AAIB Bulletin No: 5/2005 **Ref: EW/C2004/03/02** **Category: 1.1**

Aircraft Type and Registration:	Boeing 737-78J, YR-BGF	
No & Type of Engines:	2 CFM 56 - 7B22 turbofan engines	
Year of Manufacture:	2001	
Date & Time (UTC):	4 March 2004 at 1230 hrs	
Location:	Stand 214, London Heathrow Airport	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 8	Passengers - 61
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to top of No 1 engine cowling	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	51 years	
Commander's Flying Experience:	17,000 hours (of which 1,900 were on type) Last 90 days - 200 hours Last 28 days - 60 hours Note: the hours provided by the commander are approximate	
Information Source:	AAIB Field Investigation	

Synopsis

When parking nose in to Stand 214 at London Heathrow Airport, the captain thought he was expected to use the AGNIS and mirror guidance system which had been turned on by the handling agents. However, as both the flightcrew and groundcrew were unaware that Boeing 737 aircraft required a marshaller in order to park on this stand (due to an inherent difficulty in seeing the STOP mark in the mirror), the aircraft was taxied forward by the commander. Also, as a result of a previously unnoticed problem, the correct nosewheel stop mark was obscured in the mirror, from the left seat pilot's position, by an aircraft tug which was parked in the designated area adjacent to the stand. The commander, however, could see the end of the centreline marking, which took the form of a T and adjacent to which were some chocks, and assumed that to be the correct point at which to stop. Although the emergency stop light had been illuminated by the groundcrew, this was not in the commander's field of view when looking at the mirror to his left. As a result, the upper part of the No 1 engine cowling made contact with the stand jetty. Five safety recommendations are made to the Airport Operator.

History of flight

The aircraft had landed in good weather on Runway 27L at 1215 hrs after an uneventful flight from Bucharest. On vacating the runway the crew were cleared by ATC to taxi to Stand 214, their allocated parking stand. At this time, and unknown to the flight crew, no personnel were immediately available to marshal the aircraft onto stand, as required by the Airport Operator for B737 aircraft. In the absence of a marshaller, and with no indications to the contrary, the groundcrew had turned on the stand's guidance system. On approaching the stand the commander, who was also the handling pilot, could see that the AGNIS lateral guidance system had been switched on and that a member of groundcrew was waiting in the parking area with a pair of wheel chocks. This indicated to him that he was intended to park using the AGNIS and mirror.

The aircraft turned onto the stand and the commander used the AGNIS guidance system to line the aircraft up with the stand's centreline. Once the aircraft was correctly aligned he switched his attention to a pair of large mirrors to his left in order to monitor the position of the nose wheel in relation to the expected STOP mark. The commander was however unable to see a defined STOP mark although, as the aircraft progressed forward, he could see the end of the centreline marking in the mirror. This took the form of a T, next to which he could see the chocks. The commander stated that he therefore assumed that this was the correct parking position and continued to taxi slowly forward, intending to stop the aircraft when the nosewheel reached this mark. The commander then became aware of the aircraft encountering resistance to its forward motion and on looking up could see the emergency STOP light had been activated. The commander realised that the aircraft had come into contact with the stand's passenger jetty and immediately applied the brakes, before shutting down the engines.

Heathrow Stand Guidance Systems

A range of guidance aids are used to provide correct alignment with the different stands and to indicate when the aircraft has reached the correct stopping point. These are described briefly below.

Azimuth Guidance For Nose In Stands (AGNIS)

Two closely spaced lights which illuminate different combinations of red and green lights to indicate the aircraft's position relative to the centreline. They are mounted in a box at cockpit level at the end of the stand, aligned with the centreline.

Mirrors

Large mirrors are positioned on the left at the end of the stand. They are aligned to allow the pilot in the lefthand seat of an aircraft to see the position of the aircraft's nosewheel relative to a prominent STOP mark painted on the ground next to the stand's centreline.

Arrow

A large arrow, visible from the left seat of an aircraft, is painted on the ground to the left of the stand. It aligns with the pilot's seat when the aircraft is in the correct position to stop.

Parallax Aircraft Parking Aid (PAPA)

A large board is positioned to the right of the stand into which a horizontal slot has been cut. A vertical light can be seen through the slot which, when aligned from the lefthand seat of an aircraft with the appropriate mark on the front of the board for the aircraft type, indicates the correct stopping position.

Combined Laser and Radar Aircraft Systems

These are automated units which monitor an aircraft's position on the stand by use of a combination of laser and radar. They provide the pilot with both lateral guidance and correct stopping point indication by means of a series of lights contained within in one single unit, positioned on the centreline at cockpit level at the end of the stand. Two types of this system are currently in use at London Heathrow Airport – APIS and Safedock.

Marshalling

Appropriate guidance can be provided onto any stand using conventional marshalling by one or, depending on aircraft size, two suitably qualified operations staff.

Emergency Stop Sign

A prominent sign placed at cockpit level at the end of the stand which illuminates red with the word STOP. It can be switched on by the groundcrew at any time the guidance system is active to indicate that the aircraft should stop.

At present there are 198 different parking positions available on the stands at Heathrow Airport. The breakdown of guidance systems in use is as follows:

AGNIS/MIRROR	10
AGNIS/ARROW	8
AGNIS/MIRROR/ARROW	7
AGNIS/PAPA	107
APIS/Safedock	22
MARSHAL ONLY	44

It is of note that in previous cases at this airport where aircraft have over-run stands, those involving AGNIS, PAPA and mirrors have been as a result of pilots misinterpreting the guidance information available to them. One over-run accident occurred, however, on a stand using APIS, where the accident was not thought to have resulted from misinterpretation of the guidance information, but rather a failure to act upon it.

Responsibility for the control of aircraft parking on stands at London Heathrow Airport

The airport operator, Heathrow Airport Limited (HAL)

The airport operator is responsible for providing adequate guidance of aircraft onto stands. This is controlled through the Airfield Operations Safety Unit, which is responsible for checking that guidance aids are both calibrated and operating correctly. They also provide the personnel for marshalling aircraft onto stands where no guidance is available or where it is requested by an operator. Certain operators have contacted the airport operator, either directly or via their handling agents, with specific marshalling requirements for various stands. This was either due to a desire to position the aircraft to their own requirements or because their crews had experienced difficulties with the normal stand guidance provided.

Handling agents

Handling agents are responsible for turning on the appropriate stand guidance system, where fitted, and operating the emergency stop light if required. They do not provide any other marshalling instructions to aircraft parking on a stand. Handling agents are advised of restrictions with aircraft parking on stands due to unservicability of passenger jetties via the Staff Information System (SIS). This is a computerised system available to all handling agents which is controlled by the airport operator. Further information is published by the airport operator when necessary by means of an Operator's Safety Instruction (OSI). Handling agents retain these instructions and pass the information on to their staff. No readily available list, however, exists for handling agents and their groundcrew defining which type of aircraft can park on which stand and the type of parking guidance required.

Stand 214

Stand 214 is available to aircraft of DC-10 size and below. With the exception of Airbus A300 and Boeing 767-300 aircraft, which must be marshalled, aircraft originally parked by use of AGNIS and a STOP mark reflected in a single mirror. However, it became apparent to the Airport Operator that it was not possible to calibrate the single mirror for use by all aircraft and an additional mirror was therefore added below the original one, calibrated for use by smaller aircraft. Having done this, there remained a problem for Boeing 737 aircraft, for which the correct stopping position was only just visible, appearing at the very top of the lower mirror. It was therefore decided by the airport operator that a marshaller would be provided to park Boeing 737 aircraft on Stand 214. During this investigation, a further problem was identified with this stand which resulted from the location of a parking space for an aircraft tug adjacent to the stand. When occupied by a tug, the view from the cockpit in the left half of the lower mirror was obliterated, the very portion of the mirror in which the STOP mark appears for Boeing 737 sized aircraft. This problem had not been noticed and it is likely that when the lower mirror was calibrated, a tug had not been occupying the parking space.

Analysis

In the course of this investigation no procedure was identified for the Airport Operator to notify directly either the aircraft or the groundcrew that a marshaller is not immediately available and that an aircraft should stop short of a stand to await his arrival. In the absence of any indications to the contrary, both the groundcrew and the flightcrew of YR-BGF had mistakenly believed that the aircraft should park on Stand 214 using only the AGNIS and mirrors guidance system. In addition, no one had realised that a tug occupying the equipment parking bay next to the stand obscured the view in the lower of the two parking mirrors. Unable to see the correct STOP mark, the commander had identified what he believed to be the stopping point at the end of the stand's centreline and had continued to taxi. The ground crew witnessed the aircraft over-running the correct stopping point and had immediately activated the emergency stop light. Unfortunately, at this point, the aircraft commander was concentrating on the two parking mirrors to his left and the emergency stop light fell outside his field of view. At the same time, the co-pilot was trying to attract the attention of the groundcrew to the right of the stand to confirm that the aircraft was in the correct position, and he therefore did not notice the stop light either. It was only when the aircraft stopped due to the top of the left engine cowling became stuck under the passenger jetty that the crew realised something was wrong.

Safety Recommendations

London Heathrow Airport has considerable demands on space for parking both aircraft and ground equipment. The airport operator has actively sought to reduce the reliance on marshallers to park aircraft by the installation of a variety of stand guidance systems, but these systems vary in complexity and cost. Although the airport operator has stated their intention to use the Safedock system for stand parking on the new Terminal 5 at Heathrow, currently under construction, the problems associated with less sophisticated stand guidance systems, which partly led YR-BGF to collide with Stand 214, remain.

The following Safety Recommendations are therefore made:

Safety Recommendation 2005-009

It is recommended that Heathrow Airport Limited should provide information on each stand to enable the handling agents to be sure that the aircraft attempting to park is compatible with the guidance system installed.

Safety Recommendation 2005-010

It is recommended to Heathrow Airport Limited that when temporary restrictions apply, such as the requirement to use a marshaller when an aircraft is manoeuvring to park on a stand, an appropriate procedure should be developed to ensure that this information is made available promptly and clearly to all ground personnel associated with parking aircraft on such stands.

Safety Recommendation 2005-011

It is recommended that, in addition to the stop light at the end of each stand, Heathrow Airport Limited should also install an emergency stop light adjacent to any aid used by the pilot for alignment, or stopping, in such a position that, irrespective of which aid is being used, the light falls within the handling pilot's field of vision.

Safety Recommendation 2005-012

It is recommended that Heathrow Airport Limited should carry out a review of current guidance systems currently in use to ensure they provide adequate guidance for all aircraft types that are expected to use any particular stand, with particular reference to those stands where operators have already raised individual concerns.

Safety Recommendation 2005-013

It is recommended that Heathrow Airport Limited should carry out a review of parking facilities for ground equipment in the vicinity of aircraft parking stands to ensure that ground equipment does not interfere with the correct use by flight crews of the stand guidance system.

Aircraft Type and Registration:	Boeing 747-436, G-BNLG	
No & Type of Engines:	4 Rolls-Royce RB211-524G2-19 turbofan engines	
Year of Manufacture:	1989	
Date & Time (UTC):	21 April 2004 at 1002 hrs	
Location:	Stand 127L, London Heathrow Airport	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 18	Passengers - 326
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Puncture to leading edge of port wing above No 2 Engine. No 2 engine damaged by debris ingestion	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	52 years	
Commander's Flying Experience:	16,000 hours (of which 2,500 were on type) Last 90 days - 200 hours Last 28 days - 80 hours	
Information Source:	AAIB Field Investigation	

Synopsis

Whilst attempting to park on its allocated stand, the aircraft struck the airbridge, which had been parked in the wrong position, with its left wing. Recent work altering the stand's alignment resulted in a choice of parking positions for different aircraft types and corresponding parking positions for the airbridge. The investigation revealed the airbridge had been parked in a position marked for aircraft parking on a different part of the stand.

History of flight (aircraft perspective)

The aircraft had just completed a flight from San Francisco to London Heathrow and, after vacating Runway 27R, was given clearance to taxi to Stand 127, its allocated parking stand. The commander was at this point the handling pilot and also on the flight deck were the co-pilot, occupying the right hand seat, and a third pilot occupying one of the jump seats.

On approaching the stand the commander and co-pilot positively identified the correct centreline markings for Stand 127 and confirmed that there was no equipment infringing the parking area. Finally, they checked that the airbridge was parked within a marked parking box. With the stand appearing safe to enter the commander turned onto the stand, using the illuminated AGNIS (Azimuth Guidance For Nose In Stands) guidance system to maintain the correct centreline. As the aircraft neared its stopping position the commander then switched his attention to the PAPA (Parallax Aircraft Parking Aid) board to the right of the aircraft in order to judge the correct stopping position. Shortly after doing so the aircraft appeared to rock slightly and the commander had to increase power in order to continue moving forward. It was at about this time that the pilot sat on the jump seat noticed a member of the ground staff standing in one of the terminal windows with his arms crossed, indicating the marshalling signal for the aircraft to stop. The pilot immediately called for the commander to stop the aircraft, which he did. The engines were shut down and other members of staff could be seen in the terminal window looking alarmed and pointing towards the left wing. Shortly afterwards the fire services arrived at the aircraft and advised the crew over the radio that the aircraft had struck the passenger airbridge. As there were no abnormal indications on the flight deck nor signs of fire the commander decided not to order an emergency evacuation and the passengers were instead disembarked by steps at Door 1L.

History of flight (ground perspective)

The dispatcher reported for duty at 0530 hrs (local) on the day of the accident and, at about 1045 hrs, (local) went to prepare Stand 127 for the arrival of the flight from San Francisco. On inspecting the stand he discovered an aircraft power unit was infringing the parking area and arranged to have it removed. Once the area was clear he identified the correct AGNIS unit and PAPA board for Stand 127 and turned them on. He then went up the passenger stairs from the apron onto the airbridge and later stated he would normally have used a set of engineers' stairs which are fixed at the aircraft end of each airbridge. However, the hinges on the door on this particular airbridge were broken and whilst awaiting repairs the door had been locked to prevent its use.

Once on the airbridge the dispatcher checked that it operated correctly and raised it to what he considered an appropriate height for the Boeing 747-400 aircraft he was expecting. Shortly afterwards, the aircraft arrived and the dispatcher watched as it taxied past the end of the airbridge where he was standing. From experience the dispatcher was expecting the aircraft to slow down once the second passenger door had passed the end of the airbridge. When it failed to do so the dispatcher began to think something was wrong and, looking out of a window, realised the aircraft wing was about to collide with the airbridge. There was no means of alerting the aircraft from his current position and so the dispatcher turned and ran as fast as he could back up the airbridge, just before it was struck by the aircraft. Once off the airbridge the dispatcher was able to signal to the aircraft through a large window in the terminal building by crossing his arms in front of him, at which point the aircraft came to a halt. The dispatcher then immediately contacted the airport emergency services.

Engineering examination

The aircraft was manufactured in 1989 and carried the manufacturer's serial number 24049. It was delivered new to BA and first registered on 23 Feb 1990.

Initial examination of the aircraft on the stand showed that it was correctly aligned with the centreline markings, but had stopped a few feet short of the B747 stop mark. At this position, the self-levelling mechanism of the airbridge had penetrated the wing leading edge by about one or two feet, just inboard of the No 2 engine. The airbridge itself had rotated and moved backwards one or two feet, its wheels leaving skid marks, indicating that with the aircraft correctly positioned on the stop marker, there would have been an overall zone of contact between aircraft and airbridge of perhaps 10 feet or so. The airbridge had been parked in one of two painted 'boxes' on the stand, one which was rectangular and which was the correct box for a B747 operation, the other, in which the airbridge was positioned, was circular and intended for use with smaller aircraft.

The wing was penetrated through its leading edge skin and there was also damage to the composite skin behind the leading edge, resulting in a hole some one by one and a half feet in size. There was no apparent damage to any wing systems or primary structure.

As a consequence of the impact and release of debris, the No 2 engine had sustained significant impact damage to the fan blades and also to the acoustic liner. Several pieces of torn and bent grey painted aluminium alloy were found in the engine intake and bypass duct. The fan blades were subsequently all changed, however the core of the engine was found to be undamaged. The impact had forcibly rotated the head of the airbridge, failing its rotation mechanism, releasing debris and allowing the drive chain to fall across the engine intake. Initially, it was thought that the debris in the engine was from the wing but closer examination showed that the material and protective treatments were not those of the damaged part of the wing, and it was concluded that they were from the damaged airbridge mechanism.

Stand description

Changes had recently been made to the layout of Stand 127 to accommodate different aircraft types, in response to a change in airline schedules using the central terminal area of the airport. At the time of the accident the stand was divided into three different parking positions: Stand 127, Stand 127L and Stand 127R. The intention was that the stand could accommodate either one large aircraft, up to and including the Boeing 747-400 and Airbus A340-600 on Stand 127, or two smaller aircraft, up to and including the Airbus A321, simultaneously on Stands 127R and 127L.

Two airbridges were provided on the stand, one for aircraft on Stand 127L and one for aircraft on Stands 127 and 127R. Ground markings were provided to denote the correct parking positions for both airbridges so that they were in a safe position when aircraft taxied onto stand. In the case of the airbridge intended for Stands 127 and 127R two different parking areas were denoted. One, a yellow square, denoted the correct parking position when Stand 127 was in use and the other, a yellow circle, when Stand 127R was in use. There were also various lines delineating the airbridge manoeuvring areas.

Lateral parking guidance to aircraft on all three stands was provided by AGNIS units and the correct stopping points by use of PAPA boards. Each stand also had a sign positioned in line with its centreline which could be illuminated with the word STOP in case of emergency. These lights could only be operated by a switch at ground level in a centrally located position between all three stands.

Details of the new stand layout and operating procedures for the airbridges were contained in the airport operator's Operational Safety Instruction (OSI) 07/04, the contents of which are reproduced in Figure 1.

Analysis

When interviewed, the aircraft dispatcher stated that he had read OSI 07/04 relating to the new layout and operating procedure for Stand 127. This had been issued on 6 April 2004 by his company in the form of an Aircraft Dispatch Notice (ADN), little more than two weeks prior to the accident. Whilst a copy of this ADN was retained in the company's dispatch office the dispatcher himself did not carry a copy, nor was there one posted for reference in the airbridge for Stand 127.

OSI 07/04 refers both to a parking box and a parking circle. Parking positions for the wheels of airbridges had historically been marked on the ground by a rectangular box. The airport operator was however finding unnecessary wear being put on the airbridge tyres and the ground markings as a result of the wheels being slewed round whilst parked in order to align them with the markings. Some stands had therefore had the traditional rectangular box replaced by a circle. This eliminated the need to slew the wheels round as they could remain within the correctly marked position when parked, regardless of orientation. Relevant documents however continued to refer to these circles as boxes.

The dispatcher made the point that where OSI 07/04 stated:

> *'When stand 127 is used the jetty will be parked in the standard parking box',*

to him this could have meant either a circle or a rectangle. Indeed it is only under the paragraph referring to Stand 127R that any distinction is made between the '*standard parking box*' and a circle. The dispatcher further stated that he was used to seeing the airbridge parked in the position delineated by the circle, as this had been the airbridge's normal parking position prior to the realignments of the stands.

OSI 07/04 requires that the airbridge is parked in the rectangular box once an aircraft has been pushed back from either Stand 127 or 127R. This had not been done and, on further investigation, it was revealed that on dispatching aircraft from Stand 127R the airbridge is frequently not returned to the proper parking position. It is quicker for the dispatcher to leave it parked in the parking circle intended for Stand 127R. A dispatcher from a different company questioned on this point explained that they were regularly pressed for time and that to wait for an aircraft to depart and then move the airbridge would make them late in trying to meet their next flight.

The commander of the aircraft stated that he had checked the airbridge was parked within a parking box prior to turning onto the stand. The airbridge had indeed been parked within a box and there was nothing to indicate to the crew that the airbridge was in anything other than its correct parking position.

When it became clear to the dispatcher that the aircraft was about to collide with the airbridge he was faced with great difficulty in trying to stop it. In the absence of a switch to operate the STOP light from the airbridge, and unable to use the engineers' steps to get quickly to the switch positioned at ground level, he had little choice other than to run clear of the airbridge in order to save himself from injury. He did however have the presence of mind to signal to the aircraft through the terminal window in a successful attempt to catch the pilots' attention. There is no doubt his actions at this point prevented the damage to both aircraft and airbridge being considerably worse.

Parts of the following analysis are shared with the investigation into another stand collision on 4 March 2004 at the same airport, involving a Boeing 737 (Report Number EW/C2004/03/02), which is also published in this bulletin.

Operational Safety Instructions (OSI)

Operational Safety Instructions are the means by which Heathrow Airport Limited (HAL) distributes safety related information to those operating airside ground services. These can incorporate operating instructions for equipment such as airbridges (as in OSI 07/04). Operational Safety Instructions are frequently referred to in the airport operator's Aerodrome Manual and as such form an integral part in the proper operation, by all parties, of the airport services.

In the course of this investigation it became apparent that not all operators were in possession of the Aerodrome Manual, including one major airline based at London Heathrow Airport. This airline stated that the Aerodrome Manual is a document produced and maintained by the airfield operator for the purposes of licensing under CAP168. They considered that it was not directly aimed at airlines and that any relevant information for an operation (eg fire cover, declared distances etc) was supplied in the relevant Aeronautical Information Publication (AIP). As a result they did not hold the Aerodrome Manual, using instead, the relevant AIP.

