye, in which the rivet had been located, was undamaged.

Figure 8

Results of eye end test conducted by the manufacturer. Note failed rivet and undamaged eye

The actual failure load in the test was 1,680 daN. The manufacturer conducted a stress analysis of the subject area of the flying controls and concluded that approximately similar loads could result in the failure of the bellcrank mounting to the transmission deck. Thus, if a steel bolt had been used in place of the rivet, its superior strength would have resulted in it remaining intact, with failure most probably occurring in the bellcrank mounting.

The test, in conjunction with the examination of the servo input rod end from the accident aircraft, provided conclusive proof that this area of the flying control linkage was intact at the time of the accident. The rivet represented the weakest link in this part of the system and failed as a result of forces generated during the impact, evidence of which was provided in the form of brinelling marks on the eye end outer race.

Flying control servos

Each of the four flying control servos was fitted with a pneumatically charged fluid reservoir, which is designed to provide a period of hydraulic power in the event of a failure of, for example, the hydraulic pump or its drive belt. The inflation valve on the right cyclic servo had been torn out during the impact, thus exhausting the pressure. The front and left servos were found to be pressurised to 10 and 12 bar respectively, with the Maintenance Manual figure being 15 bar at 20°C. The tail rotor servo reservoir pressure was found to be 22 bar which, although high, was not considered likely to have affected the operation of the servo, and was most probably a reflection of the relative difficulty of access for charging, due to its location in the tail boom.

The servos were taken to the manufacturer's facility in Coventry, where they were tested under AAIB supervision.

The tail rotor servo had been retained within the tail boom, which had protected it during the accident to the extent that it bore no evidence of external damage. When installed on a test rig it performed satisfactorily.

All three cyclic servos had suffered varying degrees of damage as a result of their exposed position on the main rotor gearbox. The right unit had suffered severe damage to part of the actuator body and the ram was bent; this resulted in the ram failing to move when it was placed on the rig. It was decided to remove the valve body and install it on the body of an intact example, when it functioned normally.

The left servo was found to be slow in operation, especially on the retraction part of the cycle. As with the right hand unit, it was decided to install it on another actuator body but there was little improvement. Upon disassembly of the servo valve input linkage, it was noted that it was contaminated with dirt, most probably from the accident site. After cleaning and reassembly, the servo functioned satisfactorily. During disassembly, the bypass valve, which allows passage of fluid from one side of the actuator piston to the other during manual mode (ie, in the absence of hydraulic pressure), could not physically be extracted from the valve body. It was considered that this was a result of minor distortions caused during the accident. However, operation of the valve was confirmed by manually moving the actuator ram.

The forward cyclic servo was of a slightly different design to the others in that it featured a locking device in the valve input mechanism which, in the absence of hydraulic pressure, eliminated the free play arising from movement of the spool within the valve body. When the unit was placed on the test rig, no actuator movement initially occurred, possibly due to a reluctance of the spring-loaded locking device to move under the application of hydraulic pressure. Tapping the valve body elicited some movement, albeit at a very slow rate. It was decided to strip the valve body; however it was noted that the servo valve was almost seized and was difficult to remove. The components were then examined for evidence of scoring caused, for example, by a trapped piece of swarf, none was found. When the components were cleaned prior to reassembly, a slight discoloration was noted in the fluid wiped from the spool stem. The servo manufacturer pointed out that the spool valve components were machined to extremely close tolerances, with the result that a relatively small amount of distortion, together with almost microscopically small pieces of debris, could impede operation. Whilst all the cyclic actuators were equipped with plastic dust covers over the valve blocks, which were designed to minimise the ingress of contaminant particles in service, these had been largely destroyed in the impact and in any case would have been ineffective in preventing dirt from the accident site entering the valve mechanism. When the servo was retested after cleaning it operated satisfactorily.

At the completion of the examination and testing of the flying control servos it was concluded that there had been no failure of the internal components. Although the operation was often less than satisfactory, it was considered that this was consistent with damage sustained in the impact, together with the likelihood of contamination of the valve components with dirt from the accident site. However, it was not possible, in the case of the forward cyclic actuator, to entirely discount the possibility of a pre-impact seizure of the valve.

Autopilot system

The aircraft had been equipped with a three-axis autopilot system, capable of controlling the helicopter in pitch, roll and yaw. The yaw axis was an optional addition to a basic two-axis system. Autopilot control is achieved via a computer that sends electrical outputs to three 'series' actuators, which are interposed in the control linkages in all three axes. These actuators are fast acting, but have a small extension/retraction from their mid-position (± 2 mm for roll, ± 3 mm in pitch and ± 5.5 mm in yaw), thus limiting their authority to approximately 10% of the control range of movement. Integral to the system are two trim actuators which operate on the pitch and roll linkages connected to the cyclic stick. These actuators incorporate springs that provide basic artificial feel to the pilot. They have full control authority (ie they can move the controls over their full range of movement), albeit at a slow rate: 2°/sec in pitch and 4°/sec in roll. In the event of a mechanical jam within the trim actuators, a weak link within each mechanism will fail under the action of the pilot's input forces, ensuring that normal control inputs may be made.

A pitch/roll monitor automatically monitors the pitch and roll channels for faults. It receives its attitude reference from a dedicated source, for comparative purposes. The monitor has the authority to automatically deselect a pitch or roll channel if certain failure conditions are detected.

The pitch and roll autopilot actuators had escaped the worst of the fire, with visible damage appearing to be limited, in the case of the roll actuator, to the output shaft, which had broken off the end of the housing. The actuators were in turn connected to a suitable power supply. It was found that the actuating shafts would extend and retract normally; by noting the amount of shaft movement, it was established that the as-found positions were at the approximate mid-points. The yaw actuator had been severely fire-damaged and was not capable of being tested.

Two feedback potentiometers within each actuator provide inputs to the autopilot computer. A resistance check was conducted on these at the limits of shaft travel. Whilst the roll channel actuator was satisfactory, it was found that by tapping the body of the pitch actuator an open circuit condition could be provoked on both potentiometers.

The two trim actuators were recovered from the wreckage and it was found that their output arms could be rotated by hand, without being opposed by spring pressure. This indicated that the weak links had failed. It is probable that this was the result of rapid and violent control linkage movement that probably occurred during the impact.

Both units were subjected to electrical tests which confirmed the satisfactory operation of the clutches and effort switches. The motor in the pitch actuator operated satisfactorily, although no response could initially be obtained from the roll actuator. An internal inspection revealed a degree of corrosion around the motor, which most probably occurred after the accident. Manually turning the mechanism resulted in the motor subsequently operating.

The electronic components in the system, together with the associated wiring, had all been consumed in the fire and therefore could not be examined.

Mass and balance

The helicopter's maximum permitted mass for takeoff and landing was 2,250 kg. A post-accident mass and balance computation was performed which produced a mass at the time of the accident of 1,836 kg. The longitudinal centre of gravity was at 3.25 m from the datum, which represented a mid to forward centre of gravity position, within the allowable envelope of 3.17 to 3.42 m.

Pathology and survivability

Autopsy findings were reviewed by a specialist aviation pathologist, who produced a report for the AAIB. Although there was an extensive post-crash fire, all four occupants had suffered severe multiple injuries in the initial impact, which were immediately fatal. The two adults sustained the most severe injuries, which suggested that they had been exposed to peak decelerations in excess of 100 g. The crash forces were outside the range of human tolerance, and alternative or additional safety equipment is unlikely to have altered the fatal outcome. The injuries to the rear seat occupants were of a slightly lesser extent and severity than those of the two adults. Whilst this could have been due to their age and size, it would also be consistent with the fuselage impacting the ground nose first, thus absorbing some of the crash forces.

An autopsy identified no significant natural disease in the pilot that could have caused or contributed to the accident, and toxicology revealed no drugs in the pilot's blood. Alcohol was present in some of the samples subjected to toxicological analysis but there was considerable medical evidence that some degree of post-mortem production of alcohol had taken place in the pilot's body. Consequently, the values of alcohol measured in the samples could not be taken as an accurate reflection of the alcohol concentration at the time of death. There was no evidence that the pilot had consumed alcohol on the day of the accident.

The report concluded that the four occupants had died in a non-survivable helicopter crash. No recommendations arose from the medical investigation.

Pilot information

Flying history

The pilot gained a Private Pilot's Licence (Helicopters) (PPL(H)) in early 2000, after training on Robinson R22 helicopters. Between March and August that year, he owned and operated an Enstrom 280FX, which he replaced with a turbine powered Eurocopter EC120B. He qualified to fly the EC120B in September 2000 and flew it as his main type between that date and November 2003, when he acquired G-CBHL. He started training for an AS350B2 type rating on 12 November 2003, and passed the qualifying flight test on 17 November 2003. The pilot also undertook additional training in instrument and night flying techniques, and was issued a night rating to his PPL(H) in March 2004.

Under existing regulations,[4] the pilot was required to maintain details of each of his flights in a personal flying logbook, which he did until March 2004. Although he continued to fly regularly, individual entries ceased after this date, being replaced with block entries of flying time (presumably transferred from the helicopter's technical records) and entries out of sequence. There was only one entry for 2005, a Licence Proficiency Check (LPC) on 3 May 2005, which was to renew his AS350B2 type rating; after this, the pilot closed the logbook. No other logbooks, either hard copy or electronic, were found. Archived pages from G-CBHL's technical log provided a record of the pilot's flying hours in the helicopter until 27 May 2007, at which time the pilot had a total of about 900 flying hours, including 440 hours in G-CBHL.

Technical log records from 28 May 2007 onwards are believed to have been destroyed in the accident. Based on historical flying patterns, it was estimated that the pilot had accrued a total flying time of 965 hours, with 490 hours in G-CBHL.

The same examiner who conducted the pilot's initial AS350B2 check flight for the issue of the type rating also conducted the pilot's next two LPCs, which were for the purpose of renewing the rating. He described the pilot as very competent, achieving a high standard during the check flights.

Pilot's flying licence

At the time of the accident, the pilot did not hold a valid flying licence, or a valid AS350B2 type rating. He had been issued with a UK PPL(H), which was valid for five years but which expired on 14 February 2005. No other flying licence was found, or is believed to have existed, and there were no records with the Civil Aviation Authority (CAA) of the pilot having applied to renew his licence. The validity period of the type rating was one year; this had expired on 21 March 2007. In order to revalidate it, the pilot was required to pass an LPC (which the CAA defined as *'a demonstration of continuing knowledge and skill to revalidate or renew ratings')* in the same helicopter type. Again, there was no record of an application to renew it; enquiries with examiners qualified to conduct LPCs on the AS350B2 revealed that none had conducted such a check on the pilot, or been approached to do so.

Further scrutiny revealed the pilot had allowed his AS350B2 type rating to expire on each occasion before renewing it; yet he continued to fly the helicopter during these periods of invalidity, as evidenced by entries in the aircraft's technical log. During the first period, of 106 days between November 2004 and March 2005,

Footnote

4 Air Navigation Order 2000 (as amended).

the pilot made 42 entries, totalling over 20 hours of flight time. During the second period, of 18 days in March 2006, the pilot recorded nearly six hours of flight time. There were a further 18 entries made between the pilot's type rating expiry on 21 March 2007 and 27 May 2007, which was the last surviving technical log entry.

The pilot's last two LPCs in the AS350B2 were flown on 3 March 2005 and 21 March 2006, both after the expiry of his flying licence. The CAA Authorised Examiner who conducted the LPCs did not check the pilot's licence on either occasion, and did not consider it his responsibility to do so. However, he did recall on one occasion mentioning to the pilot that his type rating had expired. The examiner had known the pilot for a number of years and was under the impression that the pilot's licence had been issued with a lifetime validity.

For the LPC in March 2006, the pilot had flown G-CBHL from his home in Scotland to an airfield in the London area where the LPC was to be flown. The examiner thought that the pilot had made this flight with a properly licensed pilot, although the airfield's records showed that G-CBHL arrived there the previous evening with only the pilot on board.

The pilot held a Joint Aviation Authorities (JAA) Class Two medical certificate (validity period two years), which was valid at the time of the accident. However, there were two separate periods between November 2003 and March 2006, totalling 110 days, during which the pilot did not hold a valid medical certificate, his current one having expired: the pilot continued to fly G-CBHL during these periods.

For a 13 day period in March 2006, the pilot's flying licence, AS350B2 type rating and medical certificate had all expired yet, during this time, he recorded two entries as captain in G-CBHL's technical log.

Flight control system malfunctions

The AS350B2 can be flown without hydraulic servo assistance, but the control forces are high. If the single hydraulic system loses pressure, the main rotor servo accumulators will provide about 30 seconds of power, enabling the pilot to land the helicopter (if in a hover), or establish it in the recommended safety speed range of 40 kt to 60 kt, which minimises the control forces in forward flight.

The hydraulic system is controlled from the cockpit by a guarded cut-off switch on the pilot's collective lever and a test pushbutton on the centre console. Selecting the cut-off switch to OFF depressurises both the main system and the main rotor servo accumulators. Operating the test pushbutton also depressurises the main system, but only the tail rotor servo accumulator, leaving the main rotor servo actuators to be powered by their respective accumulators. This allows correct functioning of the accumulators to be tested before flight and is also used to simulate hydraulic failures during flight training.

A hydraulic system failure is indicated by a red warning light and a warning horn. The correct pilot response in forward flight is to fly the aircraft into the recommended speed range and then to select the cut-off switch to OFF. This last action prevents possible asymmetric accumulator exhaustion, which could cause transient control difficulties. The pilot should plan to make a shallow approach over a clear area and land with a low forward speed, typically 15 kt to 20 kt. Hydraulic failures and 'hydraulics out' approaches and landings are mandatory training for the AS350B2 type rating.

The manufacturer also provided a procedure in the Flight Manual for a main servo actuator valve seizure. This involved depressurising the hydraulic system by means of the cut-out switch on the collective lever, thus reverting to manual control. However, the manufacturer stated that, by the end of 2007, the AS350 model series had accumulated more than 14.5 million flight hours which, since there are four flying control servos per helicopter, equates to 58 million servo operating hours. The manufacturer was unaware of any stuck valve incidents having occurred during this time.

Flight control servo transparency phenomenon

General

The purpose of the main rotor servo actuators is to reduce the force required to control the aircraft by isolating the pilot from aerodynamic forces acting upon the main rotor blades. These forces are constantly changing, and increase as a function of speed, helicopter mass, density altitude, collective pitch input and normal g loading. Under normal flight conditions within the approved flight envelope, hydraulic system pressure enables the servo actuators to overcome the aerodynamic loads, and the helicopter's controls remain light and responsive.

Servo transparency

If the helicopter is manoeuvred in such a way that the airspeed and/or rotor disc loading (commonly known as g-loading) become excessive, aerodynamic forces on the rotor blades can exceed the maximum force that can be produced by the servo actuators (which is limited to a value that exceeds the requirements of the approved flight envelope, whilst protecting the airframe against overstress). If this occurs, the aerodynamic forces will be progressively fed back to the flying controls, which become heavy to operate. If unrestrained, this will cause uncommanded movement of the pilot's controls: the cyclic control moves rearwards and to the right, whilst the collective pitch control moves down (reduced blade pitch). The helicopter will thus roll to the right and may pitch up. Although the controls remain fully operable, increased pilot force will be required to overcome these effects. This phenomenon is commonly known as 'jack stall', but is termed 'servo transparency' or 'control reversibility' by Eurocopter.

Manufacturer's published advice

In a Service Letter,[5] Eurocopter advised owners of all AS350 series helicopters about the servo transparency phenomenon, stating that it:

> *'can be encountered during excessive manoeuvring of any single hydraulic system equipped helicopter, if operated beyond its approved flight envelope.'*

Concerning the uncommanded control movements, the Service Letter stated:

> *'The cyclic and collective control inputs required to counter these motions may give a pilot who is not aware of this phenomenon an impression that the controls are jammed. If the severity of the manoeuvre is not reduced, the aircraft will roll right and may pitch up. The amplitude of the induced control feedback loads is proportional to the severity of the manoeuvre, but the phenomenon normally lasts less than 2 seconds since the resultant aircraft reaction helps to reduce the factors that contribute to the severity of the manoeuvre and of the Servo Transparency.'*

Footnote

5 Service Letter SL 1648-29-03, 4 December 2003.

The Service Letter also detailed the pilot's recovery actions for a servo transparency encounter:

> *'The pilot's reaction to the first indication of control forces feedback should be to IMMEDIATELY reduce the severity of the manoeuvre.'*

Subsequent actions were detailed, which included allowing the collective pitch to decrease to reduce the overall load on the rotor system, and smoothly counteracting the right cyclic tendency. The Service Letter concluded with:

> *'Pilots should understand that Servo Transparency is a natural phenomenon for a perfectly flyable helicopter. Basic airmanship should prevent encountering this phenomenon by avoiding combinations of high speed, high gross weight, high density altitude and aggressive manoeuvres which exceed the aircraft's approved flight envelope. It is a basic rule (that) tells you that it is particularly inappropriate to perform manoeuvres which reach and exceed several aircraft limitations simultaneously.'*

In response to the Service Letter, some National Aviation Authorities, including the Federal Aviation Administration (FAA) in the USA, issued airworthiness bulletins which reproduced the content of the Service Letter.

AS350B2 Flight Manual

As originally issued, the *'Limitations'* section of the aircraft's Flight Manual contained the following, under *'Manoeuvring limitations'*:

> *'Do not exceed the load factor corresponding to the servocontrol reversibility limit,'*

In the '*Normal Operating Procedures*' section of the manual was stated:

> *'Maximum load factor in turns is felt in the form of servo-control "transparency"; this phenomenon is smooth, and presents no danger. In maximum power configuration, it is advisable to decrease collective pitch slightly before initiating a turn, as in this manoeuvre power requirement is increased.'*

In 2003, as well as producing Service Letter SL 1648-29-03, Eurocopter initiated Rush Revision 3A to the AS350B2 Flight Manual. This provided more information to owners and operators about servo transparency, including the following:

> *'The maximum load factor is determined by the servo-control transparency limit. Maximum load factor is a combination of TAS, density altitude, gross weight. Avoid such combination at high values associated with high collective pitch. The transparency may be reached during manoeuvres such as steep turns, hard pull-up or when manoeuvring near V_{ne}[6]. Self correcting, the phenomenon will induce an uncommanded right cyclic force and an associated down collective reaction. The transparency feedback forces are fully controllable, however immediate action is required to relieve the feedback forces: decrease manoeuvre's severity, follow aircraft natural reaction, let the collective pitch naturally*

Footnote

[6] The 'never exceed' speed, which was 155 kt, less 3 kt per 1,000 ft altitude.

go down (avoid low pitch) and counteract smoothly the right cyclic motion. Transparency will disappear as soon as excessive loads are relieved.'

Eurocopter's agent in the UK sent Rush Revision 3A to its customers on 29 October 2004. In the case of G-CBHL, this was sent to the contracted maintenance company, which acknowledged receipt of the revision.

The Flight Manual revision standard at the time of the accident was Revision 2 (2002) and Rush Revision 3B (2004). The Flight Manual for G-CBHL was recovered from the accident site, although it was damaged and some pages had become detached. The leading pages indicated that the manual was revised only to Revision 1 (1990) and incorporated up to Rush Revision 2P (2000). There was no indication that any later revisions had ever been incorporated. The revisions, and other pertinent information, were also available directly from Eurocopter via their internet site. Owners and operators could register on the site without charge, and be notified of material affecting their aircraft; however, there was no record of the pilot having registered. It could not be established with any certainty whether the pilot, who as aircraft owner was responsible for ensuring the Flight Manual was revised to the latest standard, had seen the most recent advice from Eurocopter concerning servo transparency.

Servo transparency onset conditions

As part of the investigation, Eurocopter were asked to predict at what point G-CBHL would have encountered servo transparency, given the helicopter's known mass and the atmospheric conditions. The predictions, in terms of airspeed and load factor, are shown in graphical form at Figure 9. They assume that maximum continuous power is applied; flight tests have shown that servo transparency does not occur under any circumstances with the collective pitch lever less than 50% raised. At 130 kt, the onset of servo transparency was predicted to occur at a load factor of 2.1 g.

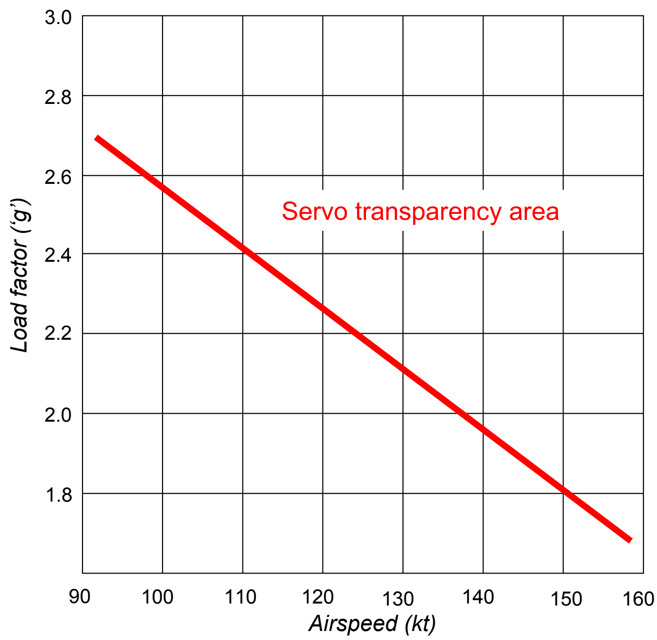


Figure 9

Predicted conditions for the onset of servo transparency

Previous occurrences

On 11 October 1994, an AS350B was involved in a fatal accident in New Zealand. The pilot, who survived the accident, reported[7] that he was in a descending right turn about a point of interest when the flight controls 'locked up'. The helicopter struck the sea at high-speed in a nose-low attitude with about 90° of right bank. An examination of the flight control system found no evidence of any pre-impact failure. It was calculated that the helicopter had descended at about 1,000 ft/min during its turn.

Footnote

[7] Transport Accident Investigation Commission, report number 94-022, 19 April 1995.

There was a 25 kt to 30 kt wind at the time, which gave rise to significant turbulence and downdraughts. The accident report considered that the wind probably caused the pilot to 'tighten' the turn to maintain a desired turn radius. The pilot stated that his attention was fixed on the ground feature (it was a sight-seeing trip for the passengers), and not the horizon. The control lock up had been a surprise to the pilot, who may have interpreted a sudden increase in control effort as a control system failure. The report found that the pilot probably encountered servo transparency, or its incipient stages, with insufficient height to recognise the problem and effect a recovery.

On 19 October 2001, an AS350B2 crashed in the USA during an informal demonstration of the helicopter's approach and landing capabilities in the air ambulance role[8]. The pilot initiated a low level right turn towards his landing site at between 115 kt and 120 kt, reaching what he thought was about a 2 g loading. He then realised that the turn had become too steep, but as he tried to reduce the bank angle he found that the cyclic control would not move to the left. The helicopter crashed, killing two of its three passengers. The accident occurred at a density altitude of 6,107 ft. The subsequent investigation found no technical reason for the accident. Although servo transparency was considered, the probable cause was reported as a seizure of the cyclic control for an undetermined reason.

Pilot training

Each Type Rating Training Organisation (TRTO) is required to submit training syllabi to its National Aviation Authority for approval. The servo transparency phenomenon was not mandated by Eurocopter as a flight training item, since it would have entailed operation at, or possibly beyond, published limits. Therefore, servo transparency was not the subject of specific study or training for the aircraft type rating. However, as an aircraft limitation, a student undergoing type rating training would be required to know of it, and to demonstrate such knowledge during training. Servo transparency is covered as a ground training item at the manufacturer's training subsidiary, Eurocopter Training Services.

Enquiries with staff pilots at the UK Defence Helicopter Flying School (DHFS), which operates the AS350BB[9], revealed that jack stall (as servo transparency is commonly referred to in the UK), was the subject of a flight demonstration on the SA341 Gazelle helicopter when that type was in military service. The Gazelle was susceptible to jack stall under certain conditions of military flying, to the extent that it was considered desirable to include the demonstration in the pilot training course. Such demonstrations were limited to the minimum number necessary and airframe fatigue was carefully monitored. Although the AS350BB is used in a similar role to that of the Gazelle, the type's susceptibility to jack stall is not considered such as to warrant an airborne demonstration.

Flight trials

Profiles were flown in AS350B2 helicopters to determine the most probable maximum IAS and rate of descent achieved by G-CBHL during its descent into the Mouse Water valley. Parameters for the profiles were set according to radar and witness information, known helicopter mass, limitations of the known terrain, and the position of the accident site. The profiles were flown by three pilots, and consistently achieved an IAS of 130 to 135 kt, with rates of descent in the range 1,500 ft/min to 2,000 ft/min.

Footnote

[8] National Transportation Safety Board, report FTW02FA017, 2003.

Footnote

[9] The AS350BB is a military variant of the AS350B2.

A helicopter flight was made over the route taken by G-CBHL, to provide an airborne perspective of the terrain and to help explore theoretical scenarios. The helicopter was flown by the CAA's Staff Flight Examiner (Helicopters) with an AAIB operations inspector on board, both type rated on the AS350B2. Weather conditions were good, with a south-westerly wind at 10 kt to 15 kt in the accident area.

In order to match witness descriptions of a steeply banked, descending manoeuvre, it was found that a relatively late left turn into the Mouse Water valley was required. Flying this profile would have necessitated a subsequent right turn in the valley through about 90° in order to fly along the river valley past the accident site. A noticeably high rate of descent was required to descend into the valley, even at the slower speed used during the trial and with less tail wind than affected G-CBHL.

For an aircraft at low height in the valley and turning steeply to the right, an accurate assessment of the true horizon would have been difficult, as attention would primarily be focussed on the valley itself. There were several isolated trees in the immediate vicinity of the impact site, of which the fir tree that G-CBHL struck was not the most obvious. It was considered possible that shadow on the south side of the valley at the time of the accident could have further hindered an accurate assessment of flight path and hence separation from the trees.

Helicopter low flying

Aviation is a complex and often unforgiving activity that demands not only skill and knowledge, but also discipline and sound judgement. Low level flying is inherently high risk, increasing the aircraft's exposure to hazards and reducing the pilot's options in the event of an aircraft malfunction. An engine failure at low height in a wooded valley would leave the pilot of a single-engined helicopter like G-CBHL with little or no chance of landing safely. The risks associated with low level operations are well known by agencies like the military, who are required to operate there. To address and minimise the risks, military pilots are subject to rigorous selection, and extensive training in low level flying techniques, and are required to maintain flying currency in the environment.

There are also sensitive environmental issues concerning helicopter operations, particularly as helicopters often operate closer to the general public than many other aircraft types. Military and commercial operators place great emphasis on lessening the environmental impact of low level helicopter operations. The CAA produced a leaflet in their '*Safety Sense*' series which covered many aspects of helicopter airmanship, including environmental considerations. Readers of the leaflet are urged to read the 'Codes of conduct', produced by the British Helicopter Advisory Board (BHAB) and available on its website.

The BHAB's main objective is to promote the use of helicopters throughout the country and to bring to the attention of potential users the advantages of using or owning a helicopter. It is also concerned that helicopter operations are conducted safely and responsibly, and that proper attention is paid to environmental issues. The first point on the BHAB's Codes of conduct is:

> *'ALWAYS FLY AS HIGH AS POSSIBLE consistent with the weather and other factors. This will reduce your projected noise at ground level, and also give you more scope to find a suitable landing site in the event of an emergency.'*

Licensing regulations and procedures

The CAA issued the pilot's PPL(H) under the licensing provisions of the United Kingdom Air Navigation Order (ANO) 1995 (as amended), which stated that there was no maximum period of validity for such a licence. However, the licensing provisions of the Joint Aviation Requirements[10] were implemented in the UK on 1 January 2000. Changes made to the ANO, and which were notified by Aeronautical Information Circular (AIC)[11], allowed for the transition between the previous national licensing requirements and the new requirements applicable under JAR-FCL. This also allowed for both UK national licences and JAR licences to co-exist, although it was CAA policy to align the licensing requirements and validity dates of national licences with those of JAR-FCL. Thus, when the pilot's UK national PPL(H) was issued on 15 February 2000 it bore a five year validity period (printed on the title page), although a similar licence issued a short while beforehand would have been issued with a validity for the lifetime of the holder. The initial issuing of the UK national PPL(H) ceased on 1 January 2001.

As part of the LPC administration process, the examiner was required to forward completed documentation to the CAA's Personnel Licensing Department (PLD), which maintained appropriate records.

A rating or other qualification issued by the CAA for inclusion in a flying licence was deemed to form part of that licence. The Air Navigation Order 2005[12] (being in force at the time of the accident) stated the following:

> *'… a person shall not act as a member of the flight crew of an aircraft registered in the United Kingdom unless he is the holder of an appropriate licence granted or rendered valid under this order.'*

In relation to the aircraft type rating, Article 29 of the ANO stated:

> *'The holder of a pilot's licence to which this article applies shall not be entitled to exercise the privileges of an aircraft rating contained in the licence on a flight unless – the licence bears a valid certificate of revalidation in respect of the rating.'*

The ANO thus placed the responsibility on the licence holder for ensuring ongoing validity of their flying licence, aircraft type rating and medical certificate, if the intention was to exercise any of the privileges conferred by them.

A number of licences issued during the transition period subsequently expired because their holders were unaware of the revised validity periods, although appropriate notification of the changes had taken place and the licences were issued bearing the correct expiry date. To assist licence holders, the CAA began notifying them when their licences were approaching expiry date. This process began in late 2006 but, as it was not applied retrospectively, the pilot of G-CBHL would not have received such notification.

CAA Authorised Examiners

The CAA authorises suitably experienced and qualified pilots as examiners, whose authority to conduct tests and checks is derived from the ANO and JAR-FCL. Guidance notes for helicopter examiners are contained

Footnote

[10] Joint Aviation Requirements – Flight Crew Licensing 2 (JAR-FCL 2), applicable to helicopter licences.

[11] AIC 92/1999 (White 363).

[12] ANO Part 4 '*Aircraft Crew and Licensing*', Article 26.

in Standards Document 28.[13] The immediate reference for helicopter examiners was the Flight Examiners' Handbook (Helicopters) (FEH(H)), which drew upon material contained in both JAR-FCL and a JAA Flight Examiners' Manual. Neither of these contained a specific requirement for an examiner to check the licence of a pilot presenting himself for an LPC.

The FEH(H) stated only that an examiner should *'inspect documents as appropriate',* before listing a number of examples, of which *'licence'* was one. However, an earlier CAA *Notice to Flight Examiners* (NOTEX 1/2001) listed an internal CAA requirement that examiners check licences. It stated:

> *'Examiners are reminded that, as an essential part of each skill test or proficiency check, they are required to check the applicant's licence and medical certificate for currency. Where an applicant's licence or ratings are expired, or approaching expiry the examiner must advise the licence holder of the situation and must remind him that he cannot exercise the privileges of any expired rating.'*

It was intended that the requirement of NOTEX 1/2001 be incorporated into subsequent versions of Standards Document 28 and the FEH(H). However, the versions current at the time of the accident (and still current at the time of writing) did not contain it, and NOTEX 1/2001 had since been withdrawn. The CAA's Staff Flight Examiner (Helicopters) stated that a check of an applicant's licence was included as a requirement in the current training and testing of examiners.

Footnote

[13] Standards Document 28 Version 01, 8 March 2004, available from the CAA's website at www.caa.co.uk.

Analysis

Engineering investigation

The examination of the accident site indicated that the helicopter had struck the trees on the south side of the river valley at a high speed and in a nominally upright attitude. Although the post-impact fire destroyed much of the helicopter, it was possible to confirm that there had been no pre-impact structural failure, with the available evidence indicating that the engine was delivering power. Although some aircraft documentation was lost in the fire, it was established that maintenance had been conducted in accordance with the Maintenance Schedule.

The nature of the impact was such that it could conceivably have been the result of a flying control system malfunction; considerable effort was therefore expended in the examination of the system components. This task was compounded by the unusual use of aluminium alloy rivets in joining together many of the control rods and bellcranks. This led, in one instance, to the possibility that there may have been a pre-impact disconnect of a rod and its attaching bellcrank. However, detailed examination of the components, in conjunction with tests conducted by the helicopter manufacturer, confirmed that they had been correctly attached at impact. No other evidence was found that indicated the possibility of a pre-impact control disconnect.

The flying control servos, with the exception of the one that controlled the tail rotor, had sustained varying degrees of damage in the impact and the deficiencies, on test, of these units could all be explained by this damage. The seized valve on the forward cyclic servo, in the absence of any internal debris such as a piece of swarf, was probably the result of contaminant particles from the accident site, although there was no hard evidence in support of this supposition. A seized servo valve, in flight, especially at low level, would be a serious event and would likely come to the attention of the helicopter and servo manufacturers and/or the airworthiness authorities. However, no such occurrence has been reported in some 58 million servo operating hours. Thus the probability of a flying control servo valve seizure occurring at a critical point when the helicopter was flying low in the river valley, and which resulted in the accident a matter of seconds later, must be considered extremely remote. Moreover, it might reasonably be expected that any such seizure would be preceded by a stiffness resulting in a resistance or 'notchy' feeling in the cyclic controls.

The aircraft was fitted with a relatively sophisticated autopilot system, of which it was possible to conduct meaningful examinations only on the trim and series actuators. The results indicated that these components were probably functioning normally, with the anomalies such as the (initially) non-operating roll trim actuator motor most likely being a consequence of the accident. Since the associated avionic components and the wiring looms were not available for examination, it was not possible to confirm that the entire system was functional.

The video evidence showed that the autopilot yaw channel remained disengaged, although it could not be established whether this was due to a fault or simply that the pilot had chosen not to engage it. There were correct cockpit indications for the pitch and roll channels and the monitoring function was selected on. As the yaw channel was an optional addition to the basic two-axis autopilot, and there was no evidence to indicate a directional control problem, the engagement status of the yaw channel was not thought to have played a part in the accident.

Whilst the incomplete examination of the autopilot system raises the theoretical possibility of a fault developing during the final minute of flight, the limited authority in terms of its effect on the range of movement and force on the flying controls would be minimal. So even in the event of a major fault, the pilot could have retained control simply by moving the cyclic stick as required, if necessary opposing the feel springs and breaking the weak links in the trim actuators.

No existing unrectified defects affected the helicopter, and the video showed no cockpit malfunctions or control difficulties in flight. The majority of witnesses described no unusual noises, smoke, flames, obvious control problems or other visible signs of distress. If a system failure or other emergency had occurred before, or during, descent into the valley, the pilot's reaction would have been to attempt to establish a safe (ie level or climbing) flight path and speed, or to set up a controlled steady descent to a clear area if level flight was not achievable. It is unlikely that he would have deliberately flown the aircraft into the valley if he was experiencing problems with the flight controls, or indeed any system that could affect the safety of the aircraft. It must follow, therefore, that there was only a very narrow window of opportunity, in terms of time, in which a technical problem could have occurred leading to a loss of control: the engineering examination found no such evidence.

Flight path analysis

For the purposes of this analysis, the aircraft's known or estimated flight path has been divided into three sections: the initial descent into the valley, the final seconds of the flight immediately prior to impact, and the manoeuvre that must have joined the two.

Initial turn and descent

The helicopter was apparently in normal flight as it approached the Mouse Water valley from the west. Its probable initial track is shown at Figure 10, based on radar data and witness information, the latter indicating that the flight path was not a direct line between radar points. Although this was an uncommon route for the helicopter to take, two witnesses had seen something similar on previous occasions. The track shown is consistent with an initial right turn, followed by a brisk left roll to a high bank angle, as described by witnesses. The helicopter maintained the left bank as it descended, until it went out of view. At this point it would have been approximately along the line marked '*witness limit of view*'. Although the helicopter was banked left as it descended, it would not have actually turned a great deal or it would have flown out of the valley to the north.

Although deliberate flight into the valley would have entailed an increased risk, it would be consistent with earlier manoeuvres seen on the video recording. If he so chose, the valley would have presented an opportunity for the pilot to link together the manoeuvres previously flown, and which were apparently enjoyed by his passengers. If this were the case, the pilot's likely intention would have been to descend into the valley before flying a steep right turn to follow its route, possibly with a further zoom climb before approaching the helipad to land. A planned zoom climb would account for the helicopter's relatively high speed, which would be required for such a manoeuvre.