Thus it might be considered that the airport operator relies upon its Aerodrome Manual as its chief operating document and the airline the AIP, with both using OSIs as an additional source of information. As these are easily published they form the main basis of disseminating information on changes to the day-to-day operation of the airport.

Once an OSI is published it is the responsibility of each organisation operating at the airport to distribute its contents internally. This is normally done by placing a copy of the OSI, or a company version of it, in a file checked by staff prior to each shift.

In reality, this results in important operating information being retained within a large collection of separate OSIs, many of which have been in effect for a considerable period of time. They are not divided into different categories, appearing in the order in which they were published. This means the user has to search through the entire collection to find required documents, assuming that they know of their existence. Individual staff members are expected to know the information contained within the OSIs but are not normally given their own individual copies. They instead have to refer to the centrally held collection retained by their company, which is often in an office some way from the point where they are working.

Airport safety system

The HAL safety system relies on categorisation of accidents and serious incidents into four categories. The most serious accidents and incidents fall into category one with a sliding scale of severity down to category three. Category four is reserved for events which fall directly outside the control of HAL. The three main criteria used to ascertain which category an event falls into, are the health and safety implications, financial cost and damage to HAL's reputation. The assessment is undertaken by the safety adviser for the area in which the accident or incident occurred.

The system is designed to cover all types of events, not only those affecting aircraft operations, and the majority of accidents and serious incidents are reported using a standard form (F3001). This is lodged on the Performance Measurement System (PMS), a computerised database managed by the HAL Safety Services Department. Investigations are carried out at a local level when the accident or incident is classed as category three or four. However, where it is classed as a category one or two event the investigation is carried out by a senior manager from a different department to that in which the event took place.

The investigation of category one and two events is monitored at board level whilst an overall review of HAL's accidents and incidents is carried out on a monthly basis at HAL's health, safety, security and environment performance meeting.

The situation is complicated where the accident or incident involves an aircraft, as additional investigations may be carried out by the Civil Aviation Authority or the Air Accidents Investigation Branch (AAIB). Events which occur airside rely on the Airside Operations Team for assessment.

In the case of this accident, and the accident referred to in report number EW/C2004/03/02, the Airside Operations Team attended the scene of each accident and made preliminary enquiries. It has subsequently been difficult to identify the individual at HAL responsible for any internal investigation and remedial actions. It is believed through conversation that, as there were no injuries or fatalities, HAL was content to await the outcome of the investigations being undertaken by the airline and the AAIB, using these in place of their own investigation and implementing any recommendations made where they were deemed suitable. HAL did however take the unilateral step of fixing an amended set of operating instructions above the control panel on the airbridge for Stand 127/127R, Figure 2.

Emergency Stop Sign

Both Stands 127 and 214 (report EW/C2004/03/02) were fitted with a prominent sign placed at cockpit level at the end of the stand. This illuminates red with the word STOP and can be switched on by the ground crew at any time the guidance system is active, to indicate that the aircraft should immediately come to a halt. Originally these signs could only be operated from ground level but a program is in place to install additional switches to allow operation from the control panel of the airbridge. Due to budgetary constraints, this program has been on-going for several years and is not likely to be completed in the very near future.

At the time of the accident, such a switch had not been fitted to the airbridge on Stand 127/127R. This left the dispatcher powerless to act although it was still possible for the switch at ground level to have been activated by a member of the ground crew present at the time on the stand. Whilst the airline involved instructs that anyone may activate the stop sign in the interests of safety, no one is actually allocated the task of standing next to the button whilst the aircraft manoeuvres onto the stand. Not only does this make suitably swift action unlikely it also removes the specific responsibility from those on the ground to actively monitor the safe progress of the aircraft. No attempt was made on this occasion to operate the ground button.

This situation is in direct contrast to the accident on Stand 214 (report EW/C2004/03/02) where the handling agents involved specifically allocate a member of the ground crew team meeting each aircraft to man the stop switch at ground level. This stand had also had a stop switch fitted to the airbridge some time before the day of the accident and both this and the switch at ground level were operated by the relevant members of the ground handling team. It is of note, however, that despite the STOP sign being illuminated it was not seen by either pilot on the flight deck. This was due to the Commander concentrating on the STOP point guidance (a mirror to the left of the stand) whilst the co-pilot was looking out of his side window to the right at the ground crew.

In a subsequent visit by the AAIB to Stand 127, on 23 August 2004, a STOP button had been fitted to the airbridge as part of the on-going program. This had however been placed in close proximity to another stop button intended to stop the airbridge moving in case of emergency and markings did not make it clear which of the stop buttons was for which purpose. Indeed, one label was found simply propped up on one on the switches, Figure 2.

Conclusions

Stand 127 had recently been realigned to allow increased utilisation, with operating instructions for the new configuration published in OSI 07/04. Both the aircraft commander and the dispatcher believed that the airbridge was parked in the correct position for Stand 127 and that it was safe for the aircraft to enter the stand and park. The airbridge was actually parked in the correct position for a different stand, Stand 127R, which resulted in the aircraft's left wing subsequently striking the airbridge whilst attempting to park. The aircraft was brought to a halt only when the flight crew noticed the dispatcher signalling to them through a terminal window, but not before considerable damage had been caused.

Numerous factors contributed to the accident.

- The commander had no means available to him to determine that, although the airbridge was parked in a box, it was the wrong one.
- The dispatcher had read OSI 07/04 but this had been some days before the accident and he had no copy available to refer to at the stand.
- The information in OSI 07/04 was open to misinterpretation.

- The airbridge had been left in the wrong parking position, contrary to the instructions in OSI 07/04.

- Ground markings were confusing.

- The dispatcher was used to seeing the airbridge parked in that position from operations prior to the stand realignment.

- The dispatcher was unable to stop the aircraft quickly as there was no means of operating the STOP light from the airbridge.

- Despite there being a switch for the STOP light at ground level it was not operated by anyone on the stand.

A review of previous ground collisions at Heathrow, specifically AAIB report EW/G2001/01/12, raises a number of issues. The report highlighted the number of aircraft being damaged at the airport and, whilst it is accepted that ground damage to aircraft is a universal problem, not one solely restricted to Heathrow, a study of recent figures for the airport indicates that there has been little improvement since report EW/G2001/01/12 was published in 2001. HAL have, however, recently introduced certain initiatives, most recently an inspection team whose function is to monitor stand operations during aircraft turn rounds. Whilst this is a positive move, there continue to be failings in other important areas of the ground operation, two specifically being revealed by this investigation.

There appeared to be little overall strategy for the guidance of aircraft onto stands. Discussions revealed improvement to parking guidance provided by the introduction of Combined Laser and Radar Aircraft Systems (APIS), driven by a request from British Airways, the airport's biggest customer, as a result of research undertaken by that airline. It was not, as might be expected, as a result of an initiative by HAL. The same discussions similarly revealed that funds were not specifically allocated to research guidance options for Terminal Five, a major addition to the airport infrastructure currently under construction. Funds were only provided at the request of operational staff. During the course of this investigation, no one individual could be identified within the HAL staff who had specific responsibility for stand guidance at the airport.

Of equal concern was the level of investigation carried out by HAL into both this accident and the previous similar accident, the subject of report EW/C2004/03/02. As a consequence, despite HAL operational staff pointing to deficiencies noted on the day of each accident, no remedial action was taken and the deficiencies were still present on a visit by the AAIB some months later.

AAIB report EW/G2001/01/12 relates to an accident occurring in January 2001. It raised concerns over the level of ramp safety at HAL and the effectiveness of their safety system. This lead to a recommendation (Safety Recommendation 2001-66) that the CAA and Health and Safety Executive (HSE) should conduct a joint audit of the airside safety system at Heathrow to determine its adequacy. HSE's response to this recommendation was that they considered hazards to aircraft the responsibility of the CAA and would therefore not be in a position to undertake such an audit. The CAA did accept the recommendation, however, it is understood that only a superficial inspection of the safety system was undertaken with no written report ever being made. This response from both the CAA and HSE is of concern and in part must contribute to the inadequate response to these accidents by HAL.

London Heathrow Airport operates within a site of restricted size. It is apparent that the airport is working to capacity and that the operation is constantly being driven to increase this capacity still further, resulting in initiatives such as the realignment of Stand 127. In this constantly changing environment it is all the more important that adequate resources are provided to support the airside operations at HAL, together with the protection afforded by a robust and proactive airside safety culture.

Safety Recommendations

In view of the continuing problem at London Heathrow Airport of aircraft colliding with airbridges, the following safety recommendations are made:

Safety Recommendation 2005-014

It is recommended that Heathrow Airport Limited should expedite the program to install duplicate emergency stop buttons at all of its airbridge control stations and ensure that all such buttons are clearly and unambiguously marked.

Safety Recommendation 2005-015

It is recommended that Heathrow Airport Limited should identify a management post responsible for the maintenance, development and safety of aircraft stand parking guidance systems.

Safety Recommendation 2005-016

It is recommended that Heathrow Airport Limited should review the system by which Operational Safety Instructions are published to ensure that they are either incorporated into a relevant document, such as the Aerodrome Manual or Aeronautical Information Publication, or are provided with an effective index such that the information they provide is readily identifiable

Safety Recommendation 2005-017

It is recommended that Heathrow Airport Limited should ensure that operating instructions are prominently displayed on any aircraft stand, including the airbridge, where changes in the operation have been made or where the mode of operation is non-standard.

Safety Recommendation 2005-018

It is recommended that Heathrow Airport Limited should review all ground markings related to aircraft parking stands, to ensure that their meanings are unambiguous, that markings are clearly displayed and that clear diagrams of such markings are prominently displayed on any aircraft stand.

Safety Recommendation 2005-019

It is recommended that the Civil Aviation Authority should conduct a comprehensive, documented, audit of the Heathrow Airport Limited airside safety system.

Safety Recommendation 2005-020

It is recommended that British Airways should require that a member of their ground crew assumes the responsibility of being adjacent to the ground level emergency STOP light button and of monitoring the arrival of the aircraft onto the stand, whenever ground crews are present on a stand whilst an aircraft is manoeuvring to park.

Figure 1

BAA Heathrow

Date: 26th March 2004 OSI/07/04

Subject: CHANGE TO STANDS 125L, 125R, 127, 127L and 127R

File:ASS/26/05

It is the responsibility of all employers to ensure that relevant OSIs are brought to the attention of their staff. However, individuals remain responsible for their own actions and those who are in any doubt should consult their Supervisor or Manager.

INTRODUCTION

1 In order to accommodate changes to airline schedules in the central terminal area, stands 125L, 125R, 127, 127L and 127R have been modified to accommodate different aircraft types.

2 This instruction details the operating procedures for the stands.

3 A drawing is attached for information.

OPERATING PROCEDURE FOR JETTY SERVICE ON 127 and 127R

4 In order to provide jetty service on stands 127 and 127R, using the same jetty, a special operating procedure is necessary. On the stand there is a jetty parking box, marked with a yellow border, in which the jetty should be parked when it is not in use.

When stand 127 is used the jetty will be parked in the standard parking box until the aircraft has parked on the stand, the jetty will then be positioned on the aircraft as normal. When the aircraft is ready to depart the jetty will be returned to the standard jetty parking box.

When stand 127R is used, the jetty must be positioned in the pre-position area marked on the stand by a circle prior to the aircraft arriving on the stand. (This is due to the fact that if the aircraft parks on the 127R centreline with the jetty in the standard parking box, there is not sufficient clearance for the jetty to swing round past the nose of the aircraft.) Once the aircraft has parked the jetty will be positioned on the aircraft. When the aircraft is ready to depart the jetty will be returned to the pre-position area. Once the aircraft has departed the jetty must be returned to the standard jetty parking box.

STAND SIZES AND INFRASTRUCTURE

5 Stand 127 can accommodate all aircraft up to and including Boeing 747-400 / Airbus A340-600 and is jetty served.

Stands 127L and 127R can accommodate all aircraft up to and including Airbus A321 and are jetty served subject to the special operating procedure detailed above.

Stand 125R can accommodate all aircraft up to and including Airbus A321 and is not jetty served.

Stand 125L can accommodate all aircraft up to and including Airbus A320 and is not jetty served.

Stand 125 remains unchanged.

GENERAL

6 All other services and operating procedures for the stands remains unchanged.

7 Any questions regarding this instruction should be addressed to Airside Infrastructure, Airside Suite, 2nd Floor, Building 820, Heathrow Airport Limited. Tel: 020 8745 0859, Fax: 020 8745 5413

Distribution: Lists A - E

Information reproduced from:

Operational Safety Instruction (OSI) 07/04

Figure 2

Sign added after accident to G-BNLG

Button labelled ‘Emergency Stop’, with ‘127 stand entry guidance’ marked above. This is the new STOP light activation button.

Note other signs partially obscuring the top of this label, with the potential to obscure the entry guidance legend. Operator would then be faced with two buttons marked ‘Emergency Stop’.

Sign found propped up on box. Unclear where this was meant to be properly attached.

Labelled ‘Emergency Stop’. Unclear if this is for the Airbridge only.

View illustrating confusing nature of displayed information/emergency stop buttons on Stand 127

AAIB Bulletin No: 5/2005 **Ref: EW/G2004/11/05** **Category: 1.1**

Aircraft Type and Registration:	Boeing 747-4Q8, G-VTOP	
No & Type of Engines:	4 General Electric CF6-80C2B1F turbofan engines	
Year of Manufacture:	1997	
Date & Time (UTC):	16 November 2004 at 0915 hrs	
Location:	Stand 327, London Heathrow Airport	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 19	Passengers - 179
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Dent near cargo loading door, cracked frame	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	53 years	
Commander's Flying Experience:	15,200 hours (of which 10,100 were on type) Last 90 days - 168 hours Last 28 days - 44 hours	
Information Source:	Aircraft Accident Report Form and accident report submitted by the airline	

Loading of the rear cargo hold prior to flight had been completed. The operator of the high lift loader lowered the platform to enable him to raise the door locks. He then raised the platform again, to level with the hold door sill, and entered the hold to check the stops and locks were all in the correct positions. When in the hold he heard a crushing noise behind him. He returned to the doorway to find that the platform had risen upwards and damaged the cargo door frame and an adjacent cargo bin. He shouted for help and attracted the attention of a colleague who activated the emergency stop button of the high loader.

An investigation into the accident carried out by the airline determined that when the high loader operator had released the control switch used to raise the platform it did not return to neutral as it was designed to do, but remained latched in the 'up' position. The platform had probably continued to rise at a slower than normal operating speed, such that the operator had not noticed it was still going up when he stepped into the hold. Since the accident all the high loader vehicles operated by the ground handling company have been modified to incorporate an override switch which must be engaged before the platform lift function can be activated.

Aircraft Type and Registration:	Cessna 310, N310QQ	
No & Type of Engines:	2 Continental IO-470-V0 piston engines	
Year of Manufacture:	1973	
Date & Time (UTC):	15 June 2004 at 2030 hrs	
Location:	Elstree Aerodrome, Hertfordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to left hand side of aircraft and left main landing gear	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	875 hours (of which 334 were on type) Last 90 days - 24 hours Last 28 days - 12 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and metallurgical examination of the failed components	

History of flight

A normal approach to Runway 26 was carried out with a wind of 330°/06 kt. The three green landing gear 'Down and Locked' indicator lights were illuminated and at approximately 2 miles from touchdown, full flap was selected and visually confirmed. The touchdown was smooth but during the landing roll the 'Gear Unsafe' warning horn sounded. The pilot looked down and noticed that the left main landing gear 'Down and Locked' green indicator light had extinguished and the red 'Gear Unsafe' indicator light had illuminated. Both the right main and nose landing gear 'Down and Locked' green indicator lights were illuminated. The left main landing gear collapsed a few moments later and the aircraft slewed to the left and came to rest in the grass area to the left of the runway. The pilot carried out the emergency shutdown drills and the aircraft was vacated without injury.

Engineering examination

The left landing gear was examined by a metallurgist who found that all the failures were caused by a one-time overload force with no evidence of fatigue, corrosion or manufacturing defect.

Assessment

The pilot/owner assessed that a possible cause may have been that the left main landing gear was slightly out-of-rig which allowed the side brace to unlock when running over a bump in the runway which resulted in the landing gear collapsing.

Aircraft Type and Registration:	Socata TBM 700B, N30LT	
No & Type of Engines:	1 Pratt & Whitney PT6A-64 turboprop engine	
Year of Manufacture:	2001	
Date & Time (UTC):	6 December 2003 at 1124 hrs	
Location:	180 metres west of Runway 01 threshold at Oxford (Kidlington) Airport, Oxfordshire	
Type of Flight:	Declared as Private (see text)	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - 1 (Fatal)	Passengers - 2 (Fatal)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	FAA Commercial Pilot's Licence	
Commander's Age:	46 years	
Commander's Flying Experience:	More than 1,573 hours (of which approximately 500 hours were on type) Last 90 days - not known (see text) Last 28 days - not known (see text)	
Information Source:	AAIB Field Investigation	

Synopsis

Towards the end of a flight from Brussels to Oxford (Kidlington), the pilot was cleared to land from a visual straight-in approach to Runway 01. The surface wind was reported as 030°/15 kt. As the aircraft crossed the airfield boundary, it started to roll to the left. Shortly after, it struck the ground to the west of the runway threshold. Despite an extensive investigation, no technical malfunction was identified which could have caused the apparent uncontrolled roll to the left. Although there was no other conclusive evidence which would explain the manoeuvre, it is possible that control of the aircraft was lost during application of power to adjust the flight path or in an attempted late go-around, or as a result of an unknown distraction.

Background to the flight

The passengers had previously flown in N30LT with the pilot and had agreed with him that he would fly them from Brussels International Airport to Oxford Airport on 6 December 2003 and return the next day.

On the morning of 6 December, the pilot flew N30LT from Liege Airport to Brussels, landing at 0840 hrs. Another pilot, who confirmed that the accident pilot flew the aircraft throughout the flight from the left cockpit seat, accompanied him on this flight. The aircraft appeared fully serviceable and the autopilot was used for the ILS approach to Runway 25L with an estimated cloud base of 300 feet agl. At 250 feet agl, the autopilot was disconnected and a manual landing was made at about 85 kt using full flap. The automatic fuel mode[1] was checked prior to takeoff at Liege and was used throughout the flight; on landing the fuel appeared balanced between the two fuel tanks. After landing, the aircraft was refuelled to full with 640 litres of JET-A1 fuel.

The accompanying pilot considered that the accident pilot was very well. He, the accompanying pilot, left before the passengers arrived. One witness in Brussels subsequently confirmed that the accident pilot was seated in the front left cockpit and thought that the passengers were seated in a row behind the pilot.

Flight classification

The flight was categorised by the commander as a 'Private' flight. However, during the investigation it was considered that this categorisation might not have been correct. One of the two passengers had a fractional ownership agreement with a company based in Luxembourg and he contacted the company when he required a flight from Belgium to Oxford. The company did not have an aircraft available and contracted N30LT from a Belgium company. The Belgium company was the owner but an American company registered the aircraft.

Enquiries made of the United States National Transportation Safety Board (NTSB) resulted in a view that the flight would have been more appropriately categorised as 'Commercial-on-demand' rather than 'Private'. N30LT was not certified by the Federal Aviation Administration (FAA) for 'Commercial-on-demand' and the national authorities in UK, Belgium and Luxembourg have been advised of the situation.

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[1] The selector which controls the fuel has three positions: left, right and off. When the system is set to automatic an actuator, commanded by an electronic sequencer, automatically allows the engine fuel to be fed from one tank or the other, for predetermined periods, without pilot intervention.

History of the flight

The aircraft took off from Runway 25 Right (R) at Brussels on a 'Costa 4C' departure at 1017 hrs; the Air Traffic Controller noted no unusual events during the takeoff. The aircraft transited at Flight Level (FL) 240 and a descent was commenced at 1052 hrs down to FL120. This flight level was then maintained for some 10 minutes before a further descent was made at 1110 hrs. By 1120 hrs, the aircraft was level at approximately 2,000 feet amsl. The aircraft had been under the control of 'Brize Norton Radar' since 1116 hrs and the pilot had requested 'radar vectors' towards Oxford. For separation reasons, the controller turned N30LT to the left and cleared the pilot to descend to 2,000 feet on a pressure setting of 1029 mb. At 1122 hrs, the controller advised the pilot that the airfield was at a range of four miles; the pilot replied that he had visual contact and was transferred to 'Oxford Tower' on frequency 133.425 MHz.

On check-in, the pilot of N30LT reported that he had Runway 01 in sight and was at a range of three miles. The controller responded by clearing the aircraft to land with a surface wind of 030°/15 kt. No other transmissions were made from N30LT and, at 1124 hrs, another pilot in the circuit transmitted to ask ATC: "Did you see what happened there?" The 'Tower' controller had just seen the aircraft start to roll to the left as it crossed the aircraft boundary and appear to impact the ground almost inverted. ATC personnel immediately initiated their emergency procedures. The Aerodrome Fire Service (AFS) recorded the alert at 1125 hrs and were on the crash scene some three minutes later. By then, other eyewitnesses were already at the scene and were moved away due to fuel leaking from both wings. Local authority fire services arrived on the scene at 1130 hrs.