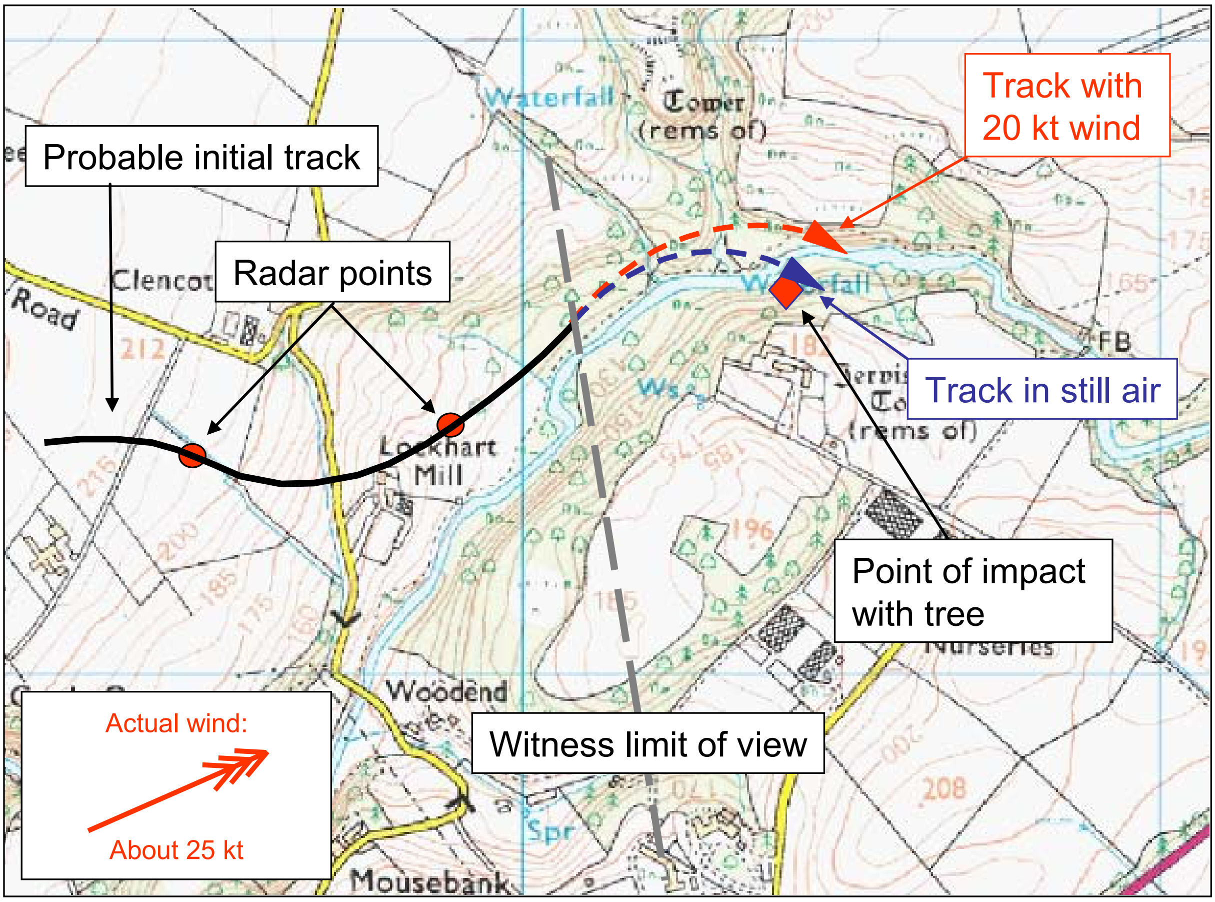


Figure 10

Probable initial flight path, shown with turns at 130 kt IAS and 60º bank angle

Final seconds of the flight

The helicopter's main rotor disc struck the fir tree about 30 ft below its top; a considerable distance, which was not suggestive of a simple misjudgement of height by the pilot, such as may have caused the helicopter to 'clip' the tree. The impact track would have taken the aircraft across the line of the valley towards rising wooded ground, which is unlikely to have been the pilot's desired or intended track. The helicopter's attitude and trajectory when it struck the trees suggests a dynamic situation rather than a steady flight path; that the pilot may have been attempting to arrest a rate of descent and was therefore trying to avoid the rising terrain.

The manoeuvre in the valley

Witness arcs of view indicate that the helicopter remained in a steep left bank until quite close to the point where the valley changed course eastwards, placing the start of the turn after the line shown at Figure 10. As the valley sides were tree covered and poorly defined, the pilot probably intended to fly along the line of the river, it being the lowest part of the valley. Before the pilot started a right turn, the obvious escape option, in case of a problem would have been to climb straight ahead out of the valley, which did not happen.

The helicopter probably reached 130 kt to 135 kt IAS as it descended into the valley and its groundspeed would have been about 150 kt due to the brisk tailwind. This speed would have necessitated a high rate of descent, in comparison with the same flight path flown at a lower groundspeed.

Figure 10 also shows two turn scenarios, illustrating turn performance and wind effect. Each turn is through a heading change of 90º, commencing from the witness limit of view line. Each of the paths is for a helicopter flying at 130 kt IAS with a 60º bank angle. One shows a turn in still air, the other with a 20 kt wind blowing along the initial line of travel. In the latter case, the helicopter would drift just over 200 ft downwind during the turn. Flown under ideal conditions, in calm air and in level flight, the turns would require a steady loading of 2g. Figure 10 shows that such a turn would not have been sufficient to keep the helicopter within the narrowest part of the valley in the prevailing wind conditions.

In attempting to fly in the valley at relatively low height and high speed, the pilot was undertaking a demanding manoeuvre. With the aircraft initially banked steeply in the opposite direction of the intended turn, descending at relatively high speed and rate of descent, and with a strong tailwind, accurate judgement of the required turn point would have been very difficult. The risk was that the pilot would start to turn late, come into unexpectedly close proximity of the terrain immediately ahead, and need to fly a harsh manoeuvre to avoid it. Even had the turn started in the correct place, it would have been difficult to judge, given the helicopter's speed, the nature of the valley, the lack of a good horizon reference, and the effect of the wind.

Possible contributory factors

In attempting to manoeuvre low in the valley, the pilot placed his helicopter in a situation in which there was a greatly reduced margin for error, or opportunity to deal with an unexpected event. From the foregoing analysis and the location of the accident site on the south side of the valley, it is probable that, at some stage, the pilot manoeuvred the helicopter at maximum performance, whether to ensure terrain avoidance and/or to arrest the descent, or for some other reason. This would have made a servo transparency encounter more likely, as well as increasing the risk of an unintentional deviation from the intended flight path due to spatial disorientation, misjudgement, or some other factor.

A sudden, harsh manoeuvre could have had other implications which, singularly or in combination with the above, could have contributed to the accident. Such a manoeuvre would have increased the potential for an involuntary of inadvertent interference with the flight controls by the front seat passenger. Dual flight controls can easily be removed. Whilst their fitment was not prohibited, it is inadvisable to have them fitted when carrying unqualified or inexperienced front seat passengers. As they had not been removed, interference by the passenger, for whatever reason, cannot be ruled out.

The camcorder was the only known potential loose article in the cabin, apart from paper documents. Had it been dropped, it could feasibly have interfered with the controls or presented a distraction at a critical time. Even a temporary control restriction at low height would be a serious event and therefore is also a possible contributory factor.

Birds are a common hazard at low level: they could have affected the flight path by forcing an avoiding manoeuvre by the pilot or, if they had struck the helicopter, by creating a distraction or restricting forward visibility. No evidence for a bird strike was found at the accident site, although it could have been lost in the post-crash fire, so the influence of birds cannot be ruled out as a possible contributory factor.

The servo transparency phenomenon

The servo transparency phenomenon is not unique to this helicopter type. It should not be encountered in normal service. Its onset marks the manoeuvre limit, and it would normally only be encountered through fairly aggressive manoeuvring. However, inadvertent encounters could occur, for which the manufacturer developed pilot procedures. According to Eurocopter, servo transparency is a transitory phenomenon which, because of the helicopter's natural response, tends to be self-correcting. However, this may not be so for a helicopter in a turn to the right. In this case, the helicopter's natural reaction will cause the angle of bank to increase which, together with a possible pitch-up, will cause an increased rate of turn. The effect, if any, on airspeed would be much less.

Although the helicopter will recover from the servo transparency of its own accord, the potential exists for a significant flight path deviation. The onset of this could be rapid and could conceivably lead to a helicopter in a right turn exceeding 90º of bank before the pilot was able to recognise what was happening and react accordingly. The associated transition from light and responsive controls to heavy controls that require considerable force to counter the uncommanded manoeuvre, could cause an unsuspecting pilot to believe that he was experiencing a malfunction, rather than a known characteristic of the helicopter when manoeuvred at the published limits. As Eurocopter have advised, a servo transparency encounter '*may give a pilot who is not aware of this phenomenon an impression that the controls are jammed*'.

A further consideration for a helicopter that encounters incipient servo transparency whilst manoeuvring in a turn to the right, is the possible delay in recognising an increasing bank angle. This is particularly so if already at a high bank angle and without a good horizontal reference, when the pilot's attention would probably be focussed on ground features ahead.

Although the helicopter's natural tendency in servo transparency is to reduce collective pitch, this will only assist recovery if the pilot does not oppose the associated movement of the collective lever. If a pilot were to be faced with an unexpected situation requiring additional power, this would not necessarily be an option. Indeed, the application of collective at a critical stage could be the factor that induces the servo transparency, rather than cyclic manoeuvring alone.

With the onset of servo transparency in this case predicted to have been at 2.1 g (with maximum continuous power set), even a modest increase in turn rate over that shown at Figure 10, if accompanied by a power increase, would have caused the helicopter to encounter the phenomenon. Any turbulence in the valley could have caused transient additional loading of the rotor disc, which would further increase the likelihood of an encounter. At the height the pilot chose to fly, there would have been very little time to recognise and deal with such an encounter, and the helicopter could rapidly have adopted an attitude from which recovery was not possible.

Pilot training

Among many other things, good airmanship dictates that a pilot knows his aircraft's limitations and does not place it in a situation in which they are, or could be, exceeded. Similarly, recovery manoeuvres need to be thoroughly understood. Operations at minimum height are demanding and are subject to specialised and regular training, such as undertaken by military pilots. Such operations incur greater risk of encountering hazards which, in other flight regimes, may present a lesser threat to the aircraft's safety.

Although flight training, or demonstration, of potentially hazardous characteristics or phenomena may appear desirable, any training which takes an aircraft to the limits of its flight envelope incurs risk and is likely to expose man and machine to additional stresses. There may also be difficulties with achieving standard, repeatable demonstrations. There are hazards specific to rotary flight that continue to cause accidents and incidents, yet cannot be experienced by a pilot in a safe and controlled way. An awareness of these hazards, including avoidance and recovery actions, is therefore confined to ground study. It follows that the information on which such study is based must be as complete as possible.

Servo transparency may have been a factor in this accident, although only because the helicopter's low level manoeuvring may have delayed recognition and made recovery from the encounter difficult. The factual information about servo transparency, distributed by Eurocopter through Service Letter and Flight Manual revision, was accurate: pilot recovery actions were unambiguous and applicable to all situations. However, although the aircraft's well-documented response can readily be applied by an informed reader to any flight scenario, a servo transparency encounter must present a potential hazard to an aircraft already manoeuvring in a right turn, particularly at low level. It is therefore arguable whether it can be correctly stated that servo transparency '*presents no danger*' or that it is always '*self-correcting*'. Indeed, such language could cause an unwary pilot to consider the phenomenon as unimportant.

The following Safety Recommendation is therefore made:

Safety Recommendation 2008-067

It is recommended that Eurocopter review current operational information and advice about the servo transparency phenomenon. This should be with a view to including a warning in applicable Flight Manuals that the associated uncommanded right roll and possible pitch-up, if encountered by an aircraft manoeuvring in a right turn, have the potential to cause a significant deviation from the intended flight path which, if encountered in close proximity to terrain or obstacles, could be hazardous.

Eurocopter's Service Letter describing servo transparency was effectively reissued in the USA by the FAA as a Special Airworthiness Information Bulletin. There was no comparative action in the UK, although the Service Letter would have been sent to all registered owners/operators of the applicable helicopter models by the manufacturer. In the light of this accident, the following two Safety Recommendations are made:

Safety Recommendation 2008-068

It is recommended that the Civil Aviation Authority should circulate, by the most appropriate means, the content of Eurocopter's Service Letter SL-1648-29-03 to owners and operators of applicable helicopter models, with a view to reminding them of the causes, symptoms, hazards and recovery actions relating to 'servo transparency' or 'jack stall' encounters.

Safety Recommendation 2008-069

It is recommended that the Civil Aviation Authority, in conjunction with the European Aviation Safety Agency, require an awareness of the causes, symptoms, hazards and recovery actions relating to 'servo transparency' or 'jack stall' encounters to be covered as a ground study item as part of the mandatory training for aircraft type ratings for those helicopter types likely to be affected.

Licensing matters

The pilot did not hold a valid flying licence or a valid type rating for G-CBHL (or indeed for any type of helicopter), and had not done so for a considerable time, in contravention of Articles 26 and 29 of the Air Navigation Order. The type rating could only be renewed by passing an LPC on the helicopter type. The LPC was a check of the pilot's continuing competence and fitness to hold the type rating, and included handling of simulated emergency scenarios such as engine failures and hydraulic system malfunctions. Therefore, the lack of a current type rating was relevant to the continued safe operation of the helicopter.

The investigation into the pilot's licensing history revealed several cases, between 2004 and the time of the accident, of non-compliance with existing regulations. When the pilot flew from Scotland to London in March 2006, he would have known that his type rating had expired, since the purpose of the flight was to meet with an examiner to renew it. Therefore, whilst the flying licence lapse could possibly be explained by confusion over validity periods, and may be seen as an administrative oversight by the pilot, the same is unlikely to be true of the type rating.

The responsibility to monitor validity periods of licences and ratings rests with the licence holder, not the CAA. However, there is no requirement for a person to renew a licence or rating, provided they do not intend to use it. Therefore, a considerable number of lapsed licences and ratings would ordinarily exist on the CAA's database. Although the CAA would have received notification of the pilot's two most recent LPCs during the period when his licence was invalid, this would not have been raised as an anomaly. A similar situation would legitimately exist if, for example, a pilot was intending to renew a licence, for which he would require a valid LPC.

There were some variations in the CAA's advice to its Authorised Examiners about checking the licences of pilots presenting themselves for proficiency check flights. Licence checks were required in guidance given to fixed wing examiners but were not explicitly required of rotary wing examiners. The examiner who conducted the pilot's last two LPCs did not believe it was his responsibility, with the result that he conducted both LPCs on a person who was not the holder of a valid flying licence, without being aware of the fact.

Whilst the CAA does not have a responsibility for the validity of individuals' licences, it does attempt to assist licence holders by alerting them to approaching expiry dates, so that they may take appropriate action. Similarly, a licence check as part of a skills test or proficiency check may serve as a timely reminder to the holder about expiry, and in cases were the licence is found to have expired, the holder could be cautioned about the need to renew it before exercising any licence or rating privileges. The following Safety Recommendation is therefore made:

Safety Recommendation 2008-070

It is recommended that the Civil Aviation Authority standardise a requirement for all Authorised Examiners to check the licence and/or other applicable documentation of candidates presenting themselves for proficiency checks or skills tests. This requirement should be stated in the applicable Standards Documents, together with the action to take in the event that the validity of any required documentation has expired or is approaching expiry.

Conclusion

The cause of the accident was not positively determined. Although no technical reason was found to explain it, a technical fault, whilst considered unlikely, could not be ruled out entirely. The available evidence indicated that the helicopter was intact when it struck the trees and that the engine was delivering power. The aircraft's trajectory suggested that the pilot was in control of the aircraft at the time of impact and was attempting to recover from a significant deviation from his intended flight path when the helicopter struck the trees.

The descent into the Mouse Water Valley appears to have been a deliberate manoeuvre. Considering the video evidence, the pilot's intention was probably to fly a hard, right turn at low height within the valley, possibly leading to a further, final zoom climb before landing at the helipad. A high-speed, low-level turning manoeuvre in the heavily wooded valley was a demanding one, which would have subjected the helicopter and its occupants to an increased risk. The circumstances of the accident, which included a strong tailwind, suggest that the pilot needed to fly an unexpectedly high performance manoeuvre which led to, or contributed to, the flight path deviation. This deviation may have been due to a servo transparency encounter, spatial disorientation, misjudgement or some other factor or combination of factors.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-BZYE
No & Type of Engines:	1 Lycoming O-360-J2A piston engine
Year of Manufacture:	2001
Date & Time (UTC):	22 September 2008 at 1400 hrs
Location:	Blackbushe Airport, Surrey
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - 1 (Minor)
Nature of Damage:	Damage to engine frame, rear undercarriage legs and both engine side panels
Commander's Licence:	Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	378 hours (of which 350 were on type) Last 90 days - 4 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After takeoff, during the transition from the hover into forward flight, the engine power varied intermittently and the pilot had difficulty in controlling the helicopter, which was damaged in the subsequent landing. It transpired that the engine had exceeded its rated speed on the previous day but the maintenance organisation had not been informed and the relevant inspection did not take place.

History of the flight

On 21 September a student was authorised for a solo flight at Blackbushe Airport, to practise flight in the hover and circuits. During the pre-start checks the student did not ensure that the throttle was fully closed and when he started the engine the rpm increased rapidly. On hearing the high engine rpm, the student instinctively closed the throttle but was unable to recall what the maximum achieved rpm had been, although he estimated it to be approximately 80–85%. The limit for the engine is 2,700 rpm, approximately 105%, but no overspeed, even momentary, is permitted. After some thought, the student decided to continue with his planned flight. Later he told his instructor what had happened during the engine start.

The instructor questioned the student and formed the opinion that the student had probably not oversped the engine. He had already briefed his next student on their planned flight, and there was no alternative helicopter available, so he decided to fly G-BZYE to see if it had been affected in any way. He considered that it behaved normally and all the engine temperature and pressure indications were normal. This reinforced his opinion that the student had not oversped the engine, so he continued with his instructional flight.

After landing, and aware that the helicopter was due to fly to its maintenance facility for a 100 hour inspection the next day, the instructor attempted to contact the maintenance organisation. As it was a Sunday afternoon he was unable to contact them, so he telephoned his Chief Pilot to discuss the circumstances. The Chief Pilot reminded the instructor that the student should have shut down the engine after the suspected overspeed and that he should not have taken the aircraft for his flight. Nevertheless, the flight had taken place without incident and without any other abnormal indications, so the Chief Pilot considered that the engine had probably not been oversped. He decided that the helicopter could be flown to its maintenance facility as planned and, as a precaution, the instructor put a loose note with the technical log to advise the maintenance organisation about the suspected overspeed.

The following day, an experienced R22 private pilot planned to fly the aircraft, with a passenger, to the maintenance facility. Whilst checking the aircraft paperwork, the pilot read the note to the maintenance organisation. The note mentioned that there had been a possible engine overspeed and that continued flight had been authorised by the Chief Pilot. However, since there were no entries in the technical log relating to an overspeed, the pilot decided to continue with his planned flight.

The engine start was normal and the pilot flew the helicopter into the hover before hover taxiing to the takeoff point. All aircraft and engine indications were within limits and, after ensuring that the area was clear, the pilot commenced his transition into forward flight. Shortly after the helicopter started moving forwards it yawed violently to the right, the manifold pressure increased and the aircraft began to climb. The pilot lowered the collective lever and applied left pedal to correct the yaw but had difficulty in maintaining control. He suspected some kind of engine governor failure, so, as soon as he felt he was able, he levelled the aircraft and attempted a slow running landing. Just before landing, when he applied the collective lever to cushion the touchdown, the aircraft yawed and climbed, becoming very difficult to control once more. The pilot stabilised the helicopter and attempted a further landing, but this time he made no attempt to cushion the touchdown and the aircraft landed more heavily than normal and quickly came to a halt. On the ground, with the rotor at 100% rpm, the pilot noticed that the manifold pressure was varying between 12 and 17 inches and the engine was running rough. He advised ATC that the aircraft was safely on the ground and shut it down. The pilot and his passenger, who sustained minor injuries in the heavy landing, vacated the helicopter normally.

The maintenance organisation inspected the helicopter and found damage to the lower frames, the rear undercarriage legs, a crosstube, and both engine side panels. The damage was consistent with a heavy landing.

An inspection of the engine found that the plastic gear for the left engine magneto was broken, which could account for the rough running engine and the fluctuating manifold pressure. The maintenance organisation had previous experience of this failure, which was normally associated with an engine overspeed or an inadvertent 'dead cut', where both magnetos are turned off whilst the engine is still running. The engineers also found evidence that the engine cooling fan had moved on its shaft, which they also considered to be consistent with an overspeed event. As a result of these findings the engine was sent to an approved Lycoming engine maintenance facility for an overspeed inspection. Clear evidence was found of an engine overspeed, with all cylinders having excessively worn valve guides and stepped valve springs.

Comment

The instructor and the Chief Pilot involved in this chain of events were open and honest about the decisions they made. They both agreed that, with the benefit of hindsight, a safer course of action would have been to ground the aircraft and seek engineering advice as soon as they became aware of a suspected engine overspeed. The Chief Pilot has since issued a company-wide memorandum to remind all instructional staff of the need to brief students always to treat incidents as 'a worse case scenario' and not to fly an aircraft after any suspected exceedence until appropriate engineering action has been completed.

ACCIDENT

Aircraft Type and Registration:	Dyn'Aero MCR-01 ULC, G-BZXG
No & Type of Engines:	1 Rotax 912ULS piston engine
Year of Manufacture:	2001
Date & Time (UTC):	30 December 2007 at 1210 hrs
Location:	Burgham Park Golf Course, near Felton, Northumberland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - 1 (Serious)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	2,000 hours (of which 50 were on type) Last 90 days - 20 hours Last 28 days - 5 hours (All hours are approximate)
Information Source:	AAIB Field Investigation

Synopsis

The pilot and his passenger, who each owned a half-share in the aircraft, were making a short flight between two airfields about 4 nm apart. As the aircraft joined the circuit to land, at a height of around 800 ft, there was a 'bang' as the tailplane separated and fell to the ground. The aircraft became uncontrollable and descended into trees. The occupants survived the impact but both received serious injuries.

The tailplane attachment lugs had failed in upload and metallurgical evidence showed that a stress corrosion mechanism had been present. Two Safety Recommendations are made.

History of the flight

The pilot and his passenger, a professional pilot, planned to fly the aircraft from a farm strip at Longframlington to nearby Eshott Airfield. At Eshott they were to meet some friends who had another aircraft and the plan was to fly both aircraft in company further afield.

The pilot prepared the aircraft for flight, which included putting in around 15 litres of fuel. With both persons on board, the aircraft taxied and took off from the north-easterly grass runway. The takeoff and initial climb to around 1,000 ft agl were uneventful and en route only light turbulence was encountered. As the aircraft was approaching the crosswind leg of the circuit for Runway 18 at Eshott a 'bang' was heard by both occupants as well as by a number of persons on the ground.

The passenger looked backwards and saw that the tailplane had detached and was floating away behind the aircraft, which then started to turn and tumble. He made a brief 'MAYDAY' call and took over control but was unable to do more than attempt to steer the aircraft towards an area of trees.

The aircraft fell through the trees and crashed into the bank of a small stream. Both occupants were seriously injured but remained conscious, despite being trapped in the wreckage. A number of persons quickly arrived at the scene but it was some time before the pilot and his passenger could be cut free by the rescue services.

The pilot was taken to hospital by air ambulance and to avoid further delay the passenger was taken to hospital by police helicopter.

Pilot information

The pilot had started flying on flex-wing microlight aircraft types, qualifying for his PPL (Microlight) in 1999. In April 2006 he converted to a three-axis fixed wing microlight type. In June 2006 he purchased G-BZXG and since then he had flown regularly, accumulating a total of around 50 hours on the aircraft.

The passenger was a professional pilot. Since buying his half-share in the aircraft he had flown it only a few times.

Meteorological information

The synoptic situation showed a weak occluded front lying over northern England at the time of the accident. There was an overcast layer of cloud between 2,000 and 3,000 ft; visibility beneath the cloud was good. The surface winds were light and variable, as were the low level winds. The passenger on the aircraft reported that the flight conditions had been good.

Aircraft description and history

The Dyn'Aero MCR-01 ULC is a very light kit-built aircraft with a low wing and an all-moving tailplane mounted on top of the fin. It has two seats, side by side, and a predominantly carbon fibre composite structure. The aircraft has manual primary flying controls, with feel augmentation achieved by the use of elastic bungees. The tailplane is controlled via carbon fibre pushrods operated by the dual control sticks. The tailplane also has a trim tab, operated on G-BZXG by a fixed rod connected between the tailplane and an electric pitch trim motor located in the fin. The pitch trim motor was operated via a switch on the instrument panel; this electric trim system is not standard on the MCR-01 but was fitted by the original builder.

G-BZXG, built in 2001, was the first MCR-01 ULC in the UK and as such, it was flight tested by the Popular Flying Association (PFA), now the Light Aircraft Association (LAA). Their report commented that the

> *'aircraft had generally weak but positive pitch stability, static and dynamic, stick-fixed and stick-free'.*

In 2006 the PFA became aware of an incident involving G-BZXG which had occurred in 2002 that resulted in damage to the tailplane. The PFA grounded the aircraft for the fitment of a new, factory-supplied tailplane and pitch control rod. Once this work was complete, the Certificate of Validity was re-issued on 9 June 2006.

G-BZXG was registered to the current owner on 18 September 2006, since when it had flown in the order of 50 hours. When not in use, the aircraft was parked inside a hangar at Longframlington Airfield. The pilot used a purpose-made trolley to manoeuvre the aircraft on the ground.

Tailplane attachment

The tailplane is attached to the top of the fin via lugs which form the hinge point about which the tailplane rotates in response to pitch inputs (see Figure 1).

Early MCR-01 models, prior to 2001, have 4 mm thick aluminium lugs ('Type 1') which are integral to the tailplane and are riveted and glued to the vertical web of the spar during tailplane manufacture (Figure 2). This was superseded by the 'Type 2' fixing, with 7 mm thick aluminium lugs and external attachments, which was introduced for the MCR4S, a four seat model, and extended to all models from 2001. A 'Type 3' lug was introduced subsequently. This is similar to the Type 2, but has a 4 mm thick lug, to fit the fin mountings on early models.

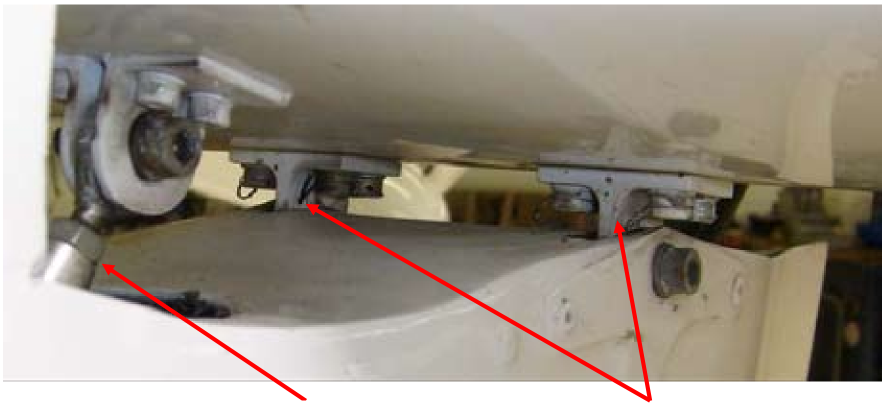
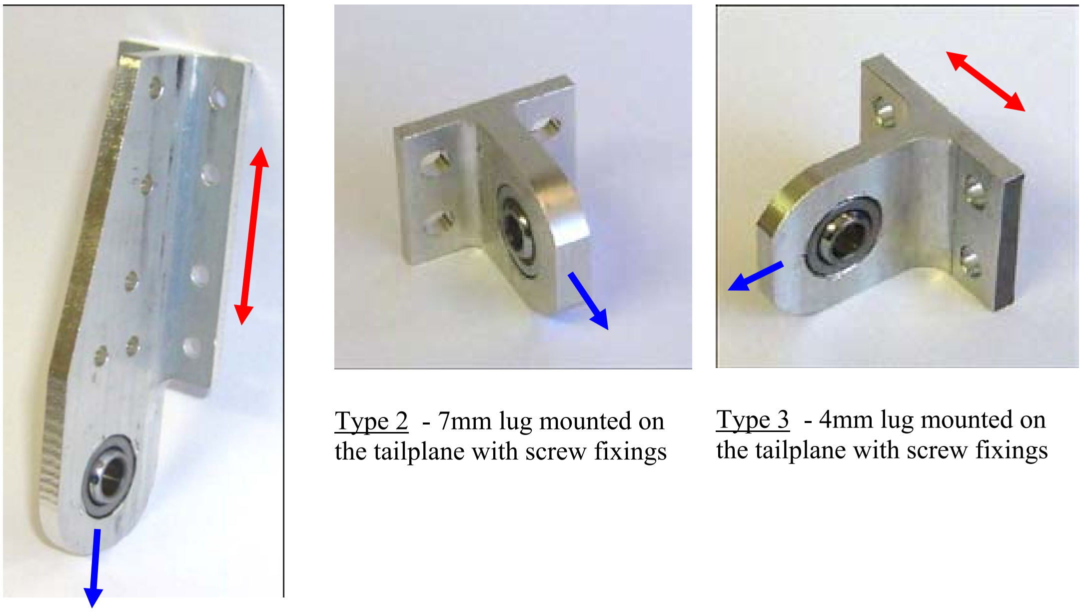


Figure 1

Tailplane attachment

(Photograph from Dyn'Aero BS 08 B 0034)

G-BZXG was originally fitted with Type 1 lugs. However, following the replacement of the damaged tailplane in 2006, newer Type 3 lugs were used, to enable the new tailplane to fit into the original fin mountings.



Type 1 - 4mm lug riveted and glued to tailplane spar vertical web

Type 2 - 7mm lug mounted on the tailplane with screw fixings

Type 3 - 4mm lug mounted on the tailplane with screw fixings

Figure 2

Different standards of tailplane fixing

(red arrows depict material grain direction and blue arrows the direction of applied loading)

(Photographs from Dyn'Aero BS 08 B 0034)

The lugs are machined from solid, rolled aluminium block in which the predominant grain direction of the material is parallel to the direction of rolling of the block. Figure 2 shows the material grain direction specified for the Type 1 lug and the grain direction for the Type 3 lugs examined by the AAIB. Material properties can be markedly different when applying load parallel, or perpendicular, to the direction of the material grain boundaries. The Type 1 lug is manufactured with the grain direction oriented longitudinally, such that the applied loads act along the direction of the grain, which is the ideal condition. The grain direction for the Type 2 and 3 lugs is not specified and thus, in theory, can be in any orientation. However, all the Type 3 lugs examined by the AAIB, including those from G-BZXG and new lugs provided by the manufacturer for testing, had a transverse grain direction. For such lugs, the applied loads act perpendicularly to the grain direction, which is the least preferable condition as the material is weakest in this direction. The aluminium alloy used for all three types of lug is a French specification AU4GN, which is similar to 2017 T4 or T451 alloys.

On-site wreckage examination

The aircraft had come to rest on the edge of a stream with steep, wooded banks, between an area of open fields and a golf course. The aircraft had descended through the tree canopy and from the damage to the right wing it was evident that the aircraft had fallen with very little forward speed and in an approximately level, or slightly nose down attitude. The aircraft was intact apart from the tailplane which had detached completely and was found approximately 150 metres from the main wreckage.

The separation of the tailplane had resulted from the failure of the two lugs attaching it to the fin. The subsequent failures of the pitch control rod eye end and the trim tab control rod, which was probably the last connection to fail as it sawed through the underside of the composite tailplane skin (Figure 3), allowed the tailplane to finally detach.

The roll control and rudder system were checked and found to have been connected at the time of impact. The

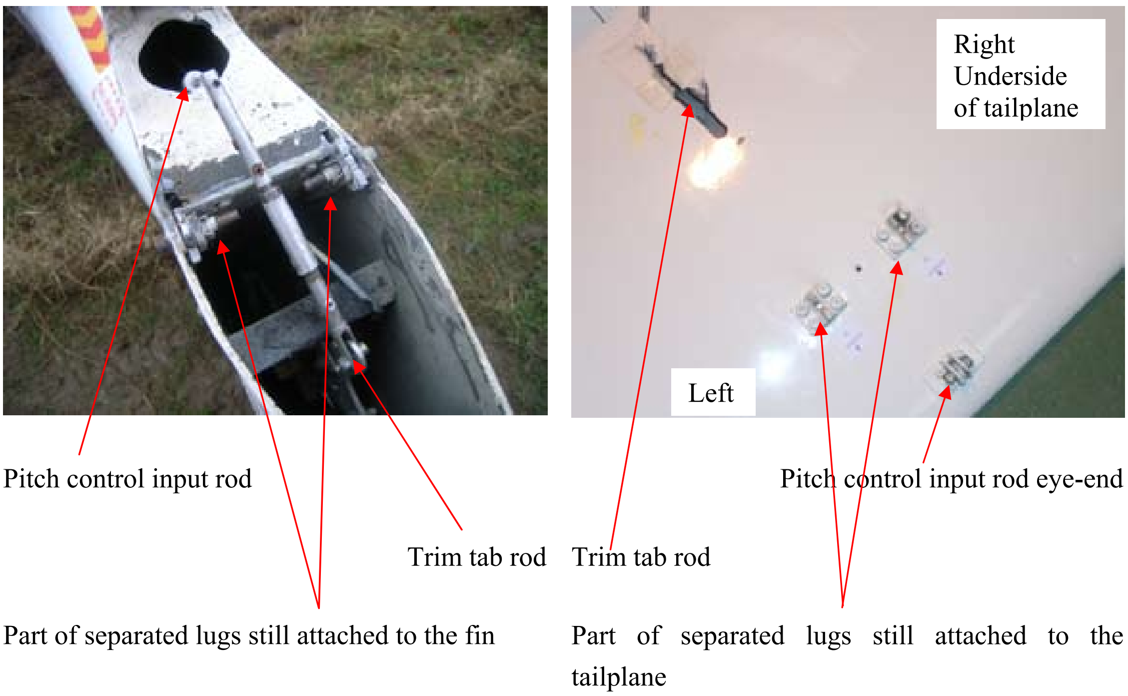


Figure 3

Top of fin (left) and underside of tailplane (right) pitch control system was intact and correctly connected, apart from the failure in bending overload of the pitch control rod eye-end that was attached to the tailplane.

The seat harness stitching was found to have been pulled through on both harnesses, although the attachment point for the shoulder harnesses was still intact.

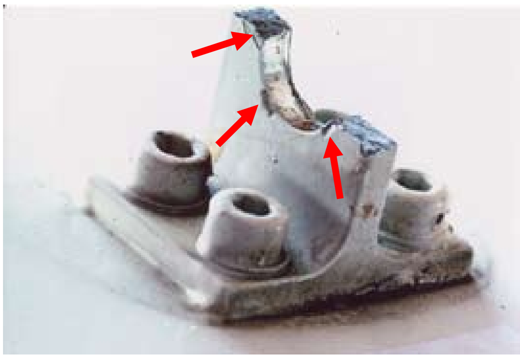
Metallurgical examination of the tailplane attachment lugs

The tailplane and its attachment lugs were subjected to specialist metallurgical examination. The separations in both tailplane lugs had occurred due to tensile overload, with the fracture surfaces aligned parallel to the grain direction. However, the left lug contained evidence of a stress corrosion mechanism, which was present prior to the accident and had weakened the lug.