One of the first witnesses on the scene was a doctor. On his advice, the fire services removed the pilot from the aircraft to check for signs of life but, once clear, the pilot was declared as dead. There were no indications of life from the two passengers who were found in the rearmost seats of the aircraft.

Witnesses

There were numerous eyewitnesses to the accident. Most were inside buildings or vehicles and none of these were aware of any changes in engine noise. However, one witness (Figure 1: Witness A) was outside on a bicycle and stated that an increase in engine noise made him look upwards as the aircraft passed almost directly overhead. None of the witnesses saw any smoke or flames, or anything fall from the aircraft.

Another witness was a flying instructor who was airborne with a student and who had just joined the Oxford visual circuit from a practice instrument approach. He stated that there was no low cloud, the visibility was 10 km or better and that he had experienced no turbulence or icing during his flight. He heard the pilot of N30LT check in on the Tower frequency and then saw a single-engine aircraft at the same height as himself and just over a mile from the threshold of Runway 01; at the time the aircraft was at about 540 feet agl. Later, with his own aircraft established on 'finals', he saw the other aircraft directly ahead on 'short finals' pointing towards the runway with no apparent drift. As he watched the aircraft, he saw it suddenly roll quite fast to the left to about 60° angle of bank. He then saw it in plan form as if the aircraft had pitched nose up. It continued to roll to the left, but at a slower rate, until it impacted the ground about 20° off the vertical. As it impacted the ground, the witness could see most of the underside of the aircraft; he could see that the landing gear was extended but was not sure about the flap configuration.

One other witness was a flying instructor (Figure 1: Witness B) who was in his car and leaving the airport. He was stopped at traffic lights to the south of Runway 01 and facing approximately west. When he heard the sound of an aircraft over his car, he looked to the right and saw a single-engine aircraft on approach to Runway 01. His impression was that the aircraft was at about 50 feet agl and in a normal position for a landing on the threshold of the runway. As he watched, he saw the aircraft begin a gentle banked turn to the left; the rate of roll was constant and he thought that the nose of the aircraft rose as the bank was at about 60°. The aircraft continued to roll and the nose of the aircraft came down as it did so; the roll continued almost through 360° and he lost sight of the aircraft shortly before he heard the noise of the impact. He left his car to go to the scene and arrived there shortly after another witness. The aircraft was lying on its left side and slightly nose down and fuel was flowing out of a large tear in the right wing.

Witness A had been cycling in a northerly direction along the left of the main road adjacent and almost parallel with Runway 01. Approximately 150 metres south of the airport, he became aware of a light aircraft and presumed that it was on an approach to land; this witness had previously held a PPL and was familiar with Oxford Airport. A considerable increase in engine noise caused him to look up and he saw an aircraft passing almost directly overhead. It was rolling to the left and was already banked about 40° left when he first saw it. It continued to roll very quickly to more than 90° of bank before the roll direction reversed. When the aircraft was banked about 60° to 70° to the left, it then commenced a turn to the left through about 90° before rolling almost level, following which it suddenly lost height and impacted the ground in a nose low attitude and with some slight left bank. Throughout the manoeuvres, the impression of the witness was that the engine noise remained constant and that the aircraft's height remained at about 30 feet agl.

Other witnesses were driving south along the same main road. Most saw the aircraft rolling continuously to the left. Some thought that it was displaced to the left of the approach to Runway 01 and some had the impression that it was lower than normal as it approached the road. Most also thought that it was beginning to go-around just as, or just after, the aircraft started to roll.

Airport information

The airport is 270 feet amsl. Runway 01 has a Landing Distance Available of 1,200 metres, is 23 metres wide and has an asphalt surface. The threshold is displaced by 170 metres from the start of the asphalt surface. The PAPIs have a 3.5° slope, are located to the left of the runway and are 128 metres from the threshold.

Weather

The Meteorological Office at Exeter provided an aftercast covering the time of the accident. The data they supplied was as follows:

> The synoptic situation at 0000 hrs on 6 December showed a weak warm front lying from Anglesea to Norfolk, moving south-west, and a weak cold front lying from Hebrides to Firth of Forth, also moving south-west. By 1200 hrs, the cold front had cleared Oxford to lie from West Wales to the Isle of Wight. A moist north-easterly flow affected the area. Weather at Oxford was cloudy with light drizzle, which had cleared by 1100 hrs. The surface visibility was 10 to 15 km and the mean sea level pressure was 1029 mb and rising. Cloud was FEW at 1,200 feet, SCT at 1,500 feet and BKN at 2,500 feet. The freezing level was 7,000 feet with a sub zero level developing between 2,500 and 4,500 feet. The surface wind was 040°/15 kt, gusting to 25 kt. Air temperature was +08°C and dew point was +05°C.

Enquiries made with the police helicopter crew, who were called to the scene of the accident and arrived there at 1144 hrs, indicated that there was no cloud below 2,000 feet amsl. The pilot flew a normal approach to Runway 01 from 700 feet to 50 feet agl and experienced no turbulence.

The route from Brussels to Oxford lay close to the frontal zone with cloud layers of varying intensity up to 27,000 feet. The freezing level was 7,000 feet with a sub zero layer forming in and behind the frontal zone. Moderate icing (defined as conditions in which change of heading and/or altitude may be considered desirable) was possible in cloud up to 14,000 feet.

Flight Recorders

The aircraft was neither equipped with a flight data recorder (FDR) nor a cockpit voice recorder (CVR) as neither was required by regulation.

The aircraft was equipped with a SHADIN Incorporated engine trend monitor (ETM) system. The ETM system consisted of a combined display and processor unit, which was installed in the instrument panel, and a recorder (not crash protected), which was mounted below the right rear passenger seat. The primary purpose of the system was to automatically record data points for use by the Pratt and Whitney engine condition trend monitoring (ECTM) program. The system also recorded data points for engine and airframe cycles and engine temperature exceedances.

The data from the ETM recorder was successfully downloaded. A total of 664 data points were recovered, dating from 13 March 2003 to 6 December 2003. The time recorded in each of the reports was acquired from the ETM internal clock, which was manually updated through the ETM display and processor unit.

On 6 December 2003 an aborted engine start was recorded, prior to the accident flight engine start. The record was generated by the inter-turbine temperature (ITT) exceeding 250º C and the gas generator speed (NG) exceeding 13%, which then proceeded to drop below 10%.

One minute after the aborted engine start, the engine was successfully started. Seventeen minutes after this start, a takeoff was recorded when the indicated airspeed exceeded 90 kt. The airspeed at takeoff was 99 kt with the aircraft on a heading of 250°. Thirty-eight minutes after the engine start, a stable cruise report was recorded at FL240 at an indicated airspeed of 186 kt and engine torque (TQ) of 96%. The stable cruise report was generated when, for two minutes, altitude did not vary by more than 200 feet, indicated airspeed did not vary by more than 20 kt and TQ did not vary by more than 2%. This report was the last data point to be recovered for 6 December 2003.

All of the downloaded data was analysed by the engine manufacturer. No anomalies were found and the engine parameters were found to be within the PT6A-64 engine operating limits. The ETM processor non-volatile memory (NVM) was also downloaded but, due to impact damage, no additional data could be recovered.

Radar information

National Air Traffic Services Limited provided secondary radar information on N30LT from two radar sources at Heathrow. Some of this information has been included in the history of flight. The final radar contact was at 1122:29 hrs, at a height between 1,420 and 1,520 feet agl with the aircraft approximately 2.6 nm from the threshold of Runway 01. The accident occurred at 1124:10 hrs. Therefore the time from the last radar contact to the runway was 1 minute and 41 seconds, giving an average ground speed of about 93 kt and an average descent rate of approximately 870 feet per minute. Figure 2 details the radar track for the last part of the flight.

Operational information

The pilot had completed his conversion to the TBM 700 on 21 July 1999 at an approved training centre. Since then, his flying logbook indicated that he had flown regularly throughout Europe and the USA. His last recorded flight in his logbook was 25 September 2003 in a single engine piston aircraft. His previous recorded flight in a TBM 700 was in N30LT on 14 September 2003. Information from one of his colleagues indicated that he had been involved at his normal work (0800 hrs to 1600 hrs each day), non-flying, during the week prior to his accident. For the month prior to that, he had been in Florida, where he owned a light piston engine aircraft; he had reportedly flown a number of flights during this period. The pilot had previously flown into Oxford with a colleague about a year before the fatal accident.

On the evening prior to the accident, the pilot had contacted a pilot colleague to ask if he would accompany him on the flight to Oxford. There was no requirement to operate with two pilots but this was a preferred option, particularly if the forecast weather was poor. The colleague was unable to do so but agreed to accompany him on the flight from Liege to Brussels. The pilot went to bed about 2200 hrs. The next morning, he left home about 0610 hrs to drive to the home of his colleague. By 0730 hrs, they had arrived at Liege. Takeoff from Liege was recorded at 0820 hrs.

At the time of the accident, there were two other aircraft in the circuit positioned behind N30LT. The previous movement had been an EC 135 helicopter, which had crossed Runway 01 at 1122 hrs from east to west at 50 feet agl about 100 metres upwind of the threshold. Once clear of the circuit, the helicopter had turned to the south-west. Subsequent to the accident, the helicopter manufacturer was asked to evaluate the possibility of turbulence from the EC 135 being a factor in the accident. Experience with the helicopter indicated that the turbulence generated was not a hazard to other light aircraft. Additionally, based on the time interval and surface wind, any turbulence would have been well clear of the location where N30LT started to bank to the left.

A weight and balance calculation, based on declared occupant weights and estimated baggage weights indicated that the aircraft was approximately 131 kg over the Maximum Take-off Weight (MTOW) of 2,984 kg with a CG position of 32.2% at the time of takeoff from Brussels. At the time of the accident, the estimated weight of N30LT was 2,942 kg and the CG position was within Flight Manual limits (19.5 % to 36 %) at 32.5%.

The Pilot's Operating Handbook (POH) recommended that a minimum of 10% TQ be maintained on final approach until the landing was assured. This was to ensure positive and rapid engine response to throttle movement. Normal approach speed with full flap is 80 kt. At the accident weight and configuration, the POH showed the stall speed at idle power with 0° bank as 61 kt.

Other TBM 700 accidents

Of the 256 TBM 700 aircraft built up to January 2004, seven (including N30LT) have been involved in fatal accidents and a further eight have been destroyed but without loss of life. These accidents covered the period between 1992 and 2003. These accident reports, plus an additional 17 reports dealing with other TBM 700 accidents, were reviewed to look for similarities with the accident involving N30LT. Of the fatal accidents, none were considered as having common features with N30LT. However, four other accidents involved the aircraft rolling to the left when engine power was increased. Two of these occurred in the UK and both were investigated by the AAIB.

The first of these occurred on 10 December 1992 to F-GLBD; it was reported in AAIB Bulletin 2/93. The flight involved a sales demonstration flight and the accident occurred during landing. The pilot in the right seat was handling and was instructed by the commander in the left seat to increase power. With no apparent reaction from the handling pilot, the commander applied some hand pressure to the power lever. As he did so, the handling pilot released his hold on the power lever and put both hands on the control wheel. The power lever moved to the fully open position and the handling pilot could not stop the aircraft rolling rapidly to the left and the left wing tip striking the ground.

The second non-fatal accident occurred on 24 October 2003 to N700VA and was reported in AAIB Bulletin 2/2004. The aircraft bounced on landing and then yawed and rolled left. The pilot applied power to go-around but was unable to prevent the left wingtip from striking the ground.

The third of these accidents occurred on 13 May 2002 to N700AR and was investigated by the Bureau D'Enquetes et D'Analyses pour la Securite de L'Aviation Civile (BEA). The pilot was on approach at low power and, just before the flare, applied power to correct his flight path. The aircraft banked to the left and the wing tip touched the runway. The BEA considered that the probable cause of the accident to N700AR was a '*Late correction of flightpath on short finals'*.

The fourth accident occurred on 15 December 2000 to N45PM and was investigated by the US National Transportation Safety Board (NTSB). The pilot was on his third attempt at a GPS approach in poor weather. When he became visual with the runway, he realised that his aircraft was low on the approach and he increased engine power. He considered that there was a slow engine response but when power increased, the left wing dropped and contacted the ground. The NTSB considered the probable cause of the accident was that '*the pilot did not attain the proper glidepath on the instrument approach*'. The pilot's decision not to fly to an alternate airport and his decision to continue the approach in weather conditions below the published minimums were contributing factors.

Fuel imbalance

On 6 January 2004, following a request by the AAIB, the manufacturer undertook a flight test to evaluate fuel imbalance. During the test flight, the fuel imbalance varied between 73 and 55 US gallons. It was found that increasing corrective aileron deflection was required with reducing speed and that full corrective aileron deflection was required at 70 KIAS to maintain wings level with a fuel imbalance of 69 US gallons. However, the company test pilot involved considered that an average pilot would have been technically able to complete a landing or go-around. The maximum allowable fuel imbalance detailed in the POH is 25 US gallons.

Flight tests

On 14 and 15 January 2004, the AAIB investigators, accompanied by investigators from the BEA, visited the manufacturer at Tarbes Airport to discuss the circumstances of the accident. During the visit, the AAIB investigators took part in a flight test in a similar aircraft to N30LT to evaluate certain possibilities. At the time, preliminary investigation had indicated that the aileron trim of N30LT at impact was at full left travel and the rudder trim at 85% left travel. Subsequent examination confirmed that the aileron and rudder trims were both close to the neutral position. A summary of the flight test, which was flown between FL100 and FL150, was as follows:

1. In a clean configuration and zero TQ, the aircraft stalled between 70 and 75 KIAS. At the stall, the aircraft always rolled to the left. The left roll could be corrected by the use of aileron. Some stalls were performed with full left aileron trim and 85% left rudder trim but this appeared to make no appreciable difference in roll.

2. With the landing gear down and 10° flap, the aircraft stalled between 67 and 68 KIAS. Stalls were performed with zero engine TQ and some were performed with full left aileron trim and 85% left rudder trim. At the stall, the aircraft always rolled to the left.

3. With landing gear down and 34° flap (normal landing configuration), the aircraft stalled between 55 and 60 KIAS. Stalls were performed with both zero and 20% TQ and some were performed with full left aileron trim and 85% left rudder trim. At the stall, which occurred at pitch attitudes of up to 11°, the aircraft always rolled to the left and rudder was required to counter the roll.

4. In all cases, the stall was preceded by the stall warning, which activated approximately 10 kt above the stall. Additionally, in the various configurations, a go-around was performed from engine settings of zero and 20% TQ and from various airpeeds down to 70 kt. These resulted in rolls to the left, which were easily controlled. However, it was

noted that the slower the initial airspeed, the more pronounced was the roll. It was also noted that there was no natural buffet prior to the stall.

5. A normal landing was achieved both with the yaw damper on and off. No difficulties were experienced in either configuration.

Subsequently, on 1 September 2004, AAIB investigators flew in another TBM 700 from Luton Airport to Oxford (Kidlington) to replicate the last recorded radar position of N30LT and review the subsequent approach. Although there was no information available on the configuration of N30LT at that point, it was possible to achieve an accurate threshold speed from that position even with a moderate tailwind. However, it did require an engine TQ close to zero.

The aircraft manufacturer performed another flight test in a TBM 700 on 28 October 2004 to evaluate the engine acceleration time from 0% TQ to 100% TQ. Their results showed that with the inertial separator turned off, the acceleration time was 3.0 sec at 85 kt and 3.1 sec at 75 kt , and with it turned on, which is the normal situation for landing, the acceleration time was increased to 3.4 sec at 85 kt and 3.9 sec at 75 kt. These times were based on the instrumented engine data and did not take into account the small time delay between throttle movement and first torque increase. The aircraft manufacturer also stated that the throttle was not moved excessively rapidly in order to protect the engine (as it was a prototype aircraft not fitted with a torque limiter).

Medical aspects

As a result of the post mortems, the pathologist concluded that the accident was not survivable and that the three occupants had died of multiple injuries. He considered that, in each case death would have been virtually instantaneous. Additionally, there was no evidence of any pre-existing disease which may have caused or contributed to the accident. Finally, there was no evidence of any alcohol, drugs or any toxic substance which may have caused or contributed to the accident in any of the occupants.

Aircraft description

The Socata TBM 700B is an all-metal, single engine turboprop, pressurised aircraft with a six or seven seat cabin configuration (including the pilot's seat). It has a maximum take-off weight of 2,984 kg and a maximum cruise speed of 300 KTAS at FL260. Its PT6A-64 free turbine engine powers a four-bladed Hartzell constant speed propeller. The aircraft is certified for single pilot operations.

The aircraft has a reversible mechanical flying control system and the wings have large span flaps which reduce the maximum stall speed to the required 61 KCAS for this class of aircraft. The flaps have three positions: up, takeoff (10°) and land (34°). A monitoring device interrupts movement if asymmetry between the left and right flap surfaces is detected. Roll control is accomplished by the combination of an aileron and spoiler in each wing that are directly connected to each other via a cable and pulley system. The aircraft also has a roll/yaw control interconnect, which is a mechanical system that applies appropriate rudder deflection when aileron is commanded and accordingly applies aileron when the rudder is commanded (ie, left rudder results in left aileron and vice versa). This allows for co-ordinated flight in turns commanded by only the use of wheel.

The left aileron and the rudder have trim tabs that are controlled by electric actuators. The aileron trim actuator is commanded by a pedestal-mounted switch in the cockpit, while the rudder trim actuator is commanded by a control wheel mounted switch. Both elevators have trim tabs that are mechanically operated either manually, by a trim wheel, or electrically, from a control wheel mounted switch via a servo motor under the cockpit pedestal.

The aircraft's autopilot operates in two axes, roll and pitch, and consists of an autopilot computer, an air data computer, a mode controller, a set of gyros and three electric servos. A roll servo controls the ailerons and spoilers, a pitch servo controls the elevator and the pitch trim servo controls the elevator trim tab. The autopilot has no control over the aileron or rudder trim tabs. A fourth servo controls the rudder and functions as a yaw damper. This is commanded in response to signals from the yaw rate gyro processed by the autopilot computer.

The aircraft is equipped with a pneumatic de-ice system that inflates boots on the wing leading edges, elevator horns, horizontal stabiliser and vertical tail. An electrical de-ice system protects the propeller, and an inertial separator is used to protect the engine air inlet from ice and debris. The separator consists of two electrically actuated movable vanes. When the inertial separator is turned on the vanes are repositioned to cause the inducted air to execute a sharp turn. Under the effect of centrifugal force this causes the denser particles to separate from the air and be discharged overboard. It is normal procedure to activate the inertial separator as part of the 'before landing' checklist.

The fuel system includes a fuel tank in each wing and a manual/electric fuel tank selector. When the system is set to manual the pilot selects the fuel tank via a 'pull and turn' wheel selector on the pedestal rear face. The selector, which controls the fuel unit, has three positions: left, right and off. When the system is set to automatic an electronic sequencer commands an actuator connected to the fuel unit, which then physically rotates both the unit and selector. This automatic selection allows the engine to feed from one tank or the other, in predetermined sequences, without pilot intervention.

Maintenance history

The last maintenance performed on the aircraft was a 100 hour/annual inspection, which was completed on 8 July 2003. The spoiler cable tension was adjusted but no defects requiring any major work were found during the inspection. The aircraft, engine and propeller had all logged 401 hours at the time of this maintenance. The aircraft had been maintained in accordance with Federal Aviation Administration (FAA) regulations and was in compliance with all relevant Service Bulletins. At the time of the accident the aircraft, engine and propeller had all logged approximately 483 hours.

Accident site examination

The aircraft had struck the ground in a field alongside the A44 on the south side of the Oxford Airport boundary. The aircraft wreckage was located 180 metres to the west of the Runway 01 threshold as shown in Figure 1. The initial impact marks and wreckage distribution were consistent with the aircraft having struck the ground upright in a nose low attitude, with a slight left bank and with a steep flight path angle. The marks and damage to the aircraft also indicated that the aircraft was in a sideslip to the left. After striking the ground on its nose and left side, the aircraft bounced, broke up into large sections and then immediately came to rest. The approximate final ground track of the aircraft, based on the wreckage distribution, was 320°(M).

All the aircraft wreckage and impact marks were located in a small 17 by 22 metre area, Figure 3, and this, together with the nature of the wreckage, indicated that the aircraft had a very low forward speed at impact.

Initial wreckage examination

The left wing had detached from the fuselage and the left wing fuel tank was completely ruptured. The right wing had remained attached to the fuselage wing box but the wing box itself was almost completely detached from the rest of the aircraft structure. The right wing leading edge had suffered a puncture such that any of its contents were likely to have drained out and the empennage was folded back with only the lower skin attached to the fuselage. The nose and left main landing gear had separated at impact but the right main landing gear was in good condition and was found in the extended and locked position. The right wing flap was fully extended and the right wing aileron and spoiler moved freely. The left wing was too badly damaged for such an assessment to be made on site.

Following the on-site examination the aircraft wreckage was recovered to the AAIB facility at Farnborough for a more detailed examination.