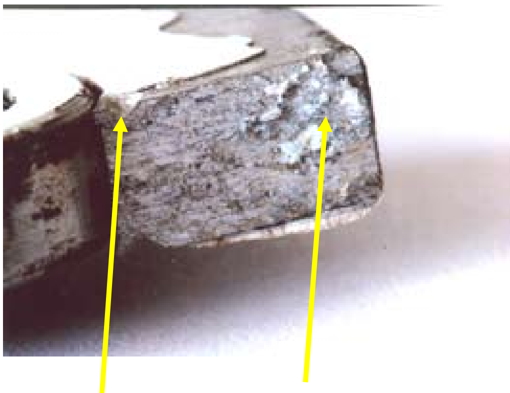
Some aluminium alloys are susceptible to stress corrosion, an intergranular cracking process, when simultaneously exposed to corrosive environments and tensile stresses of sufficient magnitude. (G-BZXG, although kept in a hangar, would have been exposed to an atmosphere conducive to stress corrosion in the normal ambient conditions present in the UK.) The stresses required for crack initiation and growth may be pre-existing or due to the applied loads, or a combination of both and can be far less than those required to fail the material in overload. Stress corrosion is aggravated when tensile stresses are applied perpendicular to the predominant grain direction.

The hinge bearings were of a spherical self-aligning type. The bearing in the left lug had been an interference fit, with hinge material having been pushed into the bore of the lug during assembly. The bearing was also rotationally tight and showed evidence of corrosion. The bearings were retained by means of staking. Significantly, the separations had all initiated at positions coincident with staking marks (Figure 4). (Staking is a method in which a tool, usually a punch, is used to locally deform the material at various locations around the bearing, thereby 'retaining' the bearing in place.) In this case the staking marks appeared deep and could therefore have given rise to areas of increased stress concentration with local distortion of the material.

A potential source of pre-existing (ie static) stress in the left hand tailplane lug is a misalignment between



Staking marks (arrowed)



Staking mark Area of stress corrosion

Figure 4

Left hand tailplane lug

(Photographs courtesy HT consultants)

the lug and the corresponding lugs in the fin, such that force would be required to engage the lugs with one another. However no evidence of lug misalignment was found.

No evidence was found of any surface conversion process such as anodising having been applied to the lugs. No primer had been used and the top coat of paint was not well-adhered.

Material testing

Testing of the lug material confirmed that it met the hardness requirements for AU4GN aluminium alloy. A test was also carried out to determine the maximum tensile strength of new 4 mm Type 3 lugs. The test was performed by applying a direct pull force to a new lug; the failure load was 1,776 daN. A further test was performed in which one side of the lug was deliberately severed in order to simulate the damage that, in this accident, had occurred due to tensile overload failure initiated by stress corrosion. In this test the lug failed at 138.1 daN.

CS-VLA requirements

The airworthiness requirements for the MCR-01 are laid down in EASA Certification Standards for Very Light Aircraft (CS-VLA). The structural requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, a factor of safety of 1·5 must be used. The tailplane is required to withstand balancing loads (loads to maintain equilibrium), manoeuvring loads, gust loads, as well as asymmetric loads arising from yawing and slipstream effects, in combination with the former factors. There is also a special requirement in CS-VLA ACJ 443:

'for aircraft where the horizontal tail is supported by the vertical tail, the tail surfaces and their supporting structure including the rear portion of the fuselage should be designed to withstand the prescribed loadings on the vertical tail and the roll-moments induced by the horizontal tail acting in the same direction.'

In the case of the MCR-01 this is the most limiting design criterion and the ultimate tensile load on the Type 1 or 3 lug is 1,162 daN.

Tailplane maintenance

The manufacturer's maintenance programme for the aircraft requires a check of the security of the tailplane attachments to be performed every 50 flying hours and calls for the tailplane attachment lugs to be greased at 3 month intervals. The maintenance records for the aircraft were not available for examination and so it could not be determined whether these maintenance requirements had been adhered to.

Survivability

The aircraft was fitted with two three-point harnesses. A single strap comes from the fuselage attachment point and is stitched onto the folded shoulder strap material. Both harnesses had failed in the area of stitching where the upper attachment strap was joined to the main harnesses (see Figure 5). CS-VLA requires the design of the seat harnesses and attachments to be capable of withstanding a 9g forward deceleration (CS-VLA.561). Shortly after the introduction of the aircraft type to the UK in 1998, the PFA issued a mandatory modification (MOD /301/001), to reinforce the harness attachment fittings with additional carbon fibre 'straps' at the rear of each fitting to improve the structural integrity of the fitting. The accident aircraft,

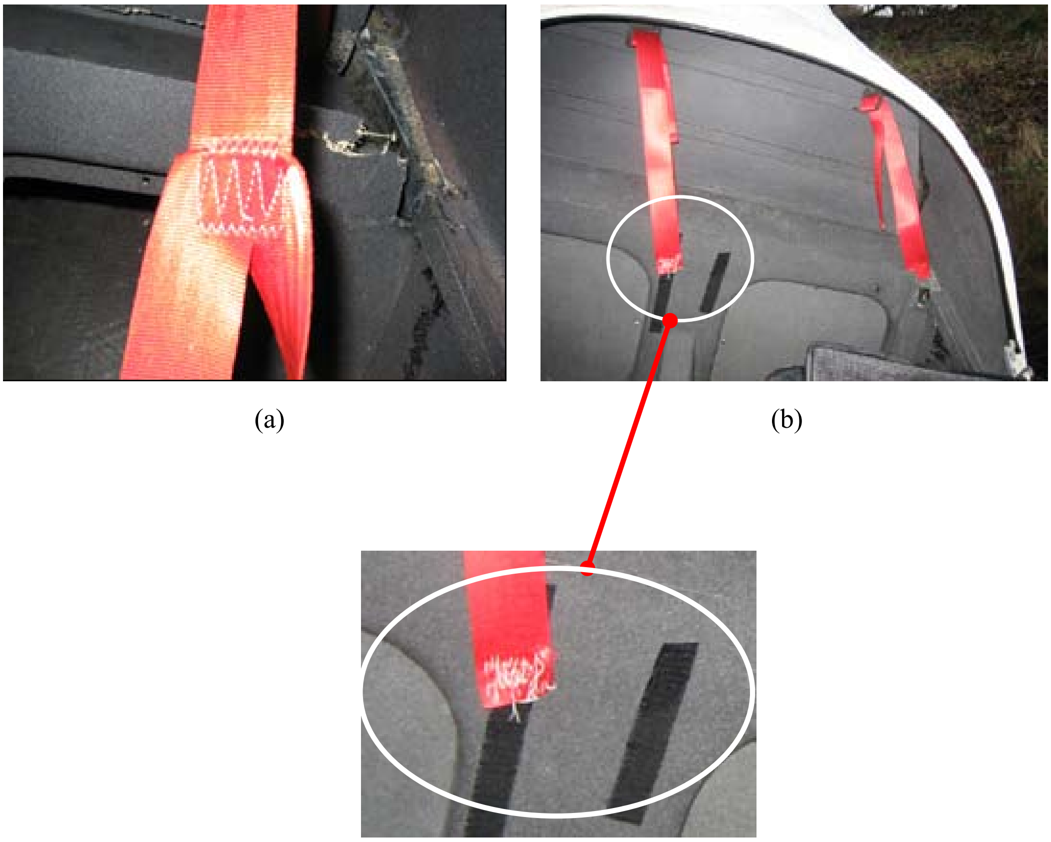


Figure 5

Shoulder straps of pilot's harnesses showing (a) intact stitching from another aircraft and (b) failed stitching from G-BZXG

built in 2001 had this modification incorporated during its build.

The stitching on the harnesses was compared to a number of other examples of MCR01 and there was found to be significant variability in the stitching.

A static test was carried out by the aircraft manufacturer on a similar harness; the shoulder harness attachment failed at a load of 682 kg and the lap harness failed at a load of 1,115 kg. The CS-VLA requires the harness to withstand a longitudinal deceleration of 9g with an occupant weight of 86 kg. Thus the failure load required by CS-VLA would be 774 kg, and this load would be divided between the shoulder and lap harness attachments. The CS-VLA does not specify the load distribution; the manufacturer assumes 45% of the load to be reacted through the shoulder harness and the remainder through the lap harness attachment. The shoulder harness failed in the area of stitching where the upper attachment strap was joined to the main harness webbing, identical to the failure that occurred in the accident. There was also some deformation in the test of the upper attachment fitting which was not present on G-BZXG.

Safety action

As a result of this accident the UK Civil Aviation Authority (CAA) issued a Mandatory Permit Directive (MPD) 2008-002 on the 6 February 2008 which grounded all MCR-01 aircraft and variants. The French Direction Generale de l'Aviation Civile (DGAC) issued an Airworthiness Directive No F-2008-002 on 27 February 2008 which mandated an inspection and/or replacement of the tailplane attachment fittings in accordance with Dyn'Aero Service Bulletin (BS 08 B0034 issued on 13 February 2008).

The Service Bulletin (SB) required the identification of the type of fitting installed on each aircraft. If found to be the 4 mm Type 3 lug as described above, the lug must be removed and returned to the manufacturer for a replacement. The replacement is of similar dimensions, but manufactured from stainless steel with 'loose-fit' bearings which are glued in position, rather than the 'press-fit' bearings and staking previously used, which can introduce stress concentrations.

For aircraft fitted with the Type 1 or 2 lugs, the SB requires the removal of the fittings, or the entire tailplane in the case of the Type 1 lugs, to perform a detailed inspection of the lugs for corrosion or other defects. This must be repeated every 100 hours.

Dyn'Aero stated that the SB has been applied on around 500 aircraft in France, Germany and Switzerland and no defect has thus far been found. Some of the aircraft are 12 years old and are operated in potentially as corrosive an atmosphere as G-BZXG. There were only three aircraft flying with the Type 3 lug; these were removed and replaced with stainless steel lugs. No defects were reported on the returned lugs.

In the UK, the Civil Aviation Authority (CAA) have additionally required the replacement of the Type 2 lugs with a stainless steel equivalent (Dyn'Aero Procedure M EH NO 01, dated 13 March 2008) and for the Type 1 lug, the addition of a stainless steel external attachment bracket (Dyn'Aero procedure M BE NO TL, dated 14 May 2008).

Analysis

The aircraft was carrying out a short flight between two local airfields. The weather conditions were suitable and the flight conditions were good with perhaps some light turbulence. Given that the aircraft was joining the circuit to land when the accident occurred, the loads on the tailplane are unlikely to have been excessively high at this point. Without any warning, the tailplane detached from the aircraft and thereafter control was lost. The passenger, a professional pilot and the more experienced of the two pilots, took over control and sent a 'MAYDAY' radio message. He attempted to guide the aircraft towards the trees although there was little or no effective control. The aircraft then descended through the trees, a factor which probably reduced the severity of the final impact and made the accident survivable.

Both harnesses had failed in the impact, although the loads experienced were probably greater than the design requirement. Testing showed that the single row of stitching, where the upper attachment strap was joined to the main harnesses, is the point at which the harness will fail first.

The tailplane lugs had failed in upload; normal loading on a trimmed aircraft would place a download on the tail. However, in turbulence, manoeuvring or ground handling, uploads could be generated. The metallurgical evidence showed that stress corrosion had been present, weakening the left lug. The most likely failure mechanism would be for the stress corrosion to develop and cause one side of the left lug to initially fail. The remaining side of the lug would then fail at a much lower load as demonstrated by the testing. The complete failure of the left lug would then expose the right lug to much higher loads, causing it to fail rapidly. The subsequent overload failures of the pitch and trim tab control rods allowed the tailplane to detach.

There were a number of factors which could have contributed to the stress corrosion mechanism which precipitated the failure of the left hand lug. A key factor was that the applied loads were perpendicular to the orientation of the material grain in the failed lug. This situation had arisen because whilst the material grain direction was specified for the Type 1 lug, there was no such requirement for the Type 2 and 3 lugs. All the Type 3 lugs examined by the AAIB had a transverse grain direction. The material is weakest in the direction transverse to the grain orientation and loading in this direction is most likely to result in stress corrosion.

Other possible contributory factors may have been the deep bearing staking marks, which could have caused increased stress concentration in those areas around the lug, and the poor corrosion protection of the lug. It was also noted that the left bearing was rotationally tight and showed evidence of corrosion. This could have introduced additional stresses in the lug from elevator control inputs.

The fleet inspection indicated no evidence of any other similar failures although it would be very difficult to see and detect stress corrosion. The new design of Type 3 lugs, in stainless steel and without the requirement for staking the bearing with the attendant stress concentration effect, are designed to eliminate the possibility of a similar failure mechanism.

The Type 1 lug has been in use for up to 12 years, without any reported failures. This design, although having potentially similar issues regarding the staked bearing retention, does have a longitudinal grain direction and so may not be as susceptible to a similar stress corrosion mechanism. However, the Type 2 lug is of a similar design to the Type 3 and, although thicker dimensionally, and therefore able to sustain higher loading, does still have similarities in the method of staking the bearing. As the material grain direction is not specified, its orientation could be unfavourable. The following Safety Recommendations are therefore made:

Safety Recommendation 2008-45

It is recommended that the Direction Generale de l'Aviation Civile (DGAC) considers mandating the replacement of Type 2 tailplane attachment lugs on all variants of MCR models with a stainless steel replacement as described in Dyn'Aero Procedure M EH NO 01, dated 13 March 2008.

Safety Recommendation 2008-46

It is recommended that the aircraft manufacturer, Dyn'Aero, should consider informing owners of all variants of MCR models with the Type 2 tailplane attachment lug fitted, as identified from Dyn'Aero Service Bulletin (BS 08 B0034 issued on 13 February 2008), of the availability of a stainless steel replacement, as described in Dyn'Aero Procedure M EH NO 01, dated 13 March 2008.

ACCIDENT

Wing:	Paramania Revolution 23
Paramotor unit:	Modified H & E Paramotores R120 series
Year of Manufacture:	2005
Date & Time (UTC):	8 July 2007 at 1950 hrs
Location:	Middle Barn Farm, Bexhill, East Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Substantial
Commander's Licence:	None required
Commander's Age:	42 years
Commander's Flying Experience:	5 years (paramotors)
Information Source:	AAIB Field Investigation

Synopsis

The paramotor was being operated by an experienced pilot who was also an instructor. He was seen to initiate what was described as a 'wingover' manoeuvre to the right, at about 1,000 ft, but this was seen to develop into a rapid spiral to the left which continued for several turns, with a high rate of descent. The aircraft started to recover at a late stage but the pilot received fatal injuries in the impact with the ground.

There was no defect identified within the wing (canopy and rigging) but structural failures were identified within the paramotor unit, consistent with having occurred in flight and precipitating the spiral descent.

One Safety Recommendation is made to the Civil Aviation Authority concerning self-regulation of this activity.

AAIB Special Bulletin 4/07

In-flight structural failures were identified in the early stages of the investigation and the AAIB published '*Special Bulletin 4/07*' in August 2007. This was to draw attention to the structural failures, which appeared to have precipitated this accident and also to highlight the lack of regulation concerning the design and construction of paramotors. The Special Bulletin also advised that pilots should refrain from extreme manoeuvres until the structural integrity of these machines be ascertained.

History of the flight

Several instructors, students and other pilots of a paramotor school had spent the day at the site discussing paramotor flying, conducting ground instruction and waiting for conditions to become suitable for flying. At around 1930 hrs, in conditions described as a light west-southwesterly wind and good visibility, three of the more experienced pilots launched.

The pilot involved in the accident was flying a combination of wing and paramotor unit belonging to the school, at which he was an instructor. He had aborted his first three attempts to launch because on each occasion the wing made an uncommanded left turn. On the first launch the wing “dipped” left and the paramotor’s propeller took “a couple of turns around the lines”. Another paramotor pilot freed the lines, the pilot checked them himself and then prepared for the next launch. On the second and third launches the wing turned left again and the assisting pilot noticed that a buckle was caught in the webbing at the base of the lines, fouling the rigging: this was in the ‘B’ line webbing and resulted in the ‘B’ line being shorter than the other flying lines, inducing the uncommanded turn to the left. After the assisting pilot had freed the buckle, the pilot launched without apparent difficulty. He then climbed to approximately 500 ft and appeared to “attempt a wingover”, during which the right side of the wing collapsed over approximately 40% of its span. It re-inflated almost immediately. The pilot then flew normally for several minutes and was seen to conduct some “low skimming”, before climbing to approximately 1,000 ft.

From that altitude he appeared to initiate a wingover to the right but the aircraft almost immediately entered a wingover to the left that developed into a left-hand spiral. The first three turns of this spiral appeared “normal” to the witnesses, in the sense that the speed of rotation was similar to other spiral manoeuvres they had observed. However, the fourth and subsequent turns appeared to develop into a fast rotational manoeuvre in which the vertical axis of the wing/paramotor unit combination appeared almost horizontal and the axis of rotation appeared to be between the wing and the harness. The aircraft completed five or six such turns until, at approximately 150 ft above the ground, witnesses heard the note of the engine increase, indicating to them that the pilot may have applied full power. The manoeuvre appeared to become less severe, as though the aircraft was beginning to recover to normal flight but, shortly afterwards, it was clear that it had hit the ground, although approximately the last 30 ft of the descent were obscured by low hedges and trees.

The school’s other instructor directed another pilot, who was airborne at the time, to fly over to the site of the impact, some distance from the main gathering. Several witnesses made their way on foot or by car but were hampered by numerous ditches which separated the fields. Others alerted the emergency services, the first of which arrived in vehicles which were also unable to reach the site. One person was able to identify the location using a handheld GPS and directed the air ambulance to within a short distance of the injured pilot.

The pilot was attended at the scene by paramedics then flown to hospital. He remained unconscious throughout and died two days later.

Pilot information

The pilot had flown paragliders since the 1980s. Although no formal record of pilot experience existed (nor was required), family members recalled that he began to fly paramotors five years before the accident. He was a member of the British Microlight Aircraft Association (BMAA) and held a current Foot Launched Microlight Instructor Rating.

Colleagues of the pilot described him as having a keen interest in improving the safety of the sport. Members of his family provided documentary evidence of this interest, including drafts of an amended syllabus of training to fly paramotors and notes of discussions he had with several other participants, regarding the foundation of a single organisation to oversee the sport.

Medical and pathological information

The post-mortem revealed the presence of relatively severe coronary artery disease. No acute changes were evident, however, and it is likely that this was an incidental finding. The post-mortem report for HM Coroner stated that the cause of death was multiple injuries.

Meteorological information

No official meteorological observations were available at the accident site. Other paramotor pilots present stated that the surface wind was from the west-southwest at about 4 mph. The wind was stronger aloft, "perhaps 16-18 mph" according to one pilot, but there was little or no thermal activity and no other turbulence. Visibility was "good", with a mostly clear sky and some cloud to the west with an estimated base at 4,000 ft.