Detailed examination

Flight controls

A thorough examination of all the control cable and control rod runs was carried out. Flight control continuity was established from the ailerons and the spoilers to the wing root in each wing. The cables had separated at the wing roots, but each was characterised by 'broomstraw' ends, consistent with overload failures of the type to be expected as a result of the impact disruption of the left and right wings. Flight control continuity was also established from the control wheels aft to the roll lever in the wing root. No disconnections or obvious signs of a control restriction were found in the roll control mechanism. The only anomaly was a missing safety pin from the lower spoiler cable turnbuckle used to adjust the tension in the cable. It is possible that this pin was missing prior to the accident but the cable end was still secure inside the turnbuckle and therefore was not a factor in the accident.

The upper rudder cable was continuous and still attached to the bellcrank between the rudder pedals and to the rudder bellcrank in the tail. The lower rudder cable was also continuous and attached at the rudder bellcrank in the tail but had separated from the forward bellcrank between the rudder pedals. The separation was consistent with an overload failure and consistent with impact disruption. No pre-accident disconnections or obvious signs of a control restriction were found in the rudder control mechanism.

The elevator control system consisted entirely of control rods, levers and bellcranks. Two control rods had failed due to overload between the wing root and the cockpit, but the control runs were otherwise continuous and no disconnections or obvious signs of a control restriction were found.

The aileron trim was determined to be neutral (0°) based on the aileron trim actuator position. The rudder trim was determined to be 1° right (normal range –9.5° to +13.5°) based on the rudder trim actuator position, but this would only have caused a slight left rudder deflection in flight. Both elevator trim tab actuators had equal extension corresponding to a deflection of approximately +3.5° (trim tab up, normal range –20° to +15°), representing an aircraft nose down trim[1].

Flaps

The right wing flap had sustained relatively little damage and was found in the fully extended landing position. The left wing flap was bent in places and had detached from its inboard roller and

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[1] A flight test by the manufacturer determined that this corresponded to an 'in trim' condition for the aircraft fully configured for landing at a speed of between 111 and 114 KIAS (assuming power between 0% and 20% TQ). An additional flight test determined that at the normal final approach speed of 80 kt, with the CG position the same as on the accident flight, the pilot would be holding between 11 and 13 lbs of force on the control wheel, in an aft direction, to maintain this speed (see section on Operational analysis for further detail).

track assembly. The rollers in the outboard track assembly were in the fully extended position and the separated roller and track assembly also showed the rollers in the fully extended position. The extension of all four screw jack arms (two on each flap) was also consistent with full landing flap extension. It was concluded that at the point of impact both flaps were in the landing position.

Autopilot

The autopilot computer had sustained impact damage but, after re-soldering a broken resistor back onto the circuit board, the computer was connected to a test rig and passed its functional test. All three autopilot servos and the yaw servo were rig tested and passed their specification tests. The breakout forces required to overpower the servos were measured and these conformed to specification. The yaw rate gyro and yaw servo were connected to the autopilot computer and movement of the yaw gyro by hand resulted in the yaw servo responding in the correct direction. The autopilot mode controller operated correctly when connected to the test rig. To the extent that it was possible to conduct meaningful testing, no faults or anomalies were found in the primary autopilot system hardware.

Fuel tank selection system

It is standard procedure in the TBM 700 to set the fuel selection system to automatic and allow the electronic sequencer to automatically switch between left and right tanks. Any failure of the automatic fuel selection system should trigger an AUTO SEL caption and any fuel asymmetry would be detectable by a split between the two needles of the fuel tank quantity gauge. The automatic fuel selector switch was found set to manual but, as this is an unguarded switch, it was possible that it could have been knocked from the automatic position at impact or during the recovery by emergency service personnel. The fuel tank selector wheel was found set to the left tank position.

The three primary components of the fuel selection system, the electronic sequencer, the electric tank selector actuator and the fuel unit (which houses the valve that controls the fuel flow) were tested and examined. When connected to a test rig, the sequencer functioned normally but the actuator only operated in one direction, from left to right. The problem was traced to a slight miss-alignment of an internal micro-switch. However, the actuator exhibited visible impact marks and it is probable that impact forces had slightly dislodged the micro-switch. The fuel unit was strip examined, but no anomalies were found, and the internal valve was found in the left tank position.

De-icing system

There was significant disruption to the pneumatic hoses and damage to the de-icing boots as a result of the impact and, thus, the complete system could not be tested. It was considered possible, however, that any significant failure of the airframe de-icing system would most likely be caused by a fault in the electronic de-icing timer or the de-icing distributing valve. Therefore, these components were sent to their respective manufacturers for test and examination. Both operated correctly and passed all the functional tests. The inertial separator actuator was found in the ON position, which is the normal position for landing regardless of icing conditions.

Cockpit controls

The engine power lever was found close to the IDLE position, and the (blue) propeller control and (red) fuel control lever were fully forward. The manual override lever, used in case of fuel control unit failure, was found fully aft in its normal deactivated position. (These lever positions were not necessarily representative of pre-impact positions, as disruption of the forward fuselage during the impact sequence could have pulled on the engine control cables.) The flap selector lever was in the landing position gate and the landing gear lever was selected to DOWN.

Instruments

The directional gyro was indicating 287°(M) and the altimeter was set to 1032 mb. This was close to the QNH value of 1029 mb contained in the Meteorological Office's aftercast for Oxford for the time of the accident. The QFE setting would have been approximately 1019 mb.

Bulb filament examination

Examination of all available filament light bulbs in the wreckage indicated that impact forces had not been sufficiently high to identify any that may have been illuminated at the moment of impact. For example, the three green landing gear 'down and locked' lights had un-stretched filaments, despite there being good evidence that the landing gear was in fact down and locked. Therefore, no useful information was gained from this examination.

Powerplant examination

The engine was shipped to Canada where it underwent a detailed strip examination by the engine manufacturer's Air Safety Investigators, under the supervision of the AAIB. The significant findings were as follows:

- The propeller shaft had fractured due to torsional overload.

- The power turbines and power turbine guide vanes displayed circumferential rubbing consistent with mutual contact at impact whilst the turbines were rotating.

- The compressor shroud displayed circumferential rubbing consistent with the compressor blades having made contact with the shroud while rotating at impact.

- The fuel nozzles passed their functional test.

- The engine accessories, including the fuel control unit, the fuel pump, the propeller governor, the overspeed governor, flow divider, torque limiter, oil to fuel heater, and bleed valve were all either tested for functionality or disassembled for examination. No defects were found with any of these accessories.

In summary, the engine displayed no indications of any anomalies or distress that might have precluded normal engine operation prior to impact, and the rotational contact signatures inside the engine were characteristic of the engine developing low power at the time of impact.

Propeller examination

The propeller was disassembled and examined by one of the propeller manufacturer's Air Safety Investigators, again under the supervision of the AAIB. The No 1 and 2 propeller blades were both mildly bent aft and were twisted leading edge aft. The No 3 blade was sharply bent aft through approximately 90° at a position roughly 2/5 of its span from the root. The No 4 blade, however, was bent forwards through approximately 20° at roughly 3/5 span and it was also bent aft and twisted leading edge aft at about 2/5 span. Tip impact with forward bending typically drives the pitch change mechanism toward a higher blade angle, while aft bending typically drives the pitch change mechanism towards a lower blade angle. According to the propeller manufacturer, when an aft bent blade has been twisted leading edge aft it indicates that the blade was rotating at the time of impact. All four blades exhibited nicks in their leading edges and rotational scoring on their camber (forward facing) surface.

However, the overall extent of the blade damage was considered relatively mild, which was consistent with the propeller having been under low power at the time of impact. All of the propeller mechanism damage was also consistent with being occasioned during the impact and no discrepancies were found that would have precluded normal operation. In summary, all of the evidence from the propeller examination strongly indicated a low power condition at impact.

Analysis

General

The accident occurred at the end of a 67 minute flight, which appeared uneventful. The pilot had reported the runway in sight and had been cleared to land from a visual approach. Other pilots airborne in the local area reported the weather as benign at the time of the accident. However, as the aircraft crossed the airfield boundary, it began to roll to the left. There was a degree of confliction in evidence from some of the witnesses as to the subsequent manoeuvres of the aircraft. Initial evidence indicated that the roll continued left almost through 360° with the nose of the aircraft pointing towards the ground as it did so. However, the initial impact marks and wreckage distribution were consistent with the aircraft having struck the ground upright in a nose low attitude with a slight left bank and a steep flight path angle. This evidence would be consistent with the account of Witness A (the cyclist) who saw and heard the aircraft continuously in the last few moments of flight. The aircraft came to rest in a distance of less than 20 metres, which indicated that the aircraft had a very low forward speed. Witness marks also indicated that the aircraft was in a sideslip to the left which was consistent with uncoordinated flight following a stall. Regardless of the exact manoeuvres, there was no doubt that there had been a left roll and/or a loss of control. The investigation considered possible technical and/or operational reasons for a left roll or loss of control at a late stage in flight.

Engineering analysis

The cause of the left roll and subsequent loss of control, observed by witnesses while the aircraft was on short final approach, could not be explained from an examination of the aircraft wreckage. No disconnections or obvious signs of a control restriction were discovered during an examination of the roll, pitch and yaw control systems. There was no evidence of a flap asymmetry as all four flap jack screws were found fully extended. No faults or anomalies were found during testing of the autopilot system hardware and normally it is possible to override any autopilot control by opposing control force from the pilot. There was no evidence of a trim runaway as the rudder, aileron and elevator trim tabs were determined as having been close to their mid positions. The fuel contents in each wing at the time of the accident were unknown, as both fuel tanks were ruptured at impact. As the fuel tank selection system was found set to MANUAL, the possibility of an unintentional fuel asymmetry occurring in flight was considered. However, no pre-impact fault of the automatic fuel tank selection system was found, which suggested that the switch might have been knocked to MANUAL during or after impact. The evidence from both the engine examination and the propeller examination was consistent with a low power condition at impact and this was also consistent with the 'as found' position of the power lever. No pre-impact faults were found in the engine, the engine accessories or the propeller. The aircraft had been maintained in accordance with FAA Regulations and was in compliance with all relevant Service Bulletins.

In summary, no technical evidence was discovered of any malfunction which could have resulted in the left roll or loss of control just prior to landing.

Operational analysis

At the stage the aircraft started to roll to the left, the pilot should have been established at his target approach speed and with all his landing checks complete. Post crash examination of the aircraft revealed that the aileron and rudder trim settings were close to neutral. The pitch trim, however, was found at a position consistent for a fully configured aircraft at between 111 and 114 KIAS (assuming power between 0% and 20% TQ). Therefore, the aircraft would have been out of trim at a normal approach speed of 80 kt; at this speed the pilot would have been applying an aft force to the control wheel to counter the aircraft's nose down tendency. The manufacturer determined from flight test that this force would have been between 11 and 13 lbs. If this were so, then any abnormal flight condition that the pilot may have experienced could have been made worse by this out-of-trim condition.

With no obvious technical reason for a left roll at that stage of the approach, the investigation reviewed other possible reasons for such a manoeuvre and looked at the evidence for and against these possibilities. These included pilot incapacitation of some degree, a distraction, fuel imbalance, icing, wing stall and loss of control during a go-around.

Pilot incapacitation

The pathologist concluded that there was no evidence of any medical condition in the pilot, which may have caused or contributed to the accident. Indications from witnesses, one of whom was a colleague and friend who had flown with him on the immediately preceding flight, was that the pilot was his normal self prior to the accident flight. However, the circumstances of the accident to N30LT could be explained by some form of brief and temporary incapacitation of the pilot without this necessarily leaving any evidence.

Distraction

There was no evidence of any distraction outside the aircraft, such as other aircraft or birds. All the known aircraft were well clear of N30LT but the possibility remains that the pilot might have been distracted by a bird. It is also possible that he was distracted by something occurring within the aircraft. At a late stage on final approach, any distraction could have serious consequences.

Fuel imbalance

If there had been a fuel imbalance, this would have become more apparent as the airspeed reduced for landing. It could not be determined whether the fuel was closely balanced in each wing at the time of the impact and, indeed, wreckage examination indicated the possibility that the fuel could have been manually selected to the left tank. Evidence indicated that the aircraft was full of fuel on departure from Brussels and use of the automatic fuel tank selection system, which was the normal operating procedure, had been uneventful on the flight from Liege to Brussels. Also, no pre-impact fault was identified with the automatic fuel tank selection system during the investigation. Therefore, there was no reason for the manual system to be used and there should have been cockpit indications to alert the pilot to any fuel imbalance. Additionally, calculations showed that the maximum imbalance that could have occurred would have been approximately 67 US gallons. Although this was in excess of the normal maximum of 25 US gallons, a flight test indicated that this should not have resulted in an uncontrolled left roll at normal approach speed. Together with the fact that, at the time of the accident, the aileron and rudder trims were close to neutral, it was therefore considered unlikely that fuel imbalance was a factor in the accident.

Icing

The weather forecast for the flight was such that the aircraft may have experienced a degree of ice accumulation at some point during the flight. Although there were no reports from other aircraft of unusual or extensive icing conditions, there was no way of knowing what, if any icing was experienced by N30LT. However, the aircraft had comprehensive de-icing equipment and post crash examination indicated that the timing and distribution valves were serviceable. Furthermore, the aircraft had been below any possible icing level for at least four minutes before the accident. It was therefore considered unlikely that the roll to the left was caused by residual ice.

Wing stall

The aircraft would have stalled in normal landing configuration, with idle power and zero bank angle, at about 61 KIAS, and an audio stall warning was installed which should have activated some 10 kt before this airspeed. In the TBM 700, a stall would almost invariably result in a left roll/wing drop. For this to have happened to N30LT, the speed would have been some 19 kt below the normal approach speed of 80 KIAS. Radar information indicated that the average groundspeed for the aircraft over the last one minute and 41 seconds of flight was 93 kt; this would equate to an average airspeed of about 107 kt. Therefore, it was likely that the pilot was reducing his airspeed from the last radar recorded position, when the aircraft was at about 1,500 feet agl, and also likely that he would have reduced engine TQ for this descent. An approach with a higher than normal descent rate at low engine TQ and with reducing airspeed is difficult to judge and any misjudgement near the ground could have resulted in a rapid reduction in airspeed. However, the aircraft was fitted with a stall warning system and this, together with the aircraft's profile, with a long nose ahead of the cockpit, should have provided both audio and visual warning to the pilot of an approaching stall. Nevertheless, a stall must be considered a possibility.

Loss of control during a go-around

It was possible that the pilot had decided to go-around at a late stage of the approach. There may have been some sort of distraction, or the pilot may have decided to apply power because of airspeed/ height considerations, but a rapid application of engine power would have induced a left roll because of the engine TQ. This would normally be easy to counter but, if the airspeed had been low, and the application of engine power had been accompanied by an increased elevator demand, any roll tendency would have been increased, with associated control difficulty. This could have resulted in a stall. It may also be relevant that a turboprop engine is not as responsive to a rapid increase in throttle as a piston engine. Although the pilot was experienced in the TBM 700, most of his recent flying experience was in piston-engined aircraft. Furthermore, the inertial separator was determined to have been ON for the intended landing and this would have further slowed the engine response. In a previous TBM 700 accident (N45PM, 15 December 2000), the pilot commented on an apparent slow engine response.

There was some subjective witness evidence to indicate that the aircraft was initiating a go-around but this could not be confirmed as fact. The cyclist was the only witness who commented on an increase in engine noise. While this may have been an actual increase in power, it could also have been an apparent increase in noise as the aircraft passed overhead. The cyclist indicated that the aircraft had rolled almost level after the initial roll and then lost height before impacting the ground. If accurate, this would indicate that the pilot may have recovered from the initial roll but then stalled the aircraft. It is difficult to then understand why engine power was at a low level at impact, but this may have resulted from an instinctive reaction to the imminent impact. Loss of control during a late go-around must be considered a possibility

Conclusions of the investigation

Despite an extensive investigation, no definite conclusion could be reached as to why N30LT crashed on a visual approach to Oxford (Kidlington) Airport. No technical evidence was found which would explain the uncontrolled roll but there were certain operational possibilities. Without hard evidence, however, none could be fully supported, but loss of control resulting from an unknown distraction, or during the application of power for flight path adjustment or an attempted late go-around, must be considered as possibilities. The lack of a crash protected data, voice or image recording system on N30LT made it impossible to successfully determine a specific cause or causes of this accident.

Crash protected image recording system

In October 1997 a Cessna 208B operated in the United States by the Department of the Interior experienced a loss of control and collided with the terrain. The pilot and eight passengers were fatally injured. In October 2002 a Beech King Air crashed on approach, killing all eight people on board. Neither aircraft was equipped (nor was required to be equipped) with either a flight data recorder (FDR) or cockpit voice recorder (CVR). These are two examples but the NTSB has reported that investigations of numerous accidents involving similar aircraft types have been hampered by the lack of CVR and FDR information.

In some instances, radar data and/or on board global positioning systems, where available, did not provide sufficient detail concerning the aircraft's flight path or flight conditions. This has also proved to be the case with regard to the accident to N30LT. The installation of an FDR on smaller aircraft is likely to be economically impracticable due to the intrusive nature of the installation itself whilst a CVR, although invaluable as an accident investigation tool, yields little parametric data. An image recording system could record audio like a CVR but, as a minimum, would capture images of parametric data from the flight deck instrumentation and possibly a part of the external, forward view. Advancements in the development of image recording now makes these systems technically and economically more viable for fitting to small aircraft.

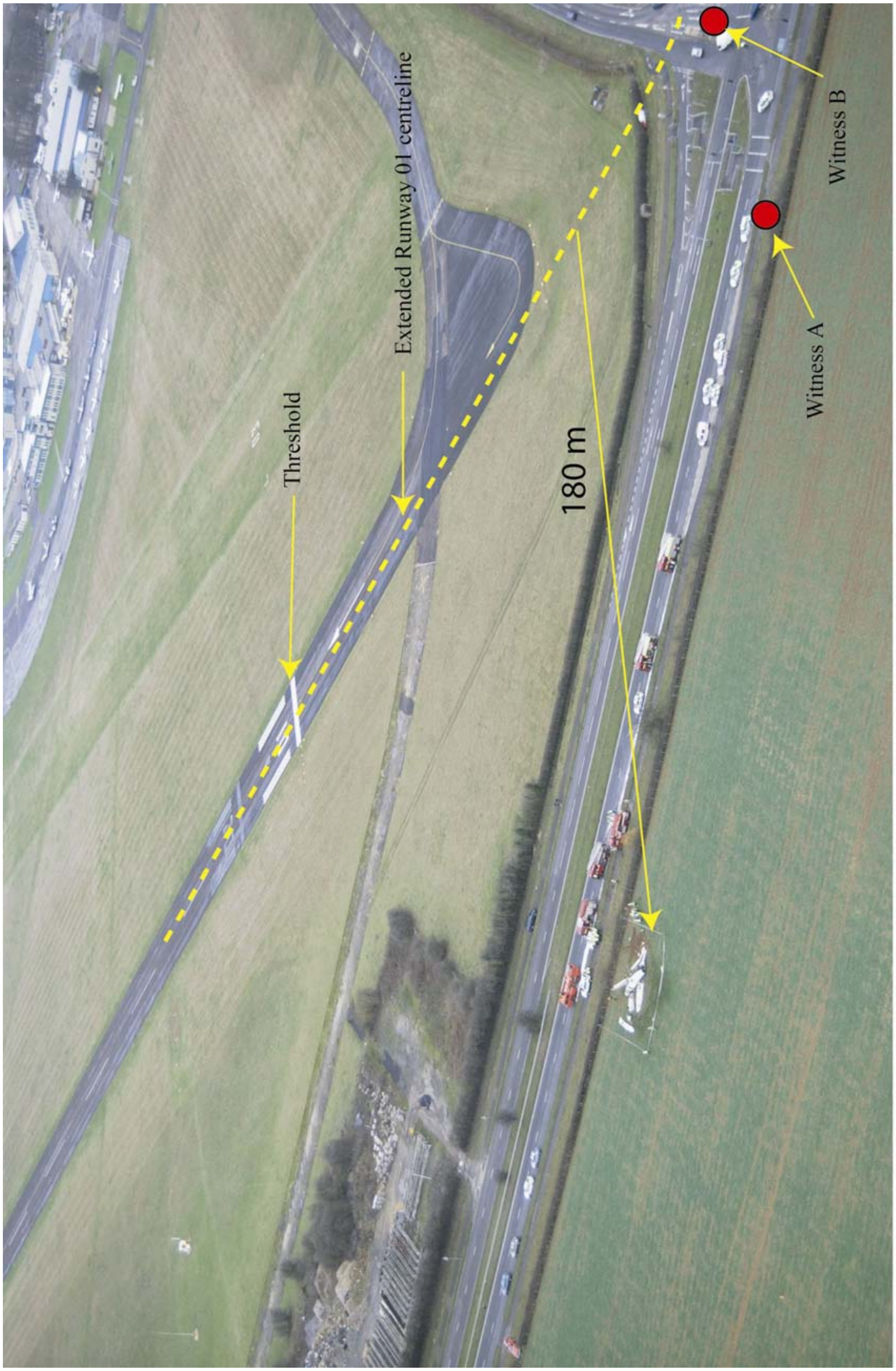
As a result of the Cessna 208B accident, the NTSB made recommendation A-99-60 on 8 February 2000, which requires:

> *'within 5 years of a technical standard order issuance, the installation of a crash-protected video recording system on all turbine-powered non experimental, non-restricted category aircraft in 14 Code of Federal Regulations Part 135 operations that are not currently required to be equipped with a crashworthy flight recorder device'.*

The international aviation community is aware of the safety benefits of crash-protected image recorders. The International Civil Aviation Organisation (ICAO) and Flight Recorder (FLIREC) Panel, specifically dealt with the need for standards and recommended practices concerning such recordings. The panel agreed that the use of these recordings in aircraft cockpits would be very useful and noted that the European Organisation for Civil Aviation Equipment (EUROCAE) was developing minimum operational performance specifications. In March 2003, EUROCAE issued a technical standard for a crash-protected image recording system. The NTSB has recommended that the Federal Aviation Administration (FAA) incorporate this standard (ED-112, Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems) into a Technical Standards Order (TSO).

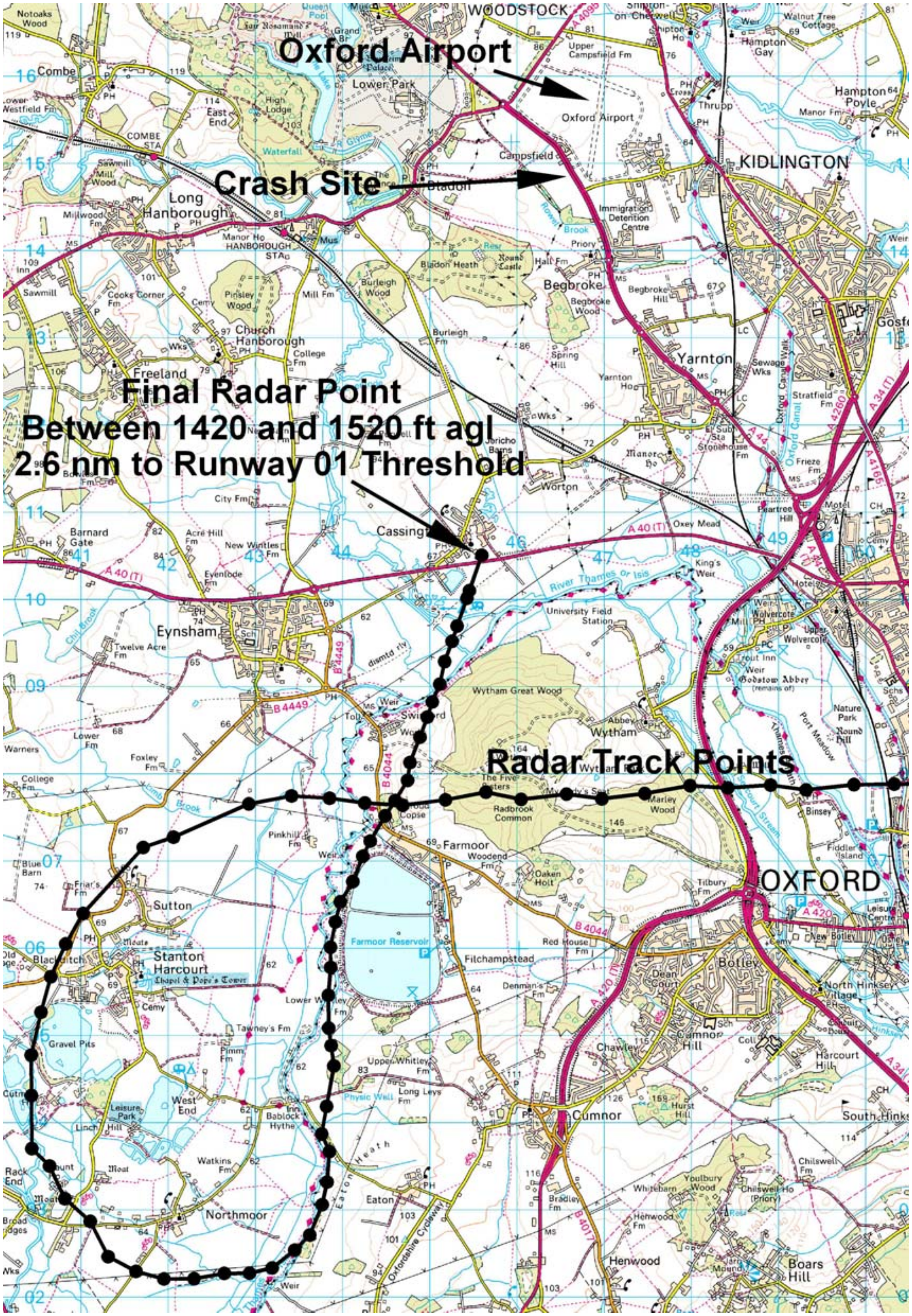
In Europe, the Joint Airworthiness Authorities (JAA) also are considering the requests of accident investigation bodies and have jointly sponsored research into the use of image recorders on the flight deck. Additional work is also ongoing to determine the requirements to protect such recordings against use outside accident investigation, a necessity to prevent them being employed for punitive means. The AAIB fully supports the introduction of such technology and is satisfied that the industry is working towards providing this additional source of information for accident investigators. As a result, the AAIB sees no need to make additional recommendations on the subject at this time. It is considered likely that, had a crash-protected airborne recorder been available to the N30LT investigation, some of the uncertainties surrounding the events of this accident may have been resolved.

Figure 1



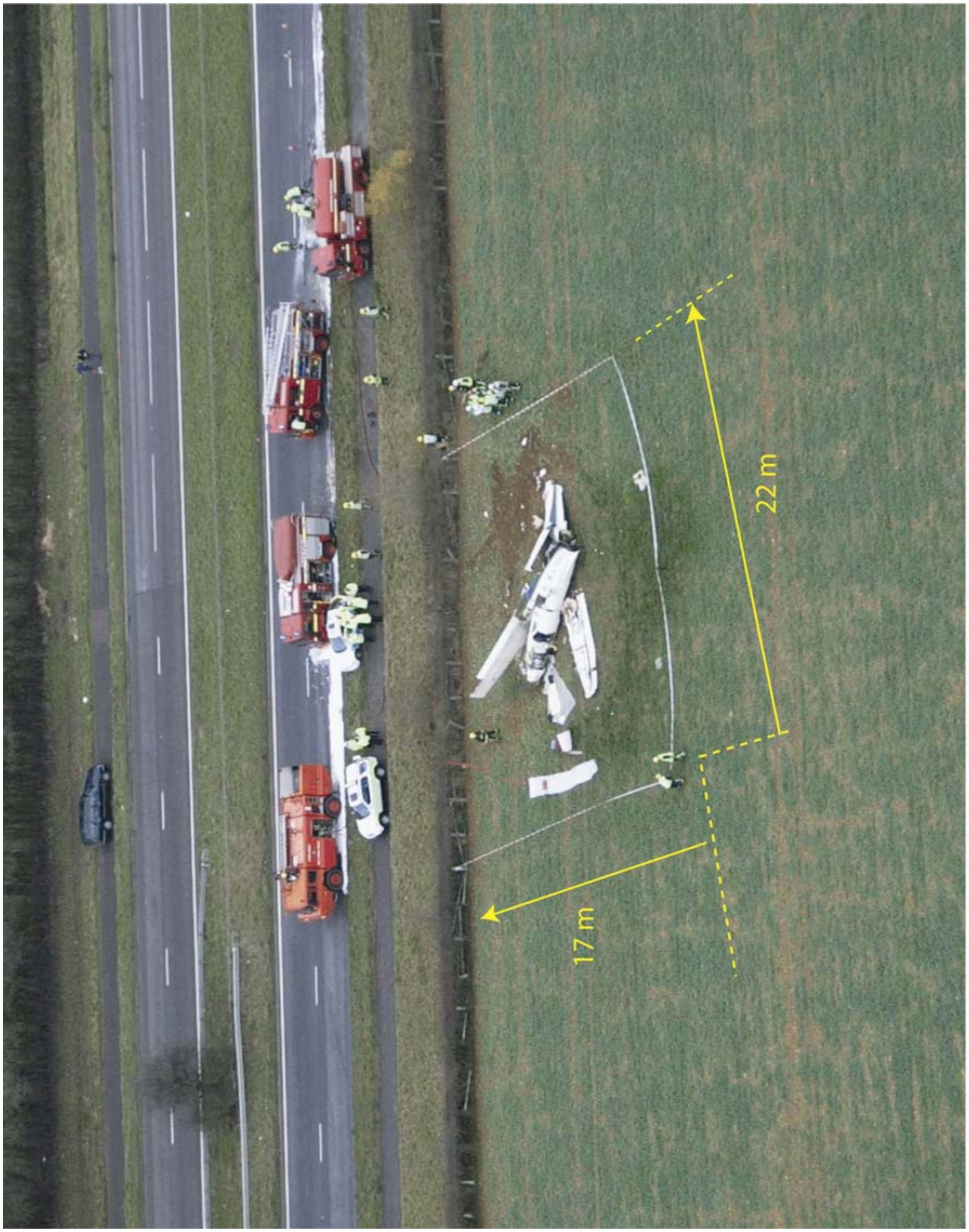
N30LT - Accident Site Location

Figure 2



Final radar track of N30LT

Figure 3



N30LT - Accident Site Details

Aircraft Type and Registration:	Cessna A185F, G-BKPC	
No & Type of Engines:	1 Continental Motors IO-520-D piston engine	
Year of Manufacture:	1979	
Date & Time (UTC):	6 March 2005 at 1700 hrs	
Location:	Barton Aerodrome, Manchester	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to the left main landing gear mounting structure, left horizontal stabiliser leading edge	
Commander's Licence:	Private Pilot's licence	
Commander's Age:	63 years	
Commander's Flying Experience:	4,000 hours (of which 2,805 were on type) Last 90 days - 30 hours Last 28 days - 11 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

G-BKPC was operated by the Black Knights Parachute Centre as a parachutist dropping aircraft and had been loaded with sufficient fuel for two flights. For the first flight, five parachutists plus the pilot were on board. The sun was low and almost directly in line with the take-off direction on Runway 27 at Cockerham, and this impaired the pilot's ability to see forward. During the take-off roll, immediately prior to the aircraft becoming airborne, the left main landing gear (MLG) wheel struck an obstruction to the left of the runway. The impact caused a failure of the mounting structure in the fuselage to which the left MLG is attached and the left gear, complete with wheel and part of the fuselage structure, became detached. As it departed the aircraft, it struck and damaged the outboard section of the left horizontal stabiliser leading edge.

The pilot declared an emergency and elected to land at Manchester Barton Aerodrome, where the aircraft was maintained. The five parachutists successfully completed their parachute descents, following which the pilot proceeded to burn off most of the fuel prior to landing. The authorities at Barton put in place their Aircraft Accident Imminent Procedure, which included full alerting of external and airfield fire and emergency services and the recall of all aircraft operating locally (two diverted). The local police helicopter was advised of the situation via Manchester Airport ATC and at 1633 hrs, it escorted the aircraft as it commenced its approach to Runway 27L at Barton. During the landing roll, the aircraft's left wing contacted the ground, causing it to slew to the left. The emergency crews arrived at the aircraft within approximately 10 seconds, but there was no fire and the pilot was easily able to vacate the aircraft.

An examination of the aircraft later showed that the failure of the left MLG mounting structure resulted from overload.

AAIB Bulletin No: 5/2005 **Ref: EW/G2005/03/05** **Category: 1.3**

Aircraft Type and Registration:	Grob G109, G-BRCG	
No & Type of Engines:	1 Limbach L 2000-EBIA piston engine	
Year of Manufacture:	1981	
Date & Time (UTC):	6 March 2005 at 1230 hrs	
Location:	Pocklington Airfield, East Yorkshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Substantial to landing gear, propeller and lower fuselage	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	49 years	
Commander's Flying Experience:	336 hours (of which 35 were on type) Last 90 days - 9 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

After an uneventful navigational exercise from Gamston, the pilot flew a shallower than normal approach to asphalt Runway 36 at Pocklington. The surface wind was 020°/10 kt and the runway was dry. The approach was flown at 60-65 kt with the throttle at idle and the airbrake marginally open; stabilising the approach on this type of motorised glider. At approximately 100 feet agl the aircraft sank rapidly. Although the pilot had time to retract the airbrakes his application of power was delayed as he had to change hands on the control column; the throttle being positioned on the opposite side to the airbrake control. Before these actions could take effect the aircraft landed heavily in rough grass in the undershoot, approximately 60 metres short of the runway threshold. The landing gear collapsed and the aircraft slid to a halt on its fuselage (Figure 1). The two occupants, who were both wearing 4 point harnesses, were able to vacate the aircraft normally without injury.

The pilot reported that, in the prevailing wind conditions, a three metre high earth bank, located 20 metres short of the runway threshold, may have created an area of sink. Exposure to this sink was exacerbated by the increased time at low level brought about by the shallower than normal approach angle. The aircraft's high aspect ratio wings are particularly susceptible to loss of lift and subsequent sink can occur very rapidly.

Figure 1

Aircraft Type and Registration:	Piper PA-34-200T Seneca, G-BHYG	
No & Type of Engines:	2 Continental Motors TSIO-360-EB piston engines	
Year of Manufacture:	1980	
Date & Time (UTC):	11 February 2005 at 0747 hrs	
Location:	1.5 miles north-east of Oxford (Kidlington) Airport, Oxon	
Type of Flight:	Training	
Persons on Board:	Crew - 3	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Front baggage bay door detached, damage to left propeller	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	49 years	
Commander's Flying Experience:	3,600 hours (200 hours on type) Last 90 days - 70 hours Last 28 days - 30 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

History of the flight

The flight was intended to be an IFR training detail, with a scheduled departure time of 0740. The crew comprised the instructor and student flying, plus a supernumerary student, who was to perform the Check 'A' (daily) inspection and accompany them on the flight.

The instructor arrived at the airport at 0655 hrs and was checking the weather shortly after 0700 hrs, when he met the crew outside the flying training organisation's Operations Room. No aircraft had yet been allocated to them and so the Check 'A' was already well behind schedule. The instructor directed the students to ask for an aircraft to be allocated and suggested that if they divided the tasks between them, they could still achieve the scheduled 0800 hrs ILS slot at Cranfield, even if they were late departing from Kidlington, but that they should aim to minimise the overrun of the 0740 hrs IFR take-off slot.

The supernumerary student went ahead to begin the Check 'A' inspection, with the instructor and student flying following soon after. He was familiar with the aircraft type, having flown it during his training and was well-versed in the Check 'A' procedures.

The student flying mentioned in conversation to the instructor that the supernumerary had not gone to bed until after 0030 hrs, having collected someone from a delayed flight at London Heathrow Airport. On approaching the flight line, the instructor noticed that the supernumerary appeared to be removing the cover from the wrong aircraft and pointed this out to him. The crew then repositioned to the correct aircraft. The instructor directed the student flying to board the aircraft and carry out the initial Check 'A' actions, with the supernumerary checking the lights and pitot heaters, whilst he checked the fuel quantity and fuel drains. He then called for the battery master and magneto switches to be checked and they were confirmed to be off by the student flying. The instructor told the supernumerary student to proceed with the airframe check whilst he checked the engine oils, whilst the student flying remained in the cockpit and commenced what preparation he could for the flight, whilst ensuring that battery master switch remained off.

The oil level in both engines was below six quarts and so the instructor left the apron to collect two quarts of oil to top-up the engines. This took some time, as the oil store was locked and he had to seek assistance from a bowser driver. When he returned to the aircraft, he established that the supernumerary student had completed the Check 'A' and sought his assistance in topping up the engine oils.

The engines were started at 0736 hrs and the student flying completed the 'After Start' and 'Taxi' checks whilst the instructor taxied the aircraft to the holding point. Take-off clearance was given at 0743 hrs, with a recorded take-off time of 0747 hrs. Runway 01 was used for departure.

The take-off roll was normal, however shortly after lifting off, the nose baggage bay door, which is on the left side of the aircraft, came fully open. The instructor, seated in the right-hand seat, had a clear view of the door and noted that the handle was in the vertical (unlatched) position. He took control of the aircraft and asked the student to remove the instrument flying screens, before contacting ATC to request a circuit to land. The door then slammed shut and open several times, before becoming partially detached and flailing around in front of the student in the left-hand seat. It finally detached and the instructor contacted ATC, declaring a PAN. The aircraft was landed safely.

Damage to aircraft

On inspection, the left propeller was found to be badly damaged, having struck the departing door and the door seal was wrapped around the OAT probe. The remains of the door were recovered from a nearby golf course (Figure 1), with the latch spring still attached, but the lock, shoot bolts and other latch components were missing, these probably having been knocked off on contact with the propeller. According to the engineer who inspected the aircraft, there was no evidence of distress to the door frame or the latch components on the aircraft. Following the incident, the nose baggage bay door key, with its high-visibility fob, was found inside the aircraft where it is normally stowed.

Nose baggage bay door information

The upward-opening door is constructed of fibreglass and is latched and unlatched via an external rotary handle mounted in a recess in the door. The door is latched by rotating the handle from the vertical to the horizontal position. This causes two shoot bolts to extend on either side of the door and drives a hook to engage with a latch on the door frame. The mechanism is held in the closed position by spring tension. The centre of gravity of the door is located outboard of the hinge line, so that the door naturally falls shut and it is possible for the door to sit flush with the fuselage even with the handle in the unlatched position, so that it at a glance, it appears to be latched.

A lock positioned adjacent to the rotary handle enables the door to be locked when it is latched. Mechanical interlocks ensure that the key can only be removed when in the locked position and that the key will only achieve the locked position if the latch is closed. Service experience shows however, that the lock and key can wear to the extent that it becomes possible to withdraw the key with the latch in the open position.

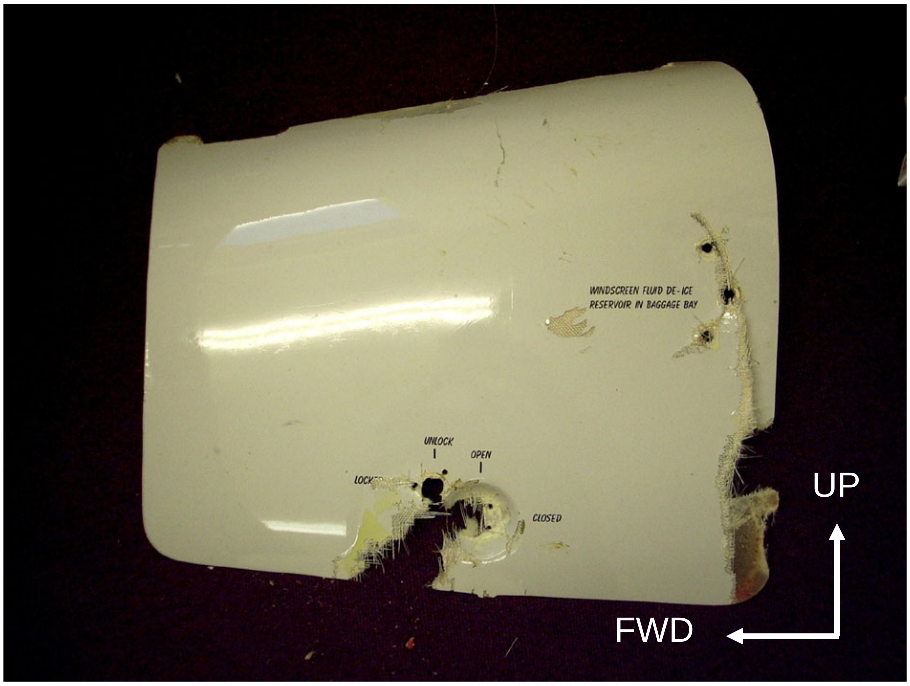
Access is required to the nose baggage bay when carrying out the Check 'A' to inspect the brake fluid and windscreen de-icing reservoirs that are located inside the bay.

Discussion

Given that the instructor saw the handle in the unlatched position when the door came open in flight, and the lack of distress to the door frame or latch components on the aircraft, it is probable that the door was not latched prior to flight. This implies that it must have been possible to either withdraw the key from the lock with it in the unlocked position, or that it was possible to turn the key to the locked position, with the door handle in the unlatched position. However, as the lock was not recovered, it was not possible to confirm either scenario.

Possible contributory factors were the time pressure on the crew to make the takeoff and ILS slots and fatigue on the part of the supernumerary crew, who may have had insufficient rest the night before.

The operator is modifying its PA-34 fleet to paint more visible alignment marks adjacent to the door handle, to make it easier to confirm that the door is latched. The fleet is also to be inspected for proper functioning of the nose baggage bay door key/latch interlock function. The operator's PA-34 maintenance schedule will also be expanded to include this as a recurring inspection on the '100-hour' Check. A communication has already been issued to all instructors and students within the flying training organisation to make them aware of the implications of lock/key wear and the need to confirm that the nose baggage bay door is correctly latched prior to flight.