Description of the paramotor

A complete paramotor (Figure 1) consists of a wing (canopy) and a system of suspension lines and risers (shrouds), akin to a paraglider, and a lower 'paramotor unit' assembly, accommodating the pilot and powerplant. In the accident aircraft the wing and paramotor units came from separate manufacturers and the paramotor unit had been modified.

The fabric wing relies on air pressure at the leading edge to inflate it and produce its aerofoil shape. The upper and lower surfaces are stitched together at the trailing edge and around the wing tips, but the leading edge has openings and chordwise vertical ribs are attached to the upper and lower surfaces of the wing, dividing it into cells. Holes in the ribs permit the cross-flow of air, so that air pressure inside the wing is equalised. The air pressure inside the wing is dependent on airspeed and the direction of the relative airflow.

In this design, four sets of cords or 'lines' are attached to the lower surface of the wing at specific chordwise locations. The lines are made of synthetic fibre and are grouped according to their chordwise location. The 'A' lines are attached to the leading edge of the wing, with the 'B', 'C' and 'D' lines being attached at progressively more rearward positions on the wing. Thus, inadvertent shortening of the 'B' line webbing on the left, as mentioned earlier, would tend to induce an uncommanded turn in that direction.

The structure of the paramotor unit, the lower assembly, supports the engine and propeller, as well as the rear attachment of the occupant seat support webbing. Hinged arms extend forward from the structure and

Figure 1
Paramotor aircraft - typical

during flight support the front attachment webbing of the seat. The arms are suspended at approximately mid-length by a system carrying the lift loads provided by the shrouds of the wing. Limit stops prevent the arms from rotating above a position approximately parallel to the seat base.

A series of holes in the arms enables the attachment point of the lift loads to be altered fore and aft. The largely unchanging load of the engine, propeller and fixed structure is centred behind the rear of the seat attachment, whereas the variable load provided by the occupant is positioned near the mid point of the seat. Variable fore and aft positioning of the lift attachments enables the balance of the system to be adjusted to allow for varying occupant weights.

The lift system is attached generally by shackles, the bolts/pins of which pass through specific holes in the arms chosen to create the desired balance between the suspended mass of the basic unit and that of the occupant. A system of webbing straps provides an alternative load path between the seat support fabric and the lift system, bypassing the arms and their attachments.

The fixed structure of the paramotor unit has slight asymmetry, to balance engine torque, causing the total suspended mass to be offset and leading to a difference in lift forces between the left and right sets of shrouds. This would normally lead to the unit having a curving flight path but the torque reaction of the engine and propeller act in the opposite direction, leading to a balanced condition where the combination has an approximately straight flight path when flying under typical engine power conditions.

Examination of damaged aircraft

General

The paramotor structure, machinery, shrouds and wing from the accident were subjected to examination some days after the accident. Examination of the wing and shrouds revealed no evidence of damage which could be attributed to any in-flight loading. Sections of the fabric webbing forming the seat and harness had been cut; this is understood to have occurred during the rescue of the pilot.

The normal lift force attachments of the wing to the hinged arms of the paramotor unit had, however, suffered a number of failures, leaving the webbing straps as the sole attachments of the seat base to the shrouds. The nature of these failures did not indicate that they had resulted from the ground impact, which predominantly affected the pilot and was not immediately fatal. In contrast, very high locally concentrated forces had failed the metallic lift attachments.

The lift arms attached to this paramotor unit were not those originally fitted to it by the manufacturer and these arms had then been further modified. As noted above, each lift arm was equipped with a row of holes which enabled the lift load attachment position to be varied to take account of different occupant weights, allowing these to be balanced with the fixed weight of the engine, propeller and mounting structure. In this example, the right hand side of the paramotor unit was equipped with a fitting, not forming part of the original structure, which appeared to be positioned to alter the offset of the lift load from the centre line of the box section of the arm. On the left side, the lift shackle was attached in a more conventional way, by means of a shackle pin passing through one of the holes in the corresponding arm (Figures 2 and 3), thus

Figure 2

Left lift arm, from above

Figure 3

Left lift arm, outboard surface

enabling vertical lift loads to be carried by applying loading to the box section of the arm, without any offset of the load.

The additional fitting on the right side consisted of an internally-threaded cylindrical component, tapering to a reduced diameter cylindrical end section (Figure 4). This incorporated an eye-end through which passed a clevis pin, supporting a shackle to which the right-hand webbing was attached. The shackle was of the 'right-angle' type, with the portion to which the webbing was attached orientated at 90° to the shackle-pin axis. Although the shackle initially appeared to have been deformed to this condition by loading, shackles with this geometry are available from, for instance, suppliers of yacht equipment.

The fitting had been secured to the arm by means of a bolt passing through a hole in the arm and into the internally threaded section of the body of the fitting. It was attached to the body via a helical thread insert.

The left arm had suffered a complex failure where the shackle-pin passed through the hole in the arm (Figures 2 and 3). This appeared to be a bending failure in two axes allowing the clevis pin to break out of the hole but, after the failure, some remaining material in the box section surrounding the hole had allowed the forward end of the failed arm to remain united with the hinged end of the arm.

The right arm was not significantly damaged but the additional fitting, described above, had 'pulled out'

Figure 4

Right lift arm, threaded connection

(Figure 4) as a result of the threaded insert failing to retain the bolt within the body of that fitting, under the influence of an axial load component. This bolt was also found to be severely bent.

The plywood seat base, on which the pilot would be directly supported, appeared to have suffered partial fracture approximately along its centre line.

Paramotor operations

During the investigation it became apparent that lift arms occasionally deform and fail on paramotors during 'high load' manoeuvres, as do the plywood seat bases, but that safe continuation of flight has generally been achieved. In such circumstances, the additional webbing straps, which are normally slack, become the connection between the loaded mid-section of the seat and the load support system, bypassing the relevant arm. In doing so, however, they lose the precise degree of individual occupant balance previously established by the selection of the fore-and-aft attachment position.

The operation of a paraglider (that is, the unpowered type of equipment from which the paramotor family is derived) normally involves suspension of the harness and seat beneath the canopy, in a symmetrical condition. Certain manoeuvres, however, cause geometric asymmetry of this arrangement and 'normal' acceleration, resulting from manoeuvres, raise the shroud attachment loads well above those relating to the basic '1G' condition experienced in straight and level flight, or whilst gently altering flight direction.

As previously stated, the paramotor has a further complication in that the torque reaction of the propeller requires a built-in asymmetry of the lower mechanical unit to enable the machine to be easily flown in a straight line during normal powered transit flights. There is thus a considerable range of load magnitudes and directions in which forces are applied to the arms.

During a dynamic manoeuvre, the increased loads may not be evenly distributed between left and right lift systems and failure of one system may cause sudden load transfer to the other side with a consequent 'domino' failure effect. With the differences in design and modification between the left and right support systems in this aircraft, the strengths of the left and right lift attachments, when loaded in any direction, would also be different. Since the loads can also vary in magnitude and direction, especially during manoeuvring flight, there would be a greater probability of an initial asymmetric failure leading to load transfer onto the second lift attachment and then rapidly to a further failure.

Detailed examination

The structural failures in the paramotor unit were examined in detail, both at the AAIB and at a specialist engineering agency. Based on the detail of the failures, and likely material strengths, a calculation was also made of the probable failure loads on the two sides.

Examination and sectioning of the right-hand load attachment fitting revealed that only two threads were fully engaged and a further four were only partly engaged. This would significantly reduce the failure load. In addition, a series of other variable factors would influence the strength of the attachments:

(1) Equivalent bolt class of the insert (a function of material, heat treatment and detailed geometry)

(2) Bolt hardness

(3) Assumed number of thread depths engaged

(4) Assumed level of engagement between insert and connector

(5) Ultimate tensile load of bolt

(6) Estimated remaining load capacity due to number of threads engaged

(7) Estimated remaining load capability due to level of engagement of the insert

(8) Magnification of tensile load due to applied moment

(9) Initial static thread pre-loading resulting from torque/tension relationship arising from level of tightness of bolt in fitting.

Calculation showed that, with a direct load (at 90° to the bolt and fitting, the 'suspended' load), the strength of the right attachment was at its lowest. The failure load progressively increased to a maximum as the load angle changed from a direct lateral load on the bolt/fitting assembly (directly suspended loading) to a pure axial load on the bolt (entirely lateral load imparted by canopy to lower unit).

The bending of the bolt during the failure of the fitting on the right arm indicated a substantial load component at right angles to the bolt axis. This suggested a failure load range falling only slightly above the lowest range of the figures predicted for a direct lateral bolt load. Circular regions of compressive distortion of the material of the right arm surrounding the shackle holes were evident. These indicated that the bolt had been torque-tightened into the fitting on a number of occasions, whilst mounted in a number of different holes. The hole occupied by the bolt on the occasion of the failure was amongst those with significant compressive distortion. Calculations showed that a reduction of load-carrying capacity would have been created by elevated stresses in the thread form produced by the pre-load forces of the tightened bolt. The small number of threads engaged would also have reduced the attachment strength.

In summary, the conclusion from the calculation of the failure loads was that it was probable that the failure of the bolted attachment (the right side of the paramotor unit) occurred first and load transfer to the shackle/pin attachment (the left side) followed. This sequence was further indicated by the bending directions of the failed left-hand arm, suggesting its failure load occurred after the seat and occupant had rotated about a longitudinal axis following failure of the right-hand attachment.

The likely effect of this sequence is detailed in the Analysis section at the end of this report.

Wing characteristics

The advent of 'reflex' wing designs, of which the Paramania Revolution series is an example, has caused a debate within the paraglider and paramotor communities concerning their characteristics and the effects on flight handling. Features of the reflex wing design may cause behavioural differences between this and the more established wing types and such differences may be to the flight path following significant control inputs, but would not manifest themselves in normal flight.

Eyewitness accounts

There were detailed accounts from witnesses with a range of levels of experience. One witness, who knew the accident pilot and was himself an experienced paramotor pilot, commented that "he had self-induced (the initial spiral manoeuvre) at good height but then accelerated. The canopy was juddering which is typical of high speed." With reference to the broken arms of the paramotor unit, he explained that "a left break would cause a right turn and vice versa."

One of the students stated that ground training earlier in the day had included a discussion of recovery from spirals, which involved using the reserve parachute if the paramotor failed to recover from a spiral in three turns. The student recalled being told that "a reserve might work even from 80 ft". The student noted that a reserve parachute is normally an individual purchase and that no reserves were fitted to the club machines. The accident pilot was flying a club machine, to which no reserve parachute was attached during the accident flight.

Another student stated that he understood a "spiral" to involve a high rate of rotation with a high rate of descent, but did not consider this an unusual manoeuvre for an experienced pilot. He had seen several pilots, including the pilot involved in the accident, conduct the manoeuvre on previous flights. Stressing that the accident pilot did not indulge in reckless manoeuvres, one witness commented that a spiral dive was "probably the most radical thing he (the accident pilot) did".

Regulatory background

The operation of paramotors, in common with all other aircraft in the UK, must comply with the Rules of the Air promulgated in the Air Navigation Order (ANO) in relation to collision avoidance, weather and flight over built up areas. However, they enjoy significant exemptions from registration, certification, maintenance and licensing requirements.

Article 153 of the ANO states:

> *'The CAA may exempt from any of the provisions of this Order (other than articles 85, 87, 93, 138, 139, 140, 141 or 154) or any regulations made thereunder, any aircraft or persons or classes of aircraft or persons, either absolutely or subject to such conditions as it thinks fit.'*

In the United Kingdom the issue was first addressed in Aeronautical Information Circular (AIC) 109/2000 – *'Foot launched powered flying machine: (powered paragliders and hang gliders)'*, issued by the Civil Aviation Authority on 14 December 2000. It stated that:

> *'The arrangements described in this Circular for the operation of such Foot Launched Powered Flying Machines (FLPFMs) have been established with the specific intention of deregulating the activity as much as possible.'*

The Circular included a statement exempting FLPFMs from certain provisions of the Air Navigation Order 2000.

On 24 December 2003 the CAA issued the 'Letter of Consultation – '*Proposal to Amend Article 129 of the Air Navigation Order 2000 to regularise the operation of foot launched self-propelled hang-gliders (including paragliders) in the United Kingdom'*. This document discussed progress on the issue since the issue of AIC 109/2000, noting that since such aircraft were excluded from regulation by the European Aviation Safety Agency (EASA) any regulatory measures remained a matter for national arrangements. It noted that:

> *'Application of conventional aeroplane requirements would be unlikely to have significant safety benefits.'*

In support of this contention, Annex B to the Letter included the following statements:

> *'Some flying activities have always been conducted without CAA regulation, for example gliding which can be considered to be self-regulated by the British Gliding Association (BGA). Hang-gliding and paragliding are newer forms of gliding and these operate on a similar basis. In each case these arrangements have been developed and refined over many years, to the satisfaction of the regulator and the relevant airsports association or governing body. The degree of supervision that can be exercised varies from one activity to another. Gliding is of necessity conducted in a club environment, whereas paragliders and paramotors can take off from any suitable site and as a consequence do not easily lend themselves to increased supervision. Nevertheless, structured training syllabi and a culture of responsibility are evident in all these activities. Safety education and information is engendered through a variety of means: by national associations, within the clubs and by individual instructors.'*

The Letter concluded that:

> *'if the proposed course of action (to amend the Article 129) were to be rejected, the existing legal provisions for aeroplanes would be applicable to foot-launched powered aircraft. This would have some cost implications for owners, operators and the CAA, yet the registration, certification, maintenance and licensing requirements would be unlikely to have significant safety benefits.'*

In the subsequent amendment of the ANO dated January 2007, Article 129 became Article 155.

Definition of self-propelled hang-glider

For regulatory purposes paramotor aircraft fall within the definition of self-propelled hang-gliders and are defined in Article 155 of the ANO as follows:

> *'Self-propelled hang-glider' means an aircraft comprising an aerofoil wing and a mechanical propulsion device which:*
>
> *(a) is foot launched;*
>
> *(b) has a stall speed or minimum steady flight speed in the landing configuration not exceeding 35 knots calibrated airspeed;*
>
> *(c) carries a maximum of two persons;*
>
> *(d) has a maximum fuel capacity of 10 litres; and*
>
> *(e) has a maximum unladen weight, including full fuel, of 60 kg for single place aircraft and 70 kg for two place aircraft;'*

Article 155 also states that:

> *'a reference in this Order to a glider shall include a reference to a self-sustaining glider and a self-propelled hang-glider.'*

Consequently, any regulation or exemption applying to gliders also applies to paramotors.

Under the terms of Articles 3 and 8 of the ANO respectively, a paramotor operating on a private flight which takes place entirely over the United Kingdom is thus exempt from the requirement to be registered or to have a certificate of airworthiness. Under the terms of Article 26, the pilot of a paramotor aircraft operated in this way is not required to hold a licence.

Organisational information

The school with which the pilot was associated was affiliated to the BMAA. In the United Kingdom, the operation of paramotors is supported by both the BMAA and the British Hang gliding and Paragliding Association (BHPA). Historically the BMAA has been associated most closely with small fixed-wing flying machines and states on its website that:

> *'The British Microlight Aircraft Association looks after the interests of microlight owners in the UK. It is an organisation approved by the Civil Aviation Authority (CAA) and has powers delegated to it to control training and airworthiness.'*

Similarly, the BHPA states on its website that:

> *'The British Hang Gliding & Paragliding Association oversees pilot and instructor training standards, provides technical support, such as airworthiness standards, runs coaching courses for pilots, and supports a network of recreational clubs and registered schools, providing the infrastructure within which UK hang gliding and paragliding thrive.'*

Participants in the sport may, but are not required to, be members of either organisation. Neither organisation is in fact responsible for the airworthiness of paramotors and, because no licence is required to operate them, neither organisation has any practical control over training to do so. Both previously offered a syllabus of suggested training but the BMAA ceased to do so in April 2008. Nevertheless, the BMAA and BHPA communicate on matters relating to paramotor operation and the BMAA has stated that it refers to the BHPA questions from participants regarding training. Referring to paramotors as '*foot launched microlight aircraft*, the BMAA is recognised by the Fédération Aéronautique Internationale (the world governing body for air sports and aeronautic world records) as a competent organisation for records and competitions involving these aircraft.

Other applicable legislation

Annex 6 to the Memorandum of Understanding between the Health and Safety Executive (HSE) and the CAA Safety Regulation Group, entitled '*Recreational Flying and Parachuting'*, outlines the interface between the HSE and the CAA in relation to the health and safety of persons involved with, or affected by, recreational flying activities and parachuting. In this context parachuting is taken to include paragliding though not specifically paramotoring. It states, in part:

> *'The CAA is responsible, under the terms of the Civil Aviation Act and the Air Navigation Order (ANO) for generally regulating the safety of all aviation activities.*
>
> *In all cases overall responsibility for the safe regulation of the flying activity remains with the CAA, however the CAA recognises the important role played by the governing bodies of sport. The degree of self-regulation exercised by these sporting bodies is not the same for each activity.'*

Also,

> *'The HSE and the relevant Local Authority (LA) are responsible for enforcing health and safety law at all premises.*
>
> *Health and Safety Commission (HSC) policy is that duplication of regulatory effort should be avoided. Therefore, HSE inspectors/LA enforcement officers would not normally take enforcement action on those matters which are subject to legislation enforced by the CAA. This includes matters relating to airworthiness of aircraft and the competence, training and conduct of pilots. However, if HSE/LA inspectors have reason for concern they should report this to the relevant authority.'*

It concludes that:

> *'The CAA will lead on those issues which concern the conduct of any flying activity itself. The HSE/LA will lead on those issues which concern the safety of premises and ground-based activities which involve employment, the self-employed or the provision of non-domestic premises as a place of work.'*

Analysis

Engineering aspects

Following this accident unusual damage, not consistent with ground impact was found in the failures of both lift arm attachments, and of the plywood seat. This damage appeared consistent with the behaviour of the paramotor observed by the witnesses on the ground. The calculations of the likely failure loads on the two sides, and the distortion of the hardware, indicated that the right-hand attachment fitting probably failed first. This could have precipitated the failure of the left lift arm, at the hole in that arm supporting the clevis pin carrying the flight loads.