Damaged Nose Baggage Bay Door

Figure 1

Aircraft Type and Registration:	Pulsar, G-MCMS	
No & Type of Engines:	1 Rotax 582 piston engine	
Year of Manufacture:	1993	
Date & Time (UTC):	25 July 2004 at 1305 hrs	
Location:	Near Taynuilt, Scotland	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Serious)	Passengers - N/A
Nature of Damage:	Damage to landing gear and fuselage belly	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	52 years	
Commander's Flying Experience:	408 hours (of which 50 were on type) Last 90 days - 24 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and metallurgical examination of radiator failure	

History of the flight

The Pulsar, pictured at right, is a low-wing composite single-seat kitplane operated under a Permit to Fly. The aircraft was on a cross-country flight from Perth to Oban. Ten miles away from Oban the pilot called Oban Radio and requested the airfield information. He did not receive a reply but he heard the wind direction and speed being passed to another aircraft. While at 4,000 feet on the Oban QFE the pilot detected a slight burning smell. He advanced the throttle but the engine did not respond. The pilot immediately declared a MAYDAY, stating his position and the nature of his emergency to Oban Radio, but the Oban radio operator was unable to decipher the message. Due to a strong westerly wind the pilot decided that he would be unable to reach Oban. There were no suitable fields nearby for a forced landing so the pilot selected a field on flat ground beside a river and planned a circuit while repeating his MAYDAY transmission several times but with no response. At approximately 1,000 feet agl the engine seized. The aircraft reached the chosen field but the touchdown was hard and the field was rough with cows grazing at the eastern (near) end. The landing gear separated during the ground roll and the aircraft decelerated rapidly to a rest. The propeller had stopped in a horizontal position and so was undamaged. The pilot was able to vacate the aircraft by opening the canopy as normal and then telephoned '999' from his mobile phone for assistance. It was later determined that the pilot had suffered from a crushed vertebra.

Aircraft's engine cooling system

The aircraft's Rotax 582 engine is liquid cooled using two small radiators that are mounted within the forward cowling (see Figure 1). The primary hoses A and D between the engine and each radiator have an inside diameter of 1 inch. The cross-over hoses B and C between the radiators have an inside diameter of 5/8 inch. There are rectangular slots within the upper and lower cowlings to hold the radiators in place. The grey adhesive 'gaffer' tape that is visible on the port radiator in Figure 1 was, according to the owner, applied to ensure a snug fit within the upper cowling slot.

The aircraft's instrument panel was fitted with a water coolant temperature gauge but not with a temperature exceedance warning light or aural warning. Because the Rotax 582 is a two-stroke engine there were no oil temperature or oil pressure gauges. The Pulsar construction manual warns: '*if the water ever leaks out of the system in flight, you'll find yourself in a glider in probably less than a minute*.'

Engine examination

A Popular Flying Association (PFA) inspector examined the engine following the accident. He discovered that all the coolant had drained from the radiators. There was a small pool of coolant in the lower cowling and the port radiator's outboard hose coupling had detached from the radiator - circled area in Figure 1 and close-up in Figure 2. The failed coupling, the port radiator and the port radiator hoses were sent to the AAIB for a more detailed examination. An engine strip was subsequently performed by the PFA inspector which revealed severe over heating damage of piston number two.

Examination of radiator hoses

There was no evidence of any leaks within radiator hoses C or D. Hose D had a slight bend in it but it was a straight hose that had retained some of its bend from having been bent into position for a long period. The Pulsar construction manual states that hose D should be constructed from two pieces of straight hose that are then joined together with the 45° copper fitting supplied with the kit (the alternative is to use a curved moulded hose). This should ensure that no side load is imparted to the radiator coupling.

Examination of radiator and failed coupling

The port radiator and failed coupling were examined by an independent organisation with metallurgy and fracture expertise. The following is a summary of their findings. A visual examination of the brass radiator showed that the whole circumference of the detached area exhibited a fracture surface and that the corresponding coupling still had a section of the brass radiator attached to it (see Figures 3 and 4). This indicated that the failure occurred in the radiator material rather than in the brazed joint between the coupling and the radiator. A cross section of the failed coupling and the intact coupling on the other end of the radiator revealed their composition (see Figures 5 and 6). A brass connecting tube had been inserted into an opening within the radiator and then brazed with a silver based filler metal. A copper coupling had then been soldered to the brass connecting tube with a lead-tin based solder. The evidence of lead-tin solder on the inner surface of the brass connecting tube suggested that the copper coupling had been dip soldered. Lead-tin solder also coated the outer surface of the brass connecting tube and radiator joint. There were no differences in the construction of the failed and intact couplings although the connecting tube of the failed coupling appeared to be offset downwards at an angle of approximately 5°.

The majority of both the fracture surfaces on the radiator and on the coupling were masked by contaminants apart from a small area of the fracture in the upper left position of the radiator (see Figure 3) which was clean. The fracture surface of the detached section was examined under a Scanning Electron Microscope (SEM). The SEM examination did not reveal conclusive evidence of the failure mechanism but it was likely that the clean area of the fracture was the last section to detach and that it occurred due to overload. The lower half of the fracture (with reference to Figure 3) was more obscured by damage and surface contamination; however, small patches were observed which showed a transgranular fracture that appeared to have corroded. This evidence suggested that this part of the crack had been present for a longer period than the cleaner area hence the crack appeared to be progressive. The fracture surface in this area also showed some faint parallel markings that may be evidence of fatigue striations, although they were not clear enough to confirm this positively.

There was a build up of solder around the lower part of the fracture (see Figure 3) and there was solder contamination on the lower right area of the fracture – the area from which the crack is likely to have propagated. Lead-tin solder usually melts in the range of 180°C to 320°C depending on its exact composition. The solder contamination on the fracture surface may have been a result of local overheating during the engine failure which resulted in some of the solder melting and being drawn into the crack. However, the radiator was not in direct contact with the engine and therefore the engine bay itself would have had to reach a temperature of 180°C to 320°C. It is also possible that the solder contamination is evidence of a repair. Because it is likely that the crack growth was progressive, it is possible that a coolant leak was observed at some point before final failure occurred. The leak around the area of failure could have been mistaken for a poor joint and re-soldering may have been carried out to rectify the leak. Re-soldering would have filled the crack and temporarily stopped any leaks but a fatigue crack in the brass radiator would still have propagated under the influence of cyclic loading from engine vibration through the hose.

History of the aircraft

The aircraft was manufactured from a kit and first registered on 3 February 1993. In 2001 the original owner, who built the aircraft, sold it to its present owner who was the accident pilot. The AAIB tried to contact the original owner by phone and e-mail but received no response. The present owner was very helpful during the investigation. He stated that no repairs had been carried out on the radiator system during his period of ownership and that no record of a repair was detailed in the aircraft's logbook. He had also not changed any of the radiator hoses. The aircraft had sat unused for one and a half years until December 2003 when it was inspected and issued with a new Permit to Fly on 22 December 2003. Since then the aircraft had flown 35 hours leading up to the accident flight and it had logged a total of 261 hours. The pilot had not noticed a leak from the radiator coupling prior to the accident flight or any preceding flights, although any leak would have been somewhat obscured by the surrounding grey masking tape and black tape around the coupling.

Analysis

The engine failed because it overheated following a loss of radiator coolant. The radiator lost its coolant in flight through either a crack or complete detachment of the port radiator outboard coupling. An examination of the coupling fracture revealed that the brass radiator had failed rather than the solder or brazing material. The results from an SEM examination of the fracture surface were not conclusive but it appeared that a crack had initiated on the lower right part of the fracture surface (with reference to Figure 3) and then propagated circumferentially until it failed in overload at the upper left part of the fracture surface. The evidence of a heavy solder deposit and solder contamination on the lower fracture surface raised the possibility that an inadequate solder repair had been carried out, although this could not be confirmed from the aircraft records.

The hose connecting the engine to the failed coupling was a straight hose that had been bent into position whereas either a moulded hose or a two-piece hose with a 45º intermediate joining piece should have been used. The bent hose would have applied some side load to the coupling which, together with the cyclic loads imparted from engine vibration, may have induced fatigue crack growth in the coupling. The crossover hose from the other radiator could also have applied a side load to the coupling. Furthermore, the brass connecting tube of the failed coupling was offset downwards at an angle of approximately 5° which may also have contributed to the loading at the edge of the joint.

The PFA and Pulsar Aircraft Corporation were contacted regarding this accident and neither organisation was aware of any similar failures having caused accidents in the past. The accident pilot was aware of another pilot who had suffered from a leak at the radiator fitting although it was not clear whether this was as a result of a stress fracture in the brass or a leaking solder joint. The AAIB spoke to another Pulsar pilot who approximately five years ago experienced a leaking radiator fitting in flight. He became aware of the problem when coolant fluid started to spatter the windscreen but he was able to carry out a precautionary landing before the engine failed. In that case the pilot stated that he had used a curved moulded radiator hose, but again the exact failure mechanism was not known. The pilot of G-MCMS said he had recently discovered that some Pulsar owners used 'Ronyflex' hose which is a more flexible type of hose than that supplied with the kit, on the basis that this would reduce the cyclic loads imparted from the engine to the radiator. The PFA was not aware of the 'Ronyflex' hose type.

The current owner of the Pulsar Aircraft Corporation did not design the original Pulsar and therefore did not comment directly on this accident but referred the AAIB to an experienced Pulsar kit builder and pilot in the USA. This builder and pilot stated that the Rotax 582 engine was known for its high level of vibration and that vibration would be transmitted through the radiator hoses. In his opinion, the use of a straight hose induced stress which caused the failure of the radiator coupling on G-MCMS. He had not heard of 'Ronyflex' hose before and could not comment on its use. He also said that the radiator was supposed to be held rigidly by the upper and lower cowlings.

Conclusions

Regardless of the cause of the coupling failure, Pulsar owners would be well advised to ensure that their aircraft is fitted with the correct hoses as detailed in the engine manual or an alternative approved by the PFA. In light of this accident Pulsar owners should also be made aware of the importance of regularly checking the radiator couplings for leaks and cracks. The AAIB therefore made the following safety recommendation:

Safety Recommendation 2005-005

The Popular Flying Association should:

a. Ensure that Pulsar aircraft owners are aware of, fit and use only radiator hoses approved for use by the Association or the Pulsar aircraft kit manufacturer.

b. Encourage Pulsar owners to carry out regular checks of the integrity of the engine cooling system, especially in the regions of the radiator hose couplings.

Safety action

On 11 March 2005 the Popular Flying Association informed the AAIB that it accepted the Safety Recommendation. Its Engineering department is designing a modification which will reduce the vibration transmitted to the radiator via the hose and avoid any pre-stress in the hose connection. The modification will be issued to Pulsar owners shortly.

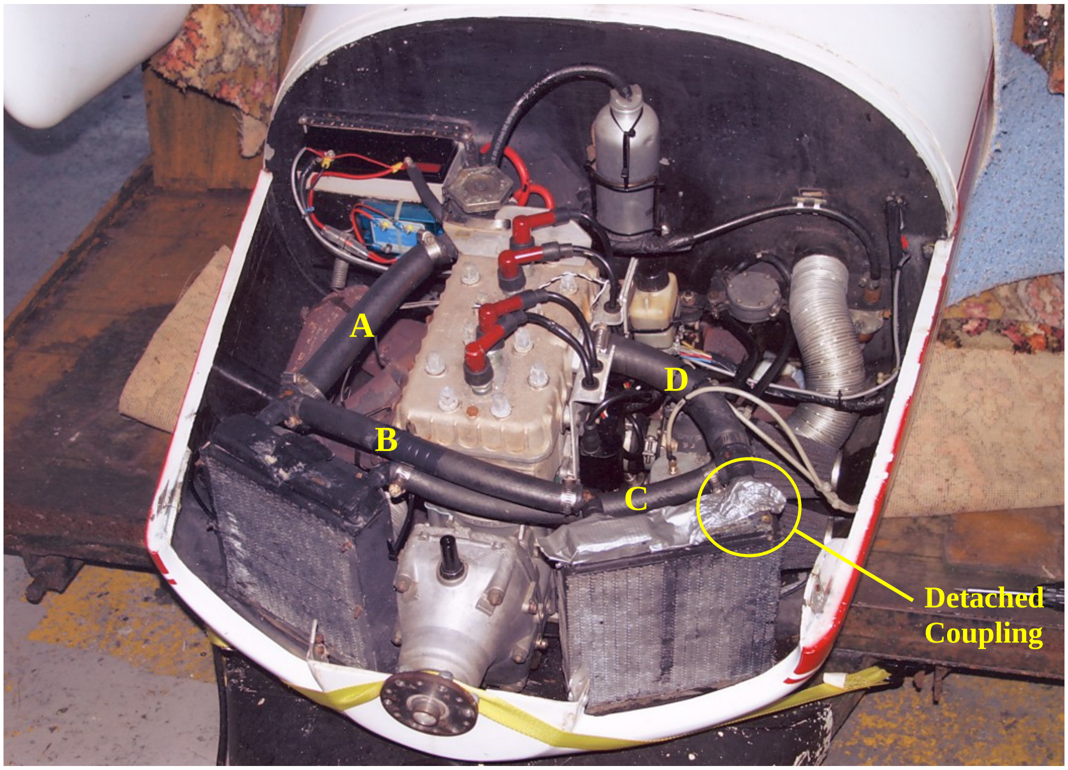


Figure 1 Engine and radiator layout inside G-MCMS post accident (photo courtesy P. Murray)

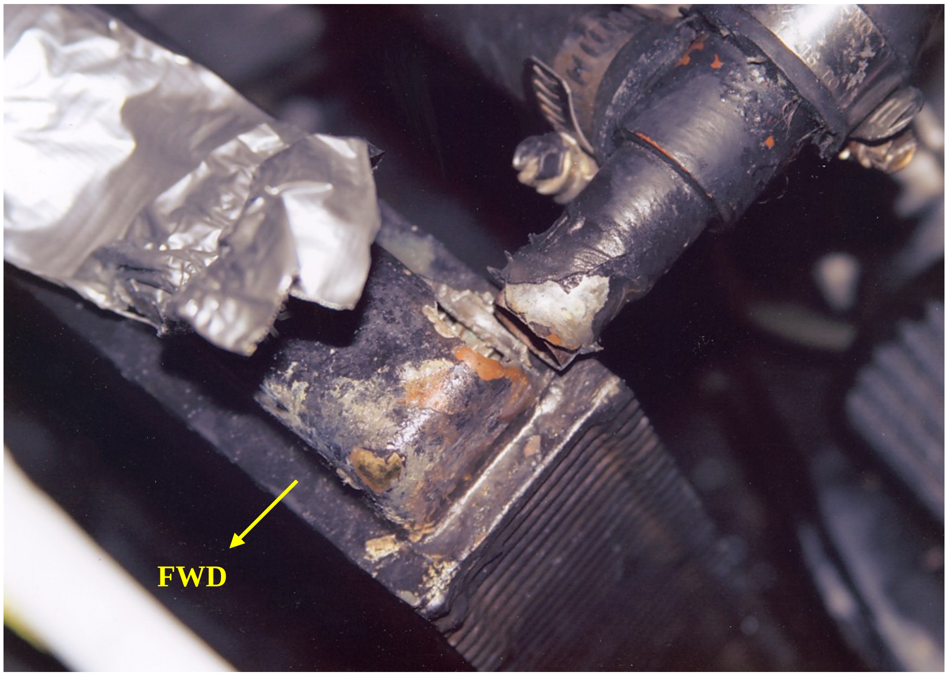


Figure 2 Detached coupling from outboard fitting of port radiator (photo courtesy P. Murray)

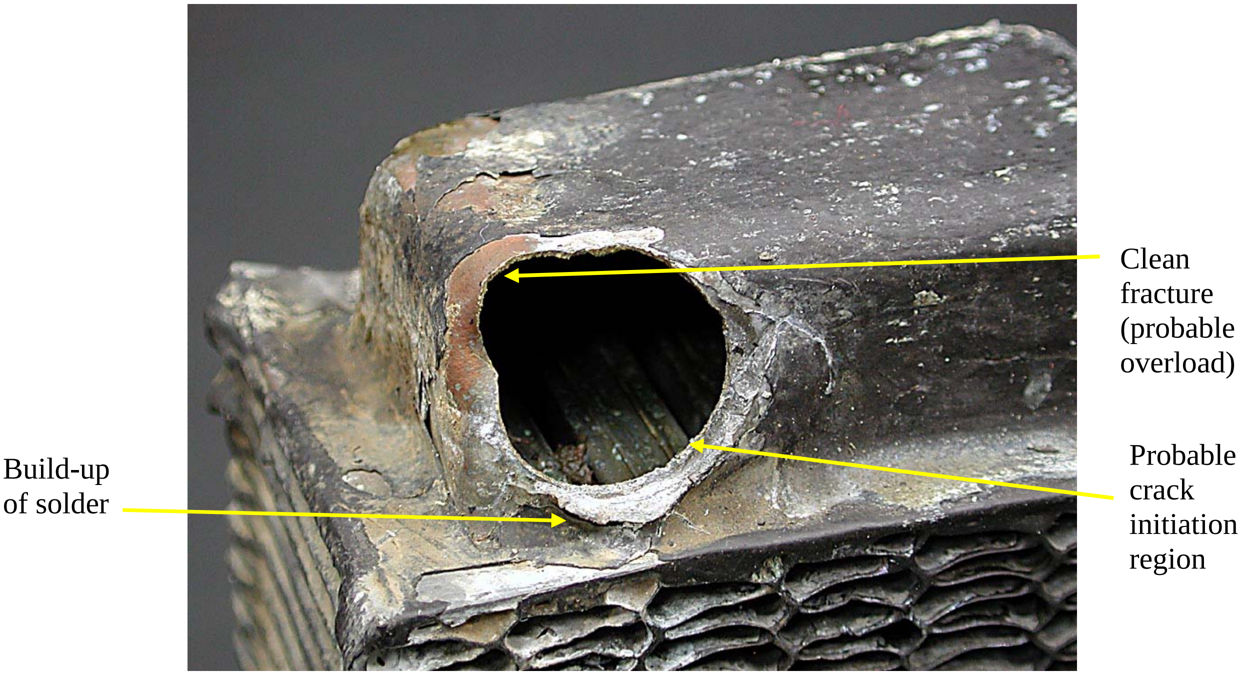


Figure 3 Detailed view of fracture surface on radiator (photo courtesy of QinetiQ)

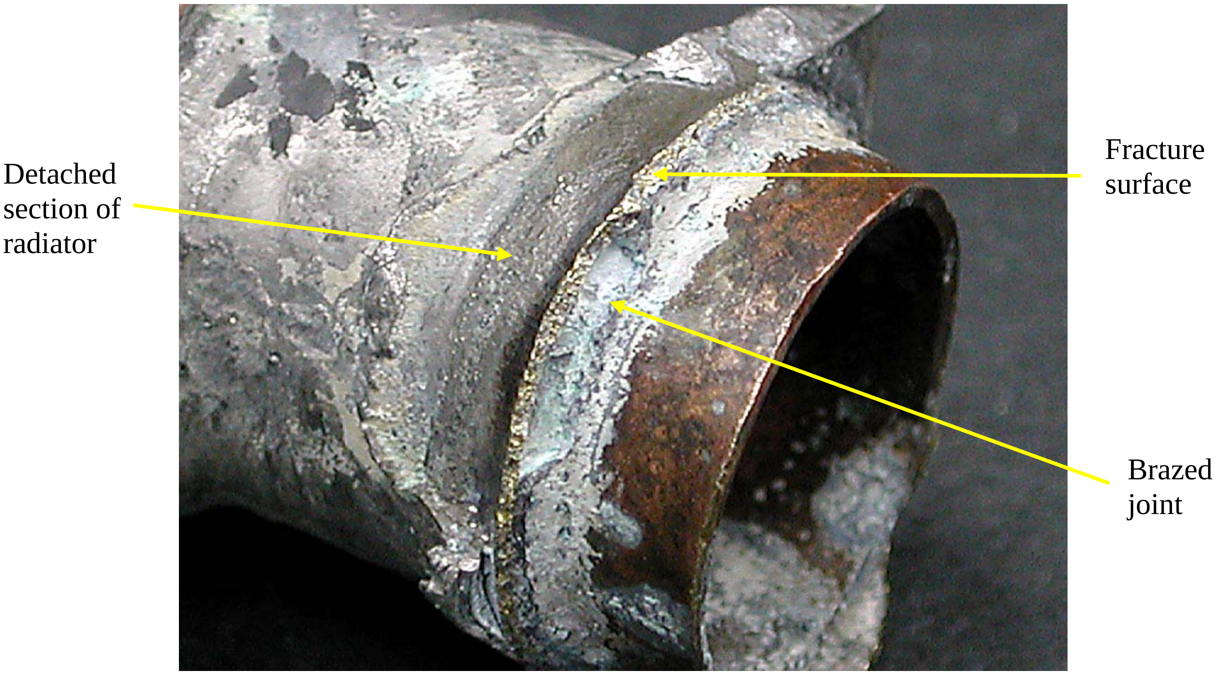


Figure 4 Detailed view of fracture on coupling (photo courtesy of QinetiQ)

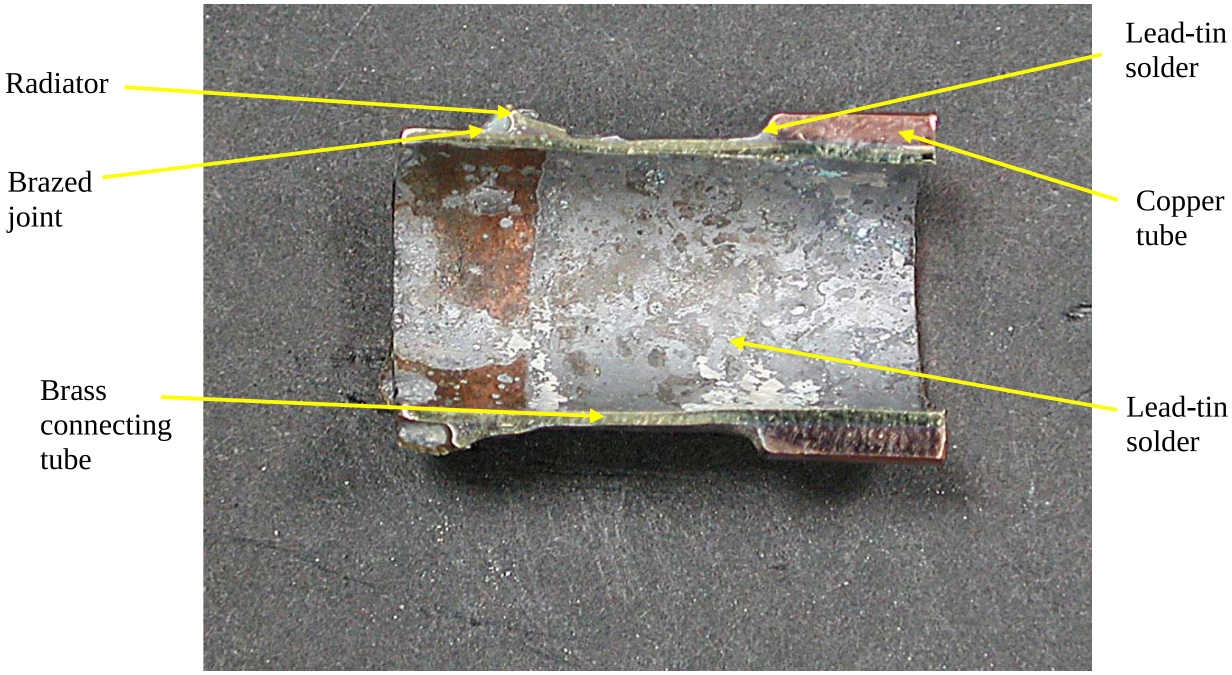


Figure 5 Cross-section through failed coupling (photo courtesy of QinetiQ)

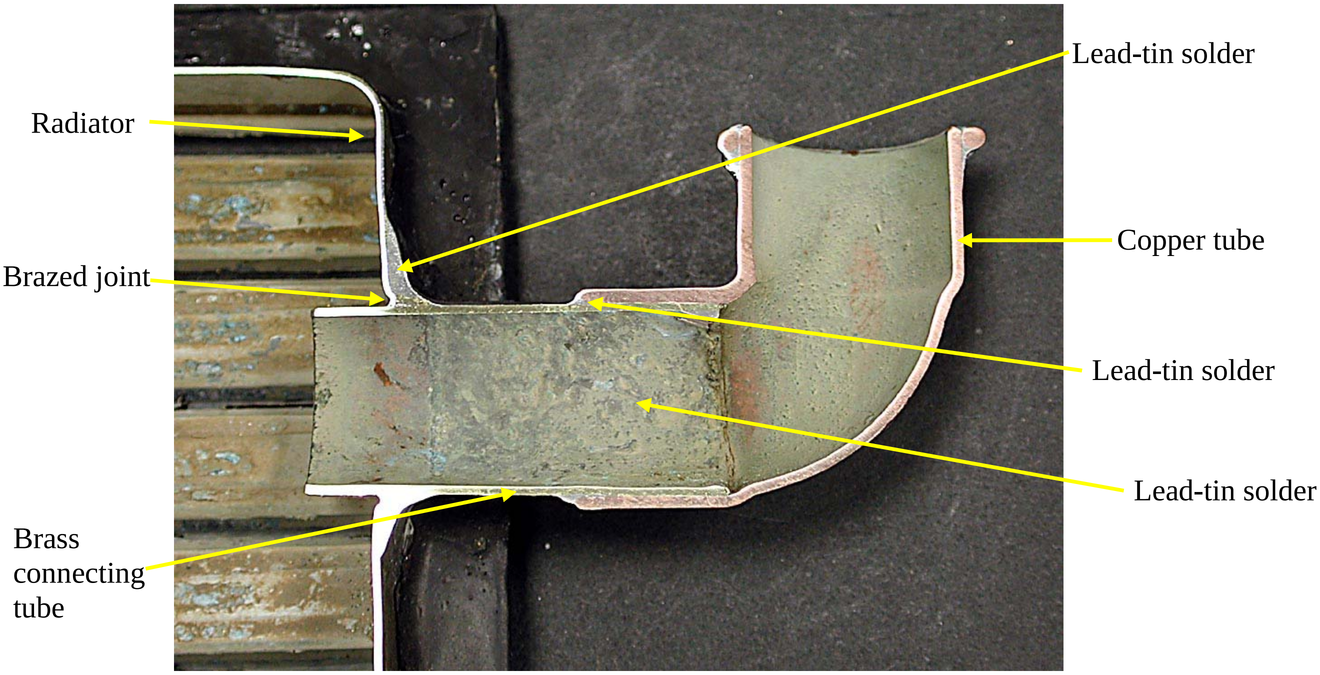


Figure 6 Cross-section through intact coupling on inboard end of port radiator (photo courtesy of QinetiQ)

AAIB Bulletin No: 5/2005 **Ref: EW/G2004/12/10** **Category: 1.3**

Aircraft Type and Registration:	Yak-52, G-YAMS
No & Type of Engines:	1 Ivchenko Vedeneyev M-14P piston engine
Year of Manufacture:	1984
Date & Time (UTC):	27 December 2004 at 1510 hrs
Location:	Hill Crest Farm, Canewdon, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 Passengers - N/A
Nature of Damage:	Damage to wings, fuselage, landing gear and propeller
Commander's Licence:	UK Private Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	316 hours (of which 26 were on type) Last 90 days - 8 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and examination of the aircraft by the AAIB

Synopsis

Whilst in the cruise, the engine began to run roughly. As a result, the pilot was unable to maintain altitude and decided to carry out a forced landing in a field. The selected field, however, was unsuitable due to power lines along the field edge being seen late on the approach, so the pilot elected to land in an area of paddocks. The landing attitude was flat and the left wing struck a fence post, which rotated the aircraft to the left, before it came to a halt against the fence. There was no fire. The pilot sustained serious injuries and was assisted from the aircraft by the land owner. Later examination of the engine revealed that the core of the No 5 cylinder rear spark plug had 'blown out', causing a loss of compression on that cylinder.

History of flight

The aircraft had been flown earlier on the day of the accident, on a return flight from North Weald to Southend, which included some aerobatics, all of which were without incident. On its return, it was fully fuelled and the engine oil topped up.

The pilot had intended to carry out basic aerobatics but he found the oil level was in excess of that recommended for aerobatics, and so he decided to fly locally instead. The engine start up and power checks were carried out without any problems and, as the aircraft had recently been flown, the oil and cylinder head temperatures quickly reached their normal operating values. The takeoff and climb were also problem free and, at 2,500 feet, the aircraft was established in the cruise. Routine checks of the engine instruments did not reveal any abnormal running and the carburettor air heat gauge indicated normally. As the cylinder temperature gauge was reading a little low, the pilot reduced the cooling air around the engine by closing the gills at the front of the cowling.

Whilst flying in the area of Osea Island, the pilot noticed an oily smell, a slight change in the noise from the engine and increased vibration. He checked the engine instruments and they were all showing normal indications. After deciding to head to the south, he noticed a puff of smoke in his peripheral vision, coupled with the engine reducing in RPM and then picking up again. The RPM continued to cyclically change. In an attempt to maintain RPM, the pilot used the primer to inject fuel directly into the engine cylinders, but he was not sure if this improved the situation.

The pilot suspected that the engine had suffered a mechanical failure, but he still carried out the 'normal' emergency checklist items including setting the carburettor air control to hot and checking each magneto in turn. This had no effect on the engine performance. Southend Approach was notified by the pilot, who indicated that the aircraft was suffering from a rough running engine and that he intended on returning to the airfield, although he was not sure whether he would be able to make it. The engine continued to run roughly and was later described by the pilot as if only five of the nine cylinders were firing correctly. The opening of the throttle only seemed to increase the vibration levels and so the pilot left the throttle at its cruise setting. He was unable to maintain height and, on reaching about 700 feet to the South of the River Crouch, the pilot decided to carry out a forced landing. The forward visibility in the Yak-52 is poor so the pilot concentrated on finding suitable fields to the sides of the aircraft. He selected a field to the east and turned towards it, losing speed and sinking in the process. At this point he noticed power lines along the edge of the field and he realised that the aircraft did not have sufficient height to clear them.

The pilot then saw some small paddocks ahead and decided to land in one instead. He closed the throttle and flared, before contacting the ground in a flat attitude.[1] The left wing struck a fence post causing the aircraft to spin round to the left before coming to rest against the fence. The left wing fuel tank was punctured but there was no fire.

The pilot was badly shaken and seriously injured but was able to secure the aircraft systems. He was assisted from the aircraft by the land owner and taken to hospital by the emergency services who attended the scene.

Survivability

Due to the deceleration forces during the landing, with the aircraft stopping in a very short distance, the pilot sustained serious injuries despite wearing a five point harness and a helmet. His head had struck the top of the instrument panel with sufficient force to put a split in the helmet and he sustained serious chest injuries from the harness. However, had he not been wearing the helmet or the harness, it was considered that this accident would most likely have resulted in fatal injuries.

Aircraft examination

The aircraft was retrieved from the field by a specialist Yak-52 maintenance organisation and taken to their facility where the AAIB carried out an examination.

It was initially suspected that the rough running had been due to water collecting in the fuel filters and then subsequently freezing. However, on inspection, the fuel filters were found to be clean and to contain some fuel, but with no signs of water.

The engine was then examined in detail. This revealed the high tension (HT) lead for the No 5 cylinder rear spark plug had been 'blown out' of the elbow fitting to the plug. Subsequent removal and inspection of the plug showed that the ceramic insulating core of the plug had been damaged and the inner electrode was missing. There were also signs of significant local heating of the elbow fitting, Figure 1. The remaining spark plugs fitted to the engine were all in a satisfactory condition. The damaged spark plug was identified with the markings SD-49SMM and was a product of the original plug manufacturer, in Russia, for this engine type. It had been fitted to G-YAMS for approximately 60 flying hours; the spark plugs were last inspected during a routine 50 hr inspection, 11 flying hours prior to the accident.

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[1] When performing a forced landing away from an airfield, it is recommended that the landing gear is left in the retracted position. The landing gear on the Yak-52 retracts to lie below the wing and forward fuselage and, as such, provides a measure of protection to the aircraft. Also, the aircraft is more stable and less prone to flipping over on soft ground.

Previous occurrence

The AAIB investigated a previous similar occurrence to spark plug on a Yak-52, G-BWOD (EW/G2003/10/16, Bulletin 4/2004). This failure also resulted in a rough running engine, vibration and a forced landing in a field. The spark plug had the same markings as that found on G-YAMS and was fitted to the No 4 cylinder.

Discussion

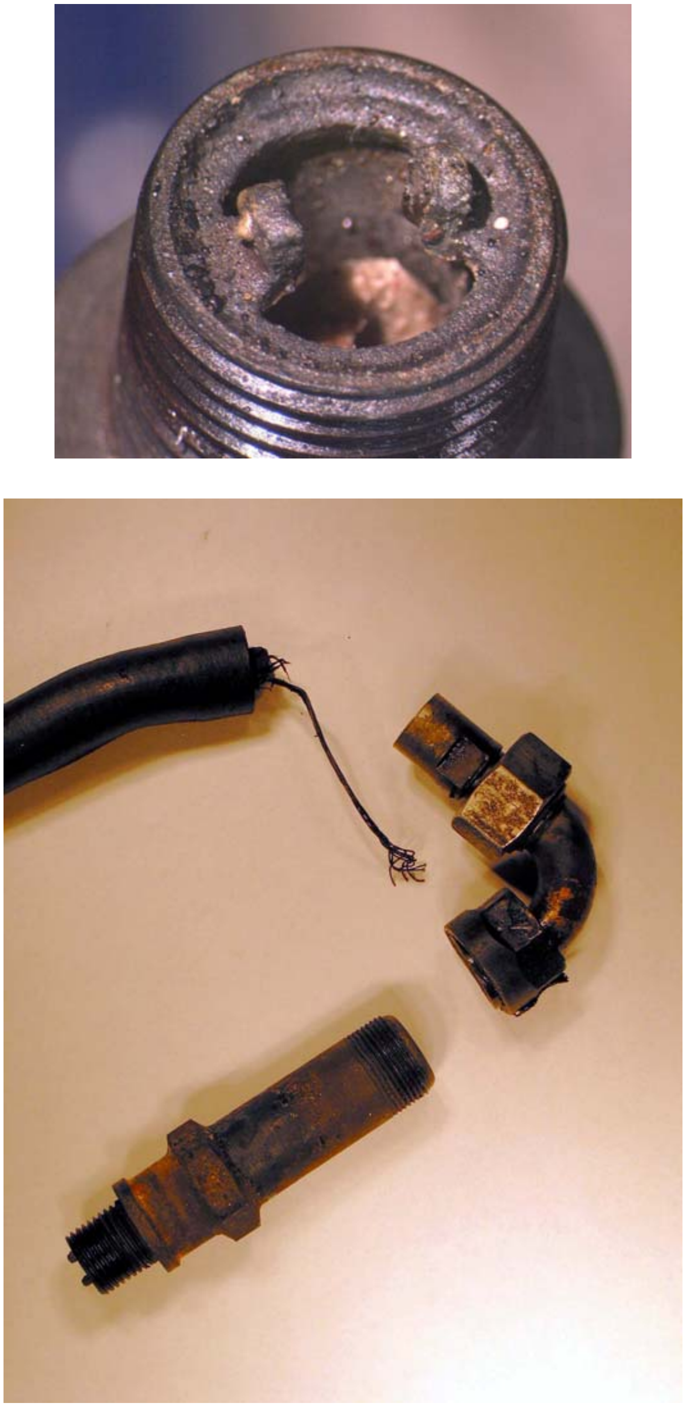
The rough running of this engine could be directly attributed to the failure of the No 5 cylinder rear spark plug. The inner insulating core had 'blown out', resulting in the hot gases from the cylinder escaping through the plug and blowing out the HT lead connection. The hot gases had then caused localised heating of the spark plug elbow fitting. As a result of the failure, the compression on cylinder No 5 was compromised, resulting in the engine running roughly, but with the remaining eight cylinders operating normally.

The spark plugs fitted to the M14P engine are usually those from the original equipment manufacturer in Russia. There is anecdotal evidence to suggest that these plugs are not as robust as those manufactured in Europe or the USA. It was stated by the aircraft maintenance organisation that 'blown' spark plug cores affect about two of their maintained aircraft per year and are normally limited to the lower three cylinders (Nos 4, 5 and 6). The cause, although not proven, is thought to be a mini hydraulic lock where oil, which may collect in the lower cylinders, is compressed during engine start, causing high localised stresses on the spark plug cores. Prevention of hydraulic lock is normally achieved by draining any oil from each of these cylinders, usually by removing a spark plug, and to turn the engine over by hand several times prior to starting.

Some Yak owners have converted their engines to take spark plugs manufactured in the USA, but these are approximately double the cost of the original Russian plugs and require an adapter to be fitted to the engine cylinder. The life of the USA manufactured plugs is no different to those of the Russian manufacture at 200 hours, but they have not been known to suffer from blow out of their cores.

As mentioned in the report on G-BWOD, tests conducted in the USA revealed that it may be theoretically possible for an engine with a spark plug removed to continue to produce enough power to enable continued flight, hence giving an improved chance of a safe landing at an airfield. However, the emergency procedure for a rough running engine is to land as soon as possible, which is especially relevant in this case, given the risk of an engine fire due to the hot gases escaping through the damaged spark plug.

Figure 1



Details of the failed rear spark plug from cylinder No 5

Aircraft Type and Registration:	X'Air V2(2), G-CBTY	
No & Type of Engines:	1 Simonini Victor II piston engine	
Year of Manufacture:	2002	
Date & Time (UTC):	27 June 2004 at 1620 hrs	
Location:	Newtownards, Northern Ireland	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to fibre glass pod, propeller blades and nose landing gear	
Commander's Licence:	Private Pilot's License with Instructor Rating	
Commander's Age:	55 years	
Commander's Flying Experience:	1,550 hours (of which 30 were on type) Last 90 days - 140 hours Last 28 days - 50 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and examination of the aircraft engine by the AAIB	

An instructor and student, who was also the aircraft owner, were flying a circuit detail. During the downwind checks the instructor noted that the engine was performing normally and that the Exhaust Gas Temperature (EGT) was within limits. After the first touch-and-go the aircraft climbed normally, but at 300 feet the engine stopped abruptly. A forced landing was carried out into a field of three feet high standing crops. As the main wheels entered the crop, the aircraft pitched forward onto its nose, which then dug into the soft ground, causing the aircraft to pitch inverted. There was no fire and both occupants were able to exit the aircraft without difficulty

After the accident the instructor rotated the engine by hand and noted that there appeared to be no compression. Neither occupant recalled any unusual EGT or coolant temperature indications prior to the engine failure. The engine was examined more closely the next day and two small burn holes were found in the head of the rear cylinder. The engine had been inverted following the accident and there was no coolant remaining.

Engine description

The Simonini Victor 2 engine is a 2-stroke, twin cylinder, twin ignition, water-cooled engine with two 'Bing' double float carburettors. The engine is designed to run on leaded or unleaded petrol or avgas mixed with 2-stroke oil. The manufacturer recommends that a 3% mixture with a fully synthetic 2-stroke oil is used with unleaded fuel, or 2.5% mixture is used with leaded fuel or avgas. The liquid cooling system includes an integral belt-driven pump with coolant being pumped under pressure around the cylinder water jackets. Two heat dissipators route the coolant to and from the radiator. The top dissipator is fitted with a coolant temperature sender and a thermostat. The thermostat is designed to open at 65°C. The coolant should be a mixture of 70% water and 30% anti-freeze, suitable for aluminium. The maximum coolant temperature should not exceed 80ºC. The coolant system also has a radiator filler/expansion bottle with an overflow tube.

The Operator's Handbook contains the following advice on storage procedures if the engine is not going to be used for a period of two months or more:

> *'Start the engine and remove the air filters from the carburettors. Spray 2-stroke oil … directly into the carburettor throat until the engine stalls. This will ensure that all parts in the crankcase and the top and bottom conrod bearings are well lubricated. Reinstall the air filters and after the engine has cooled down cover with suitable covers. You may also cover the exhaust opening with suitable cover to stop foreign material from entering.'*

Aircraft history

The aircraft had first flown in 2003 when it flew a total on 5 hours 15 minutes during August and September. The aircraft did not fly again until May 2004 when it completed a one hour flight. No inhibition of the engine, as described in the Operator's Handbook, was carried out. A further brief flight was made on the day before the accident. The aircraft had completed a total of 6 hours 35 minutes and the engine 6 hours 45 minutes at the time of the engine failure.

The fuel used on G-CBTY is 2-stroke motor gasoline. The aircraft owner recalled that prior to the accident flight he had added a cup of water to the coolant system and replaced the filler cap. This was the first occasion he had had to add liquid to the coolant system.

Engineering investigation

The engine without the cooling system and the propeller was returned to the AAIB in August 2004 for further examination. Two burn holes were observed in the side wall of the rear cylinder head (see Figure 1). The engine could not be rotated by hand. The plating on the top end of the inner walls of both cylinders was cracked and partially detached in places. The burn holes passed through both walls of the liquid cooling jacket and the seal between the head and the block. The seal, an elastomeric O-ring, had suffered thermal degeneration. The front cylinder seal had suffered similar degeneration although no gas leaks from the cylinder had apparently occurred.

The ignition timing was checked in accordance with the manufacturer's drawing and found to be correctly adjusted. The coolant system pump was free to turn. The carburettor float chambers contained liquid and some white deposits, which were found to consist primarily of corrosion products of zinc, with lesser amounts of copper and aluminium. The liquid samples were analysed and shown to consist mainly of water. One sample that contained a larger percentage of fuel was found to contain approximately 3% of the 2-stroke additive.

Further disassembly revealed that the front engine roller bearing could not be rotated by hand and the rear roller bearing was rough in operation. The front bearing is fitted into the crank case end plate; internal staining on the end plate indicated that a liquid had been present in the crankcase for a prolonged period. The bearings were removed from the end plate and metallurgical examination revealed that they had been contaminated with an oxygen carrying liquid for prolonged periods which had resulted in general and crevice corrosion at and around the position of the balls within the roller bearing whilst the engine was stationary.

It was considered that the engine failure was caused by the loss of coolant allowing hot gases to burn through the cylinder casing. The evidence of corrosion in the bearings indicated that liquid had been present in the crankcase for some time. The accumulation of liquid in the crankcase probably resulted from a leak past one or both of the cylinder head elastomeric seals.