Effect of structural failure on flight control

Failure of the bolted (right-hand) attachment would result in an effective increase in the length of the lines on the right-hand side and an increased tendency of the paramotor to turn left. If the paramotor was already in a left-hand spiral, this would increase the speed of the spiral and might make recovery difficult using conventional control inputs. If the left-hand attachment failed subsequently it would restore some symmetry to the control system and allow the aircraft to recover more readily, which might accord with the sequence of manoeuvres and the partial recovery seen by some witnesses. It is likely, however, that this change occurred too late for the pilot to effect a complete recovery before striking the ground.

The lack of recorded information (from photographs, video, radar or onboard recording) made it impossible to quantify the speeds and attitudes of this aircraft's final manoeuvres. However, it is likely that a combination of the manoeuvring and the modified structure were the significant contributing factors in the accident.

Possible 'fouling' of the rigging buckle

During the three unsuccessful launches, fouling of the buckle in the webbing of the left lines resulted in the 'B' line being shorter than the other flying lines to the extent that it induced an uncommanded left turn. The success of the fourth launch indicates that the buckle was no longer fouled when the paramotor was launched. The geometry of the webbing under flight load is such that the buckle could not then have become fouled except if this load was removed. The only opportunity for such unloading was presented by the partial collapse of the wing following the manoeuvre characterised by witnesses as an "attempted wingover". However, since it was the right side of the wing that collapsed it is highly unlikely that the left side would have been unloaded sufficiently for the buckle to become fouled again. There is also no indication from subsequent manoeuvres, during a period of several minutes prior to the commencement of the final spiral, that the pilot was having difficulty controlling the aircraft. It is therefore highly unlikely that the buckle had become fouled at any time during the flight, following the successful fourth launch.

Regulation

Many participants have expressed a desire for greater regulation of paramotor activity. In this case the pilot involved was engaged in a flying activity with which he was familiar, in conditions that his colleagues considered suitable. He was widely regarded as experienced, competent and safety conscious and there was documentary evidence that he was a proponent of more rigorous training and oversight of the sport. Given his background, therefore, there is no evidence that greater regulation of the *operation* of paramotors (as distinct from their *airworthiness* - design, manufacture and maintenance) would have prevented this accident.

In assessing the effects of exempting self-propelled hang-gliders from certain requirements, the CAA envisaged that:

> *'Safety education and information' would be 'engendered through a variety of means: by national associations, within the clubs and by individual instructors.'*

Although in practice the BMAA and BHPA aim to communicate on related issues, oversight by two organisations risks the division of the sport into two 'camps', potentially with opposing views and lacking a common voice. Likewise, there is no single body to which recommendations can be addressed and no single body able to identify, and implement, suitable codes for design, manufacture and maintenance. The gliding movement in the United Kingdom has, in general, developed effectively and safely under the single entity of the British Gliding Association and this is an example of 'enlightened self-regulation' in sports aviation.

Under current legislation, the CAA retains ultimate responsibility for the regulation of sport flying activities in the United Kingdom and accordingly the following Safety Recommendation is made:

Safety Recommendation 2008-052

It is recommended that the Civil Aviation Authority should actively develop oversight of the sport of self-propelled hang-gliders, including paramotors, by a single organisation.

ACCIDENT

Aircraft Type and Registration:	Pegasus XL-Q, G-MTPS
No & Type of Engines:	1 Rotax 462 piston engine
Year of Manufacture:	1987
Date & Time (UTC):	16 September 2008 at 1230 hrs
Location:	Redlands Airfield, near Swindon, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Cockpit cracked across. Upright to wing connection block - broken, base tube broken
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	59 hours (of which all were on type) Last 90 days - 4 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

G-MTPS overflew the grass airstrip and its pilot assessed the wind to be from the south. He made an approach to Runway 17 but, after rounding out and at a height of about 10 ft, there was a "swirling gust of wind" from the east. The pilot was unable to control the effect of the wind and G-MTPS landed heavily causing it significant damage.

ACCIDENT

Aircraft Type and Registration:	RAF 2000 GTX-SE, G-BXAC
No & Type of Engines:	1 Subaru EJ22 piston engine
Year of Manufacture:	1997
Date & Time (UTC):	14 September 2008 at 1430 hrs
Location:	Eaglescott Airfield, Devon
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to rotor, top of mast, propeller, axle and front wheel
Commander's Licence:	Private Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	253 hours (of which all were on type) Last 90 days - 16 hours Last 28 days - 12 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Following a stable final approach and just prior to landing, the pilot elected to move his touchdown point significantly further down Runway 07 to reduce the transit distance to the turnoff and thus vacate the runway more rapidly. The weather was fine but with a 4 kt breeze blowing from the south-south-east, across the runway, resulting in the pilot flying the approach with 'crossed controls'. When the gyroplane was about five feet above the ground, it descended rapidly and turned to the left. The pilot responded by increasing engine power, but could not arrest the rate of descent and the aircraft landed heavily on the runway before rolling onto its left side. The pilot candidly admits that insufficient airspeed and inadequate use of available engine power resulted in the accident.

ACCIDENT

Aircraft Type and Registration:	X'Air 700(1A) X'Air, G-CBCM
No & Type of Engines:	1 HKS 700E V3 piston engine
Year of Manufacture:	2001
Date & Time (UTC):	20 September 2008 at 1400 hrs
Location:	West Common, North Road, Yabblethorpe, near Southorpe
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor damage to left main landing gear
Commander's Licence:	Private Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	240 hours (of which 71 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

During initial climb after a normal takeoff, the pilot heard the engine note change unexpectedly. Seeing a suitable field ahead, he elected to carry out a precautionary landing. The landing was uneventful until at a low speed, the left main landing gear wheel rolled into soft ground. Subsequent inspection showed that the stub axle had cracked. The pilot considered that the engine problem was caused by vapour lock, and following discussions with the engine manufacturer's agent, he re-routed the fuel line to the left side of the engine so that it ran behind, rather than in front of, the carburettor. The aircraft was inspected by a BMAA Inspector and returned to service.

BULLETIN RE-ISSUED

A report on this event was originally published in the August 2008 issue of the AAIB Bulletin. Since publication, additional information has came to light, and the investigation was re-opened, in accordance with Section 15 of *The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996*, and the report is herewith re-issued.

INCIDENT

Aircraft Type and Registration:	Cessna 208 Caravan I amphibious floatplane, G-MDJE
No & Type of Engines:	1 Pratt & Whitney Canada PT6A-114A turboprop engine
Year of Manufacture:	2001
Date & Time (UTC):	24 May 2008 at 1930 hrs
Location:	Overhead Partick, Glasgow
Type of Flight:	Commercial Air Transport (Non-Revenue)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Water rudder detached in flight
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	34 years
Commander's Flying Experience:	4,615 hours (of which 6.5 were on type) Last 90 days - 32 hours Last 28 days - 6.5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB examination

Synopsis

Whilst flying at 1,200 ft over Glasgow, the left float water rudder fell from the aircraft due to a failure of the rudder attachment post. The damage to the attachment post was consistent with the aircraft 'reversing' into a submerged object during manoeuvring with the water rudders deployed.

History of the flight

The aircraft had taken off from the River Clyde on a positioning flight to Loch Lomond. Shortly after reaching its cruising altitude of 1,200 ft, a vibration was felt through the aircraft which lasted for approximately 10 seconds. The pilot carried out a visual inspection of the airframe from the cockpit and observed that the left water rudder was missing. The aircraft diverted to Glasgow Airport where an uneventful landing was made. The water rudder was later recovered in a garden in the Partick area of Glasgow. No one on the ground was injured.

Description of the aircraft

The aircraft was a Cessna 208 Caravan 1 fitted with a pair of Wipaire Inc Wipline model 8000 amphibious floats. These are fitted with a retractable wheeled landing gear to allow the use of conventional runways in addition to waterborne operation. Each float is fitted with a retractable water rudder on its rear bulkhead, connected to the aircraft's rudder system via a series of cables and bellcranks. The rudders are retracted when taking off and landing on water, and are deployed to when manoeuvring on water at slow speed. With the rudders retracted for takeoff and landing, it is highly unlikely that the rudders could be damaged by any floating or semi-submerged objects. The rudders are designed to pivot upwards in the event that they do hit an object passing forward to aft, thereby minimising any potential damage.

Rudder system examination

It was reported that there were no entries in the aircraft's technical log relating to the water rudder system. Initial examination by the operator and their maintenance organisation revealed that the water rudder attachment post at the rear of the left float had been distorted and that the welds on the rudder pivot tube had failed, allowing the rudder to separate from the float. Prior to the removal of the rudder post, the water rudder steering cable tension was checked and found to be 8 lb.

A photograph of the post, Figure 1, showed that it had been liberally coated with grease as a corrosion prevention measure. After removal, it was dispatched to the AAIB for detailed examination. Damage was also found on the rear float bulkhead, Figure 1, which indicated that the rudder had, at some time, rotated sufficiently to allow the pivot bolt to make contact with the bulkhead.

Maintenance history

The approved inspection program for the Wipline model 8000 floats details two periodic inspections of the water rudder system. One should be conducted at 25 flying hour intervals involving inspection of the rudder blades and posts for damage, security and corrosion. The other should take place every 100 flying hours, inspecting the rudder steering and retraction system for damage as well as ensuring correct rigging. Both checks are also carried out during the aircraft's annual inspection.

The aircraft records showed that the last 100 hour inspection had been completed on 1 May 2008 and the 25 hour inspection on 21 May 2008, four days prior to the incident. There was no documented evidence to suggest that any problems had been identified during these inspections. A manufacturer's installation drawing for the water rudder and its cable systems, provided by the operator, indicated that both the steering and rudder retraction cables should have a tension of 30 lb, plus or minus 5 lb, whereas the service manual states *'CABLES SHOULD BE TENSIONED TO 10 POUNDS +/- 5'*

Figure 1
Damaged rudder hinge post

Detailed examination

The rudder mounting post consists of a square-section steel tube with hinge points and a rudder 'steering input bar' secured to its forward face. A tube is welded into a 'cut out' in the lower aft portion of the post which provides the attachment and retraction pivot point for the rudder blade, Figure 2. A mechanical stop is fitted to the bottom of the rudder post to prevent the rudder swinging too far forward when deployed. Examination showed that the steering input bar had been bent to the left, and the mounting post distorted rearwards, where the pivot tube had been welded to the post, Figure 3. The tube had separated from the post. The rudder post was distorted on its aft face, and there was 'tearing' of both tube sidewalls where the pivot tube had been secured.

Damaged water rudder hinge post

Microscopic examination revealed that the upper and lower failure surfaces, together with the 'tears' in the post sidewall, exhibited characteristics of a failure due to overload. The circumferential welds securing the pivot tube to the rudder post had not completely penetrated the post sidewall, and had also failed in overload, Figure 4. Both of the rudder post sidewalls in the region of the circumferential welds had been distorted by the application of a torsional load in a clockwise sense (viewed from the rear). There was no evidence of corrosion or crack progression by a fatigue mechanism on any of the fracture faces. When operating from water, the water rudder pivot is below the waterline which together with the presence of a liberal

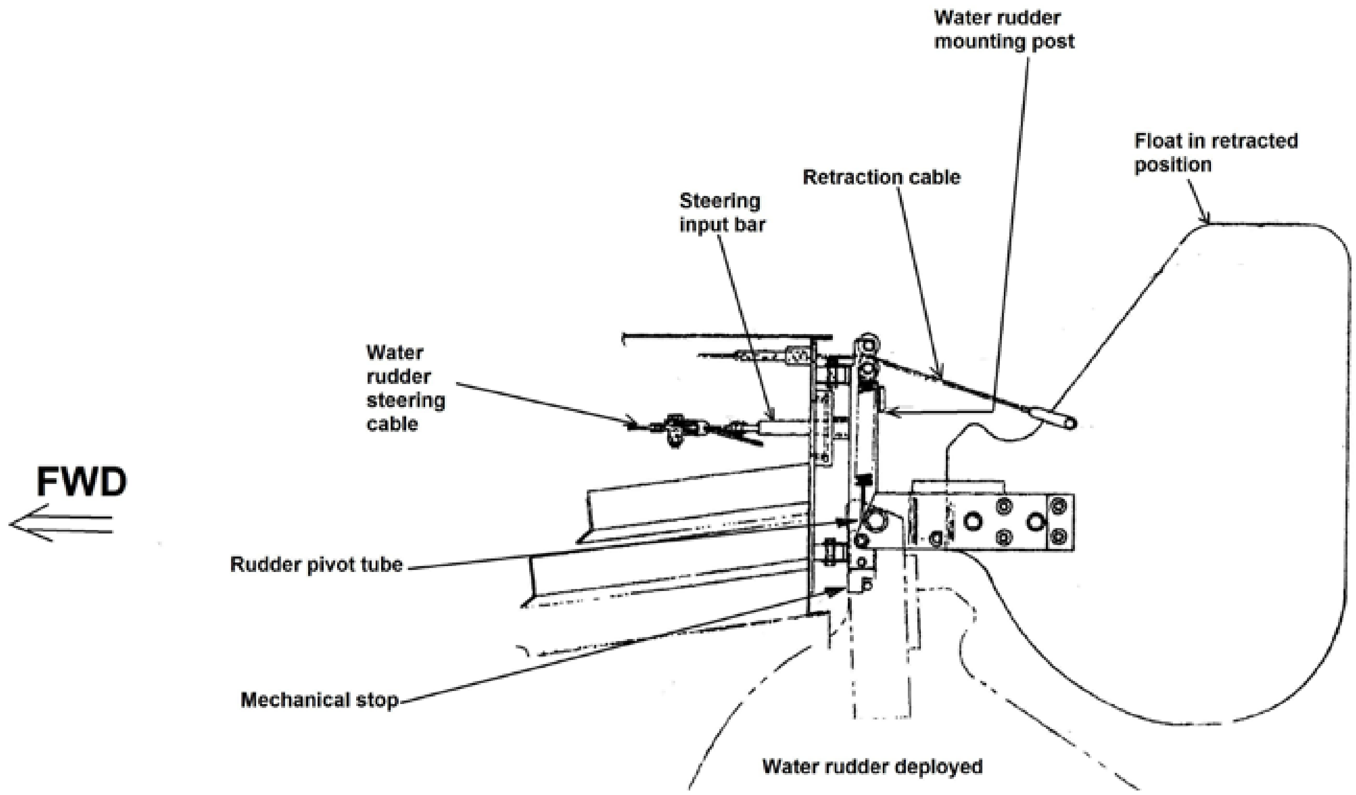


Figure 2

Water rudder installation diagram

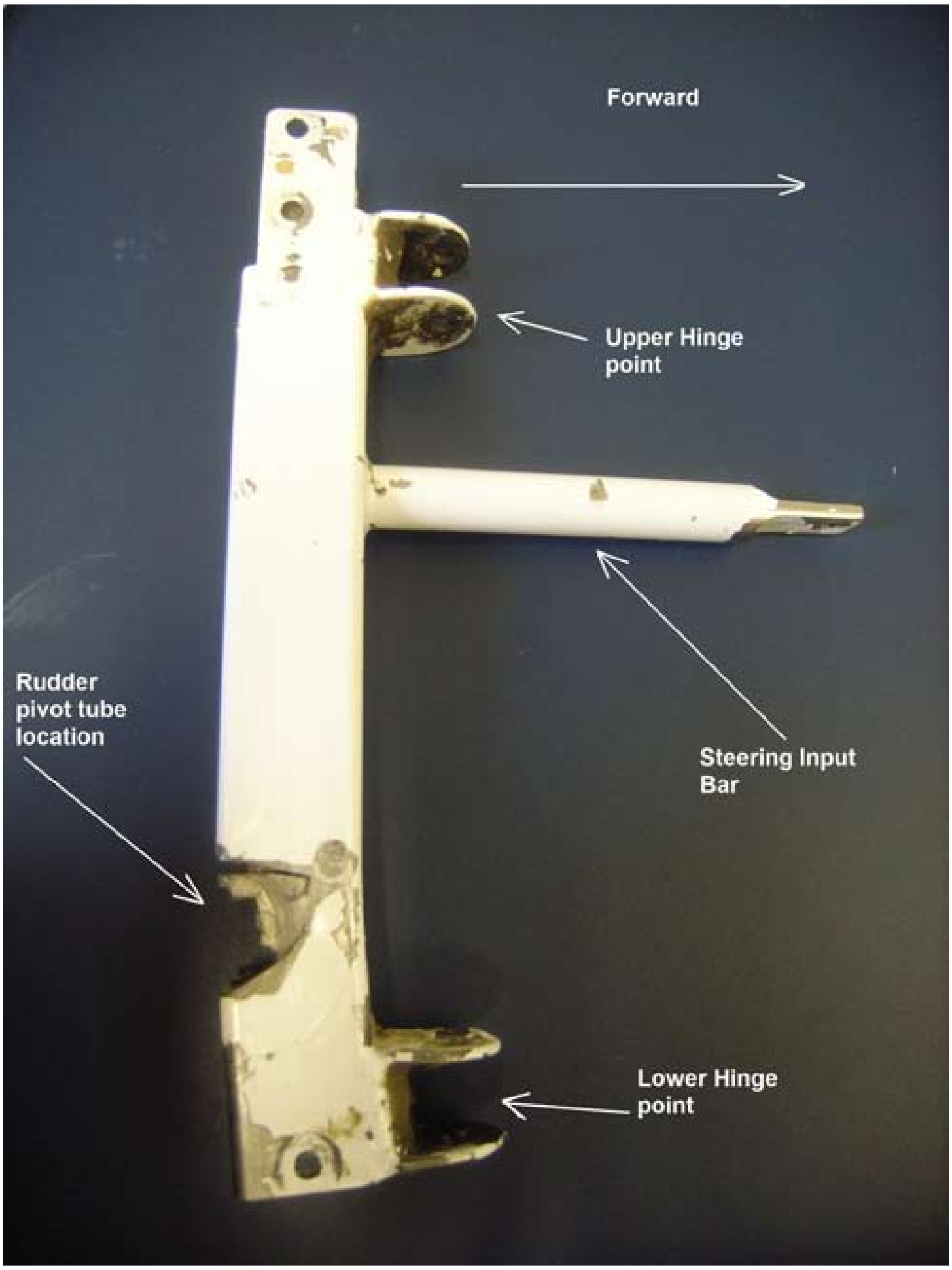


Figure 3

Damaged water rudder hinge post

coating of protective grease, may have prevented the damage to the post being observed during a pre-flight inspection on the water.

Analysis

The operator has highlighted to the manufacturer the disparity between the cable tension requirements detailed in the float installation drawing and the manufacturer's service manual. The manufacturuer is reviewing the situation and has undertaken to issue clarification of the cable tension requirements.

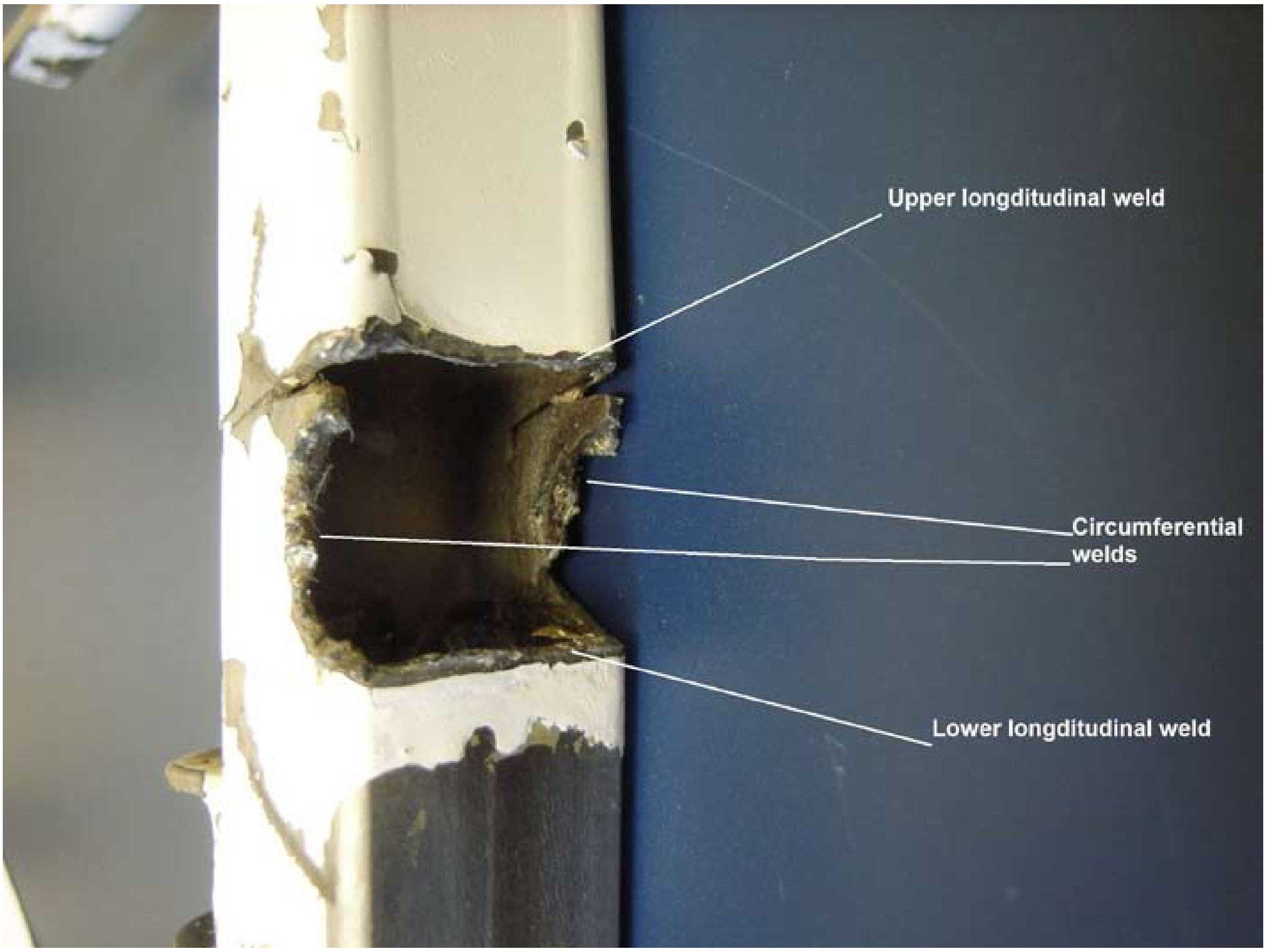


Figure 4
Rudder post weld details

The deformation of the rudder mounting post indicated that the rudder pivot tube had been pulled aft, causing the aft wall of the rudder post to fail where the pivot tube was attached. The 'tears' in the post sidewalls illustrate that, despite the welds securing the pivot tube having only partial material penetration, they were able to transmit sufficient load to damage the rudder post sidewalls without failing. The damage observed was consistent with a force being applied to the lower portion of the rudder from the rear whilst deployed. This caused the rudder to 'pivot' about the lower mechanical stop, producing the rearward bending of the post where the pivot tube was attached. The force was of sufficient magnitude to cause the failure in overload of the two longitudinal welds securing the pivot tube. The distortion of the post sidewalls close to the circumferential welds showed that a torsional load had been applied through the pivot tube, in a clockwise sense (aft looking forward), after the failure of the upper and lower longitudinal welds which resulted in the failure of the sidewalls. The subsequent failure of the remaining circumferential welds allowed the rudder to separate from the aircraft. It could not be determined when the damage to the rudder post had occurred. The bending of the steering input bar indicated that, either the rudder had been restrained against a right rudder input from the cockpit or, more probably, given the use of cables in the water rudder system, an external force being applied to the rudder, forcing it to the left. The damage to the rear bulkhead of the float was indicative of 'overtravel' of the water rudder. It is considered possible that this could be caused by the water rudder cables being incorrectly rigged. However, the aircraft records made available during the investigation showed no evidence of this prior to the incident. The damage to the rudder mounting post was inconsistent with it being damaged as a result of hitting the rear bulkhead of the float.

Conclusions

Given that the rudder became detached from the aircraft in-flight, the force applied to the rudder, although sufficient to cause significant damage to the mounting post, did not result in the immediate separation of the rudder. Whilst the point at which the rudder became damaged was not identified, the lack of evidence of crack progression through fatigue suggests that the damage had not been present on the aircraft for a prolonged period. Given the rudder's location, the damage to the post should have been visible during an 'out of water' pre-flight inspection but unlikely to have been seen during an inspection whilst water-borne.

All the damage observed on the rudder mounting post was consistent with the rudder being struck from behind, with some force, whilst deployed. It is considered that this was more likely to have occurred whilst the aircraft was being manoeuvred on the water, when it may have 'reversed' into a submerged object, rather than being struck from behind by a moving object.

BULLETIN ADDENDUM

AAIB File:	EW/G2004/10/06
Aircraft Type and Registration:	Gulfstream AA-5B Tiger, G-BFZR
Date & Time (UTC):	15 October 2004 at 1545 hrs
Location:	1 mile west of Oxford Kidlington Airport, Oxfordshire
Information Source:	Report submitted by maintenance organisation

AAIB Bulletin No 2/2005, page 57 refers

During a recent inspection of this aircraft an incorrect type of fuel drain was found fitted to its left wing. The sampling holes of this drain were located higher up the body of the fitting than on the correct type such that a greater depth of fluid in the wing remained unchecked during its operation (Figure 1). This might account for the significant amounts of water found in the fuel system after the accident which were not detected in samples taken during preflight checks.

Each type of fuel drain can be identified by its part number which is visible on the outside (bottom) face of the drain.

Figure 1

Image showing difference between the fuel drains

AIRCRAFT ACCIDENT REPORT No 1/2009

This report was published on 9 January 2009 and is avaiable on the AAIB Website www.aaib.gov.uk

REPORT ON THE SERIOUS INCIDENTS TO BOEING 737-81Q, G-XLAC, ON 29 DECEMBER 2006; AVIONS DE TRANSPORT REGIONAL ATR-72-202, G-BWDA ON 29 DECEMBER 2006 EMBRAER EMB-145EU, G-EMBO ON 29 DECEMBER 2006 AND BOEING 737-81Q, G-XLAC ON 3 JANUARY 2007 AT RUNWAY 27, BRISTOL INTERNATIONAL AIRPORT

Three aircraft were involved in the principal events described in this report:

(i) Aircraft No 1 (This aircraft was involved in two events)

Registered Owner and Operator:	XL Airways UK Ltd
Aircraft Type and Model:	Boeing 737-81Q
Registration:	G-XLAC
Place of Incident:	Runway 27, Bristol International Airport Latitude: 51º 22' N Longitude: 002º43' W
Date and Time:	(i) 29 December 2006 at 1150 hrs (ii) 3 January 2007 at 1832 hrs

(ii) Aircraft No 2

Registered Owner and Operator:	Aurigny Air Services Ltd
Aircraft Type and Model:	Avions de Transport Regional ATR-72-202
Registration:	G-BWDA
Place of Incident:	Runway 27, Bristol International Airport
Date and Time:	29 December 2006 at 1215 hrs

(iii) Aircraft No 3

Registered Owner and Operator:	British Airways CitiExpress PLC
Aircraft Type and Model:	Embraer EMB-145EU
Registration:	G-EMBO
Place of Incident:	Runway 27, Bristol International Airport
Date and Time:	29 December 2006 at 2133 hrs

All times in this report are UTC unless otherwise stated.

Synopsis

The serious incidents involving G-BWDA and G-EMBO were notified to the Air Accidents Investigation Branch (AAIB) on 29 December 2006. An investigation into the two serious incidents began on 2 January 2007. During this investigation, the events involving G-XLAC, and others, were identified. All events took place during landings at Bristol International Airport, hereafter referred to as BIA.

The AAIB investigation team comprised:

Mr K Conradi	(Investigator-in-Charge)
Mr T J Atkinson	(Operations)
Mr S J Hawkins	(Engineering)
Mr C J Scott	(Flight Recorders)

Resurfacing and re-profiling work was taking place on parts of the runway at BIA as part of a major project to resurface the manoeuvring area pavements, and sections of the runway surface were ungrooved 'base course' asphalt. From 14 November 2006, there were reports from flight crew of a variety of problems related to the friction characteristics of the temporary runway surface, though no serious incidents occurred until 29 December 2006. On that day, the flight crew of G-XLAC experienced poor stopping performance during landing. Later that day, the flight crew of G-BWDA experienced stopping and lateral control difficulties during landing, and the aircraft departed the runway surface and came to rest on the grass area at the side of the runway. Later still, the flight crew of G-EMBO experienced lateral control difficulties during landing, and the aircraft partially left and then regained the runway. On 3 January 2007, another flight crew, also operating G-XLAC, experienced poor stopping performance. The airport was subsequently closed whilst grooves were cut in the base course. After it re-opened there were no further incidents.

The investigation identified the following causal factors:

1. Reduced friction on the wet ungrooved base course sections of the runway caused flight crews to experience reduced braking action and reduced lateral controllability on landing in strong crosswinds.

2. The Flight Operations Department Communication (FODCOM) advice published by the CAA regarding operations on runways notified 'slippery when wet', in wet conditions, was not communicated by operators to flight crews.

3. The passing, by ATC, of braking action reports based on Mu-meter friction assessments, gave flight crews a false confidence in the braking action available on the wet runway.

The investigation identified the following contributory factor:

1. G-BWDA landed in a crosswind outside the operator's published limits and the subsequent use of reverse thrust was contrary to the advice contained in the company's Operations Manual.

The AAIB has made five Safety Recommendations.

Findings

The aircraft

1. There was no evidence of the aircraft involved in the incidents having experienced a technical fault.

2. The only damage was to G-BWDA, which suffered damage to its left propeller.

3. The tread depths and pressures of the tyres on the incident aircraft were, as far as could be determined, within allowable limits.

The runway

4. The runway resurfacing work at Bristol Airport was complex because it involved an attempt to reshape parts of the runway prior to resurfacing.

5. Several separate areas of the runway had a temporary ungrooved base course Marshall Asphalt surface.

6. The runway resurfacing work was undertaken at night and during the winter to avoid disrupting flight schedules.

7. The longest stretch of ungrooved base course was the central runway portion and was 295 m long and covered the full width.

8. Marshall asphalt is not porous and, when used as a surface course, is usually grooved to allow water to drain to the side of the runway.

9. The surface friction of the ungrooved base course had not been assessed using a Mu-meter with self-wetting in dry conditions predominantly due to the prevailing weather. There was a dry period on 8 December 2006 but no staff were available to conduct the runs.

10. Mu-meter runs carried out in wet conditions revealed that the ungrooved base course had significantly less friction than the grooved runway sections.

11. Mu-meter runs of the central ungrooved section, undertaken in natural wet and damp conditions, indicated that the friction of the ungrooved base course was probably below the Minimum Friction Level (MFL) of 0.50.

12. The airport operator's risk assessment plan had not adequately addressed the hazards presented to aircraft operating on the temporary surfaces in wet and windy weather.

13. Runway surface contractors believed that temporary ungrooved base course did not represent a significant risk and were more concerned about limiting the length of ungrooved surface course to 100 m; no length limitation was specified for the ungrooved base course.

14. The information promulgated by NOTAM, that braking action information would be available during wet conditions, was incorrect.

15. Following the incidents investigated in this report, the airport operator closed the runway on 7 January 2007 and cut temporary grooves in the ungrooved base course.

16. The runway was re-opened on 8 January 2007; no further runway excursion or braking difficulty reports were received after this date.

17. The instruction in CAP 683 concerning friction assessment for resurfaced runways did not clearly include portions of runways which have been resurfaced.

18. The 295-metre full width section of runway surface covered with ungrooved base course asphalt did not provide adequate friction for safe operations when the runway surface was wet.

19. The airport authority was aware of the poor braking action provided by the ungrooved base course asphalt but did not take steps to increase the braking action available until 3 January 2007.

Flight operations

20. A significant number of flight crews experienced difficulties decelerating the aircraft after landing.

21. The flight crews of two aircraft were unable to prevent their aircraft leaving the paved surface while landing in strong crosswinds.

22. The operators of aircraft involved in the four principal events described in this report had not provided guidance concerning operations on runways notified *'slippery when wet'* to their flight crews.

23. During the landing roll of G-BWDA, the use of reverse thrust did not comply with the handling advice in the FCOM for operations in crosswind conditions.

24. The final wind information passed to G-BWDA was in excess of the wet crosswind limit for that aircraft.

Air traffic control

25. The instruction to air traffic controllers in the MATS Part 2, that they should provide runway friction value information based on Mu-meter measurements in wet conditions, was incorrect.

26. The use, by air traffic controllers, of the snow and ice table for conversion of mu-meter reading into braking action in wet conditions, was incorrect.

27. The passing of braking action reports based on CFME readings on a wet runway, ceased on 5 January 2007.

Causal Factors

The investigation identified the following causal factors:

1. Reduced friction on the wet ungrooved base course sections of the runway caused flight crews to experience reduced braking action and reduced lateral controllability on landing in strong crosswinds.

2. The Flight Operations Department Communication (FODCOM) advice published by the CAA regarding operations on runways notified 'slippery when wet', in wet conditions, was not communicated by operators to flight crews.

3. The passing, by ATC, of braking action reports based on Mu-meter friction assessments, gave flight crews a false confidence in the braking action available on the wet runway.

Contributory Factor

The investigation identified the following contributory factor:

1. G-BWDA landed in a crosswind outside the operator's published limits and the subsequent use of reverse thrust was contrary to the advice contained in the company's Operations Manual.

Safety Recommendations

Safety Recommendation 2008-075

The Civil Aviation Authority should inform airport operators about the potential hazards of operating aircraft on sections of ungrooved Marshall Asphalt base course during wet and windy conditions and require that these hazards be controlled during any runway resurfacing programme.

Safety Recommendation 2008-076

The European Aviation Safety Agency should require operators to ensure that flight crews are provided with guidance material on aircraft performance when operating on a runway that is notified as 'may be slippery when wet', or has sections thereof notified as 'may be slippery when wet'.

Safety Recommendation 2008-077

The Civil Aviation Authority should review the manner in which it transmits FODCOM information to ensure that safety critical information is effectively transmitted to private and commercial operators flying in the UK and that it is acted upon.

Safety Recommendation 2008-078

The Civil Aviation Authority should clarify to airport authorities, pilots, aircraft operators and air navigation service providers, that Continuous Friction Measuring Equipment must not be used to assess braking action on runways which are wet, although it may be used in the wet for assessing the relative friction of different runway sections for maintenance purposes.

Safety Recommendation 2008-079

The European Aviation Safety Agency should research the technical and operational feasibility of developing equipment and procedures to measure aircraft braking friction with respect to runway position, using on-board aircraft data from landings. As part of this research the European Aviation Safety Agency should develop appropriate standards of recording and methods for sharing this information, and its tolerances, in a timely manner, with interested parties.

FORMAL AIRCRAFT ACCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

2008

1/2008 Bombardier CL600-2B16 Challenger 604, VP-BJM
8 nm west of Midhurst VOR, West Sussex
on 11 November 2005.

Published January 2008.

2/2008 Airbus A319-131, G-EUOB
during the climb after departure from London Heathrow Airport
on 22 October 2005.

Published January 2008.

3/2008 British Aerospace Jetstream 3202, G-BUVC
at Wick Aerodrome, Caithness, Scotland
on 3 October 2006.

Published February 2008.

4/2008 Airbus A320-214, G-BXKD
at Runway 09, Bristol Airport
on 15 November 2006.

Published February 2008.

5/2008 Boeing 737-300, OO-TND
at Nottingham East Midlands Airport
on 15 June 2006.

Published April 2008.

6/2008 Hawker Siddeley HS 748 Series 2A, G-BVOV
at Guernsey Airport, Channel Islands
on 8 March 2006.

Published August 2008.

7/2008 Aerospatiale SA365N, G-BLUN
near the North Morecambe gas platform, Morecambe Bay
on 27 December 2006.

Published October 2008.

2009

1/2009 Boeing 737-81Q, G-XLAC,
Avions de Transport Regional ATR-72-202, G-BWDA, and
Embraer EMB-145EU, G-EMBO
at Runway 27, Bristol International Airport
on 29 December 2006 and 3 January 2007.

Published January 2009.

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