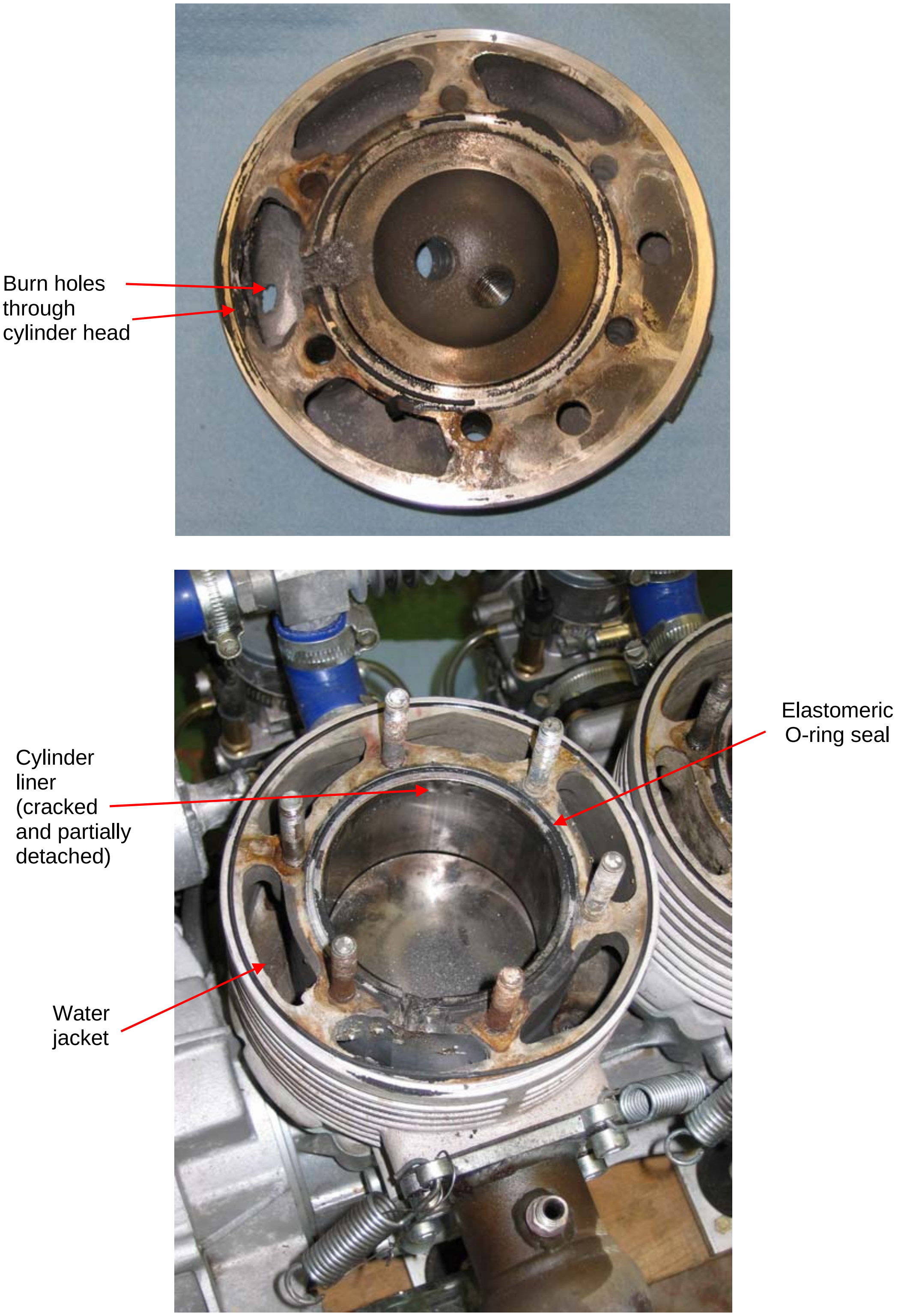


Figure 1 Rear cylinder with cylinder head removed (shown above)

Aircraft Type and Registration:	Sikorsky S-61N, G-BDOC	
No & Type of Engines:	2 General Electric CT58-140-2 turboshaft engines	
Year of Manufacture:	1976	
Date & Time (UTC):	15 September 2004 at 0800 hrs	
Location:	Near Sullom Voe, Shetland	
Type of Flight:	Commercial Air Transport	
Persons on Board:	Crew - 4	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Four main rotor blades damaged	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	37 years	
Commander's Flying Experience:	6,905 hours (of which 4,100 were on type) Last 90 days - 49 hours Last 28 days - 10 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a winching operation, the rotors of G-BDOC struck the top of a mast on the deck of the receiving ship. The helicopter recovered safely to Scatsta Aerodrome. The investigation revealed some misunderstandings between the helicopter operator and the maritime operator about the winching deck markings on the ship. Accordingly, recommendations have been made to the CAA and to The International Chamber of Shipping (ICS) to ensure that aircraft and ship crews are aware of the information required before undertaking winching operations. Shortly after the accident, the helicopter operator instituted revised rules to clarify the information required before any winching operation.

History of flight

The crew, consisting of the commander, first officer, winch operator and winchman, had been on SAR duties at Sumburgh Airport since 1200 hrs on 14 September. That evening, a Commercial Air Transport (CAT) tasking was received to transfer marine pilots to and from ships near Sullom Voe on the morning of 15 September.

The next morning, the crew were informed of the timing of the task and lifted-off from Sumburgh Airport at 0715 hrs to fly to Scatsta Aerodrome to collect the first marine pilot. By 0800 hrs, the marine pilot had been uplifted and G-BDOC set course for the designated ship, which was located some 15 nm north of Scatsta. On departure from Scatsta, the weather was as follows: Surface wind 340°/18 kt; visibility greater than 10 km; light rain; cloud FEW at 1,400 feet amsl and SCT at 2,400 feet amsl; temperature +05°C; QNH 1017 mb. The commander subsequently confirmed that the helicopter had been fully serviceable during the flight to the ship.

From the transit altitude of 300 feet amsl, the crew visually acquired the ship and, having established communication on FM radio, identified the winching area; this was indicated by a solid yellow circle surrounded by a broken yellow circle (Figure 1). Having completed the standard pre-winching checks and an engine power check, the helicopter was positioned on the port side of the ship. The ship was heading north at approximately 8 kt and the commander, who was the handling pilot in the right cockpit seat, assessed the surface wind as northerly 25 kt gusting to 30 kt. There was no significant cloud in the area and no turbulence. The first officer in the left cockpit seat was operating VHF communications with Scatsta and the winch operator, positioned in the opening of the cargo door on the right side, was operating FM communications with the ship.

In position, the crew reviewed the designated winching area and considered that there would be a possible obstruction (mast) to the rear of the helicopter when in the winching position. Accordingly, the crew agreed that they would move their intended winching position forward some 40 feet to an area marked by a green walkway. This new area was assessed to be clear although the crew was aware of a yellow-topped mast riser located on the deck and to the right of G-BDOC. In the new winching position, this mast would be in the commander's four o'clock position; from the open cargo door, the winch operator would be monitoring the relative position of the mast.

The commander then manoeuvred the helicopter over the new winching position and established a hover at approximately 40 feet above the deck. After a further power check, and with good visual references, the crew agreed that the position was suitable for winching operations. The commander then descended to approximately 20 feet above the deck. He noted that there was a slight 'heave' and 'roll' on the ship but assessed the conditions as suitable. As the commander held G-BDOC in position the winchman was lowered to the deck where he released himself in preparation for receiving the marine pilot. With the winch operator 'looking in' to prepare the marine pilot for winching, the commander considered that he was maintaining his position over the deck. The first officer was monitoring the situation and also considered that the commander was holding a steady hover, albeit that the ship was rolling slowly. Shortly after, the commander became aware that the helicopter had drifted slightly forward and to the right. As he began to correct for this, the winch operator also called for a movement back and to the left. Then, with the desired position reestablished, the winch operator started to lower the marine pilot. Shortly after, the commander heard a short repetitive noise and he immediately moved the helicopter slightly higher and to the left. His impression was that the event was similar to a 'birdstrike' that he had previously experienced. The first officer was also aware of a vibration through the airframe and heard the winchman on the deck calling on FM that there had been a possible "*Blade strike*". The winch operator was aware of the crew comments but had seen or heard nothing else to confirm any such event. From the new position, some 6 feet to the left and some 10 to 20 feet higher, the commander reviewed the situation. The controls appeared normal and, with no vibration and no other abnormal indications, the commander followed the winch operator's guidance back to the original winch position but maintained the new height (some 30 to 40 feet above the deck). The marine pilot was then lowered to the deck and the winchman was winched back on board G-BDOC.

The winchman had not been confident that his original message had been heard and immediately informed the crew that there had been a blade strike. On the deck when he was facing to the rear of the ship, he had heard a loud noise to his left when the marine pilot had been some 6 feet above him. At the time, he looked to his left and saw that the rotors were very close to the mast riser.

With all the crew back on G-BDOC, the commander manoeuvred the helicopter to the left, clear of the ship and carried out an uneventful control check. He then slowly increased height and speed before making a gentle turn directly for the land nearest Scatsta Aerodrome. A 'PAN' call was transmitted to Scatsta. During the transit, there was no apparent vibration in the cockpit or cabin and a visual observation of the blade tip movement indicated no abnormality. Additionally, there was no indication of any defect from the Health and Usage Monitoring System (HUMS) or from the Blade Integrity Monitoring (BIM) system. Once over land, the commander headed directly for Scatsta and landed into wind on the intersection of the runway and taxiway.

Engineering information

Following the landing at Scatsta, the helicopter was examined for damage. Four of the five main rotor blades had extensive damage on the lower surface of the blade, starting at about 25 cm from the blade tip. Examination of the top of the yellow mast riser on the tanker showed corresponding damage to the vent, including the loss of a substantial lifting lug welded to the upper edge.

All five blades were removed from the helicopter, which was subjected to a thorough inspection. There was no evidence found of other damage and the aircraft was returned to service with replacement main rotor blades

Figure 2 shows the damage to the lower surface of the Red blade. This blade showed evidence of two strikes, with the inboard marking at about 25 cm from the tip and the outboard mark at about

10 cm from the tip. The damage was similar to the Blue blade, with both blades having suffered extensive gouging of the main rotor spar and disruption of the bonded blade skin. The Black and Yellow blades had similar inboard damage but no outboard strike and there had been no visible contact with the White blade. None of the blade spars had been fully penetrated so the BIM system, which operates on pressure release, would not have been activated.

A review of the maintenance records for G-BDOC by the AAIB showed no indication of the condition of the aircraft being a factor in this accident.

Deck dimensions and clearances

Figure 1 shows a photograph of the tanker berthed at Sullom Voe following the accident, with the shadow of another S-61N at the winching circle. The following ship dimensions are derived from a general arrangement drawing from the tanker management company and the manufacturer's dimensions for the S-61N.

The drawing shows the diameter of the manoeuvring zone as 27 metres (radius 13.5 metres) and the winching circle as five metres. The distance from the edge of the manoeuvring zone to the obstruction to the rear was 11 metres, compared with 5.5 metres to the yellow-topped mast riser obstruction. Thus the nearer obstruction from the winching circle was the mast riser, which had a height over the tanker deck of 10 metres. The radius of the S-61N main rotor is 9.45 metres and so, with the main rotor over the centre of the winching circle, the average clearance of the main rotor disc from the mast riser would have been approximately 9.6 metres. In the same position, the average clearance of the tail rotor disc from the obstruction to the rear would have been approximately 11.8 metres.

The precise position of the helicopter's new winching position relative to the green walkway is not known. However, positioned with the centre of the main rotor directly forward of the winching circle and over the centre of the walkway, the average clearance of the main rotor disc from the mast riser would have been approximately 2.1 metres.

The roll of the ship was not significant to the crew and has been estimated as 3°. With the top of the mast riser approximately 18 metres above the ship's centre of gravity, the total arc of the top of the mast riser would be approximately two metres, bringing it very close to the main rotor disc.

Recorded information

The helicopter carried a combined CVFDR recorder. This provided 60 minutes of CVR, 5 hours of FDR and health monitoring recordings. The quality of the recordings was good.

The CVR confirmed the recollection of the crew as detailed in the History of Flight section. The only additional information yielded by the CVR relates to the analysis of the noise during the blade strike. This would indicate that the blades struck with unequal audible effect and at least one blade struck a second time.

Figure 3 shows relevant FDR parameters together with related crew activities. Given a lack of data pertaining to the ship's movements, the FDR data could not be used to reconstruct the motion of the helicopter relative to the ship except that the radio altitude shows when the helicopter was over the deck of the ship. The radio altitude also indicated that the peak-to-peak wave effect at the time was about five feet. The radio altitude above the deck started at 55 feet and settled to approximately 20 feet after about a minute, holding steady at 20 feet plus/minus wave action for a further minute and a quarter before the blade strike. After the blade strike, the helicopter altitude increased to approximately 45 feet above the deck. Over the next 40 seconds, the helicopter remained over the deck with a slow reduction of mean radio altitude of about five feet. Some 45 seconds after the blade strike, the helicopter was over water.

The health monitoring data only sampled the blade tracking once after the event. This showed a marked change in blade tracking but the track split was within acceptable limits.

Crew information

Interviews with the crew confirmed the following information:

1. During winching, the winch operator was monitoring the yellow-topped mast and considered that it was clear of the rotor disc but he was aware that the top of it was above the disc.

2. The winchman remained in the same position during his time on the deck.

3. The marine pilot could not identify his exact position over the deck whilst being winched down, but he considered that the winchman was directly below him.

Aviation regulations

Civil Air Publication (CAP) 437 (issued Sep 2002) contains guidance for helicopters landing or winching on offshore areas. This includes information on winching areas and states that a winching area should provide a 'manoeuvring zone' with a minimum diameter of 2D (D being the overall length, with rotors turning, of the largest helicopter able to use the area) and marked by a yellow 0.2 metre wide broken line. Within the 'manoeuvring zone' a yellow painted clear area (five metres in diameter) should be centred. Near the clear area, the words WINCH ONLY should be marked in white so as to be clearly visible to the helicopter pilot. Within the inner 1.5D diameter of the 'manoeuvring zone', outside the clear area, there should be no objects higher than 3 metres. In the outer 0.5D diameter, there should be no objects higher than 6 metres. (Note: 'For the S-61N helicopter, D is defined within CAP 437 as 22.2 metres.')

For Commercial Air Transport (CAT) operations, the helicopter company had received written dispensation from the CAA *'from the provisions of Rule 5(1) (e) of the Rules of the Air Regulations 1996, so as to permit the said helicopter to fly within 500 feet of any person, vessel, vehicle or structure' when it is being used for the purpose of picking up, raising or lowering persons or articles to or from a site which:*

1) *Is at least 10 feet square*
2) *Provides a level, non-slip surface free from spray, and*
3) *Provides at least 20 feet horizontal rotor clearance at all hover heights.'*

The company Operations Manual detailed the procedures for CAT winch operations. Relevant extracts were as follows:

1. *'The commander must ensure that the manoeuvring area satisfies the requirements laid down in the exemption held on the operation.*
2. *During a transfer, the winch operator is responsible for providing guidance to enable the pilot to position the helicopter accurately and clear of obstructions.*
3. *The winch operator must endeavour to maintain the passenger at a height no greater than 40 feet above the sea or 10 feet above the deck'*

Maritime regulations

The International Chamber of Shipping (ICS) has published a 'Guide to Helicopter/Ship Operations' (latest edition published in 1989), which comprehensively describes physical criteria and procedures on ships. This includes the same information on 'manoeuvring zones' described in CAP 437. The publication also includes comprehensive guidance on communications between 'Master', 'Agent' and

'Helicopter Operator' and between 'Helicopter' and 'Ship'. This includes guidance to 'Masters' that information on the size of the manoeuvring zone should be passed to the 'Agent' at least 24 hours before the anticipated operation. The publication also includes guidance on the information to be passed by the 'Agent' to the 'Helicopter Operator' and this includes the dimensions of the Clear/ Manoeuvring Zone. Additionally, the guidance for the communications between the 'Ship' and 'Helicopter' includes confirmation of the dimensions of the Clear and the Manoeuvring Zones. The Guide also includes information on the D values of commercial helicopters in marine use and this shows the S-61N with a D value of 22.3 metres (slightly different from CAP 437). It also emphasises that: *'It is essential that the type and overall length of a helicopter are known before it is accepted by the ship.'*

The ship involved in the accident, which was non-UK registered, held a copy of the '*Guide to Helicopter/Ship Operations*' as required by the ship's manager. The master of the ship involved provided information on dimensions, obstructions and markings related to the winching area. This included the following:

1. The clear area was marked with a yellow painted five metre diameter circle, which was located 6.5 metres inboard of the port shipside.
2. The 'manoeuvring zone' had a diameter of 27 metres and was marked by a yellow 0.2 metre wide broken line.
3. WINCH ONLY was marked in white alongside the clear area.

Subsequent actions

Five days after the accident the helicopter company circulated the following instruction to their crews:

> *'As a result of a recent air accident during CAT winch operations, the following additional requirements are effective immediately.*
>
> *Before accepting a CAT winching task, the aircraft commander shall obtain the following information from the vessel:*
>
> *1) The location of the intended winching area.*
>
> *2) The diameter (in feet or metres) of any "manoeuvring zone" marking.*
>
> *3) The distance, from the centre of the winching 5 metre "clear zone", of the nearest obstruction higher than 5 metres together with its height above deck level.*

> *This information shall be included in the pre-departure crew briefing and shall be used in deciding the planned minimum winching height. The Operations Manual guidance that the winch operator must endeavour to keep the passenger at a height no greater than 10 ft above the deck (OM Pt A. CAT Winch Operations Supplement, para. 7f) may be disregarded as long as persons being raised or lowered are kept at the lowest height commensurate with safe operations. The Operations Manual will be amended.'*

The management organisation for the ship involved in this accident has taken the following actions after a review of their operations:

1) *Ships Masters have been instructed to ensure a proper exchange of information with the helicopter operator regarding the vessel's marking, and specifically to include the diameter of the winching area.*

2) *Albeit that the current markings are valid they are now studying, and considering changing, the markings in order to facilitate the reception of larger helicopters if feasible.*

Discussion

The accident occurred during a winching operation involving a very experienced crew. The crew assessed the situation prior to winching but their decision to move the winching area resulted in a reduced safety margin. It was not possible to determine whether the strike occurred due to movement of the ship or to the movement of the helicopter. The investigation revealed that the winching instructions for crews were not sufficiently comprehensive. Furthermore, the winch markings on the ship did not comply with the '*Guide to Helicopter/ Ship Operations*' for winching involving an S-61N helicopter. Therefore, this discussion considers both helicopter and ship aspects with a view to reducing the possibility of a similar event in the future.

The helicopter crew were primarily on SAR duties. This could involve winching a casualty from any sea vessel and, in order to save lives, the crew would need to assess the situation and make appropriate decisions once they were positioned close to the vessel. However, any pre-planned winching of an individual to or from a vessel is a Commercial Air Transport operation. When undertaking CAT duties, there is a clear responsibility for the helicopter operator and the commander to have sufficient information prior to flight to ensure that the operation can be safely conducted using the relevant regulations. One of the contributing factors of this accident may have been that the crew moved temporarily from SAR duties, where flexibility is required, to the more structured environment associated with CAT duties. While the commander has overall responsibility for ensuring the safety of any operation, when undertaking CAT duties he is reliant on the provision of full information and effective regulation.

Recommendations

Immediately following the accident the helicopter operating company recognised the limitations of their extant regulations and issued amended instructions to all crews. This emphasised the essential requirement for the commander to obtain all essential information from the appropriate vessel for any CAT winching task. However, other similar companies also have crews operating primarily on SAR duties but being given CAT tasks. Therefore, the AAIB has issued the following safety recommendation:

Safety Recommendation 2005-027

The Civil Aviation Authority should establish clear guidance for companies operating both Search and Rescue (SAR) tasks and Commercial Air Transport (CAT) tasks to ensure that current and future operators have clear regulations for crews involved in both types of task during one period of duty.

The guidance material for ships is comprehensive but its usefulness is obviously dependent on availability, accuracy and compliance. Although the document was available, the deck markings did not comply with the '*Guide to Helicopter/ Ship Operations*' for a helicopter of the size of an S-61N. However, while the guidance is useful, it remains of paramount importance for the crews of the helicopter and ship to have and exchange essential information. Both crews should be aware of the type of helicopter involved and the dimensions of the deck markings. During the investigation, it was noted that for helicopter landing areas on board ships, the D value is required to be displayed at the perimeter of the deck. An indication on a winch 'manoeuvring zone' of the D value or even the actual diameter of the 'zone' would reduce the amount of necessary communication between the ship and helicopter crews. However, any such indication would be dependent on the accuracy of the declared dimensions. At present, there is a confliction between the D values for the S-61N in CAP 437 and in the '*Guide to Helicopter/ Ship Operations*'. Accordingly, it would be appropriate for the relevant maritime organisation to review the guidance provided for ship masters and to encourage the carriage of such guidance on board relevant ships. Therefore, the AAIB has issued the following safety recommendations:

Safety Recommendation 2005-028

The International Chamber of Shipping should review the current '*Guide to Helicopter/ Ship Operations*' to ensure that it is accurate and includes information on all current helicopters.

Safety Recommendation 2005-029

The International Chamber of Shipping should encourage the practice of holding a current copy of the '*Guide to Helicopter/ Ship Operations*' by all ships that may be involved in helicopter operations.

Safety Recommendation 2005-030

The International Chamber of Shipping should review the deck markings on ships involved in winching operations with the aim of including a requirement to clearly display the dimensions of the 'manoeuvring zone', such that it can be clearly seen by the helicopter crew.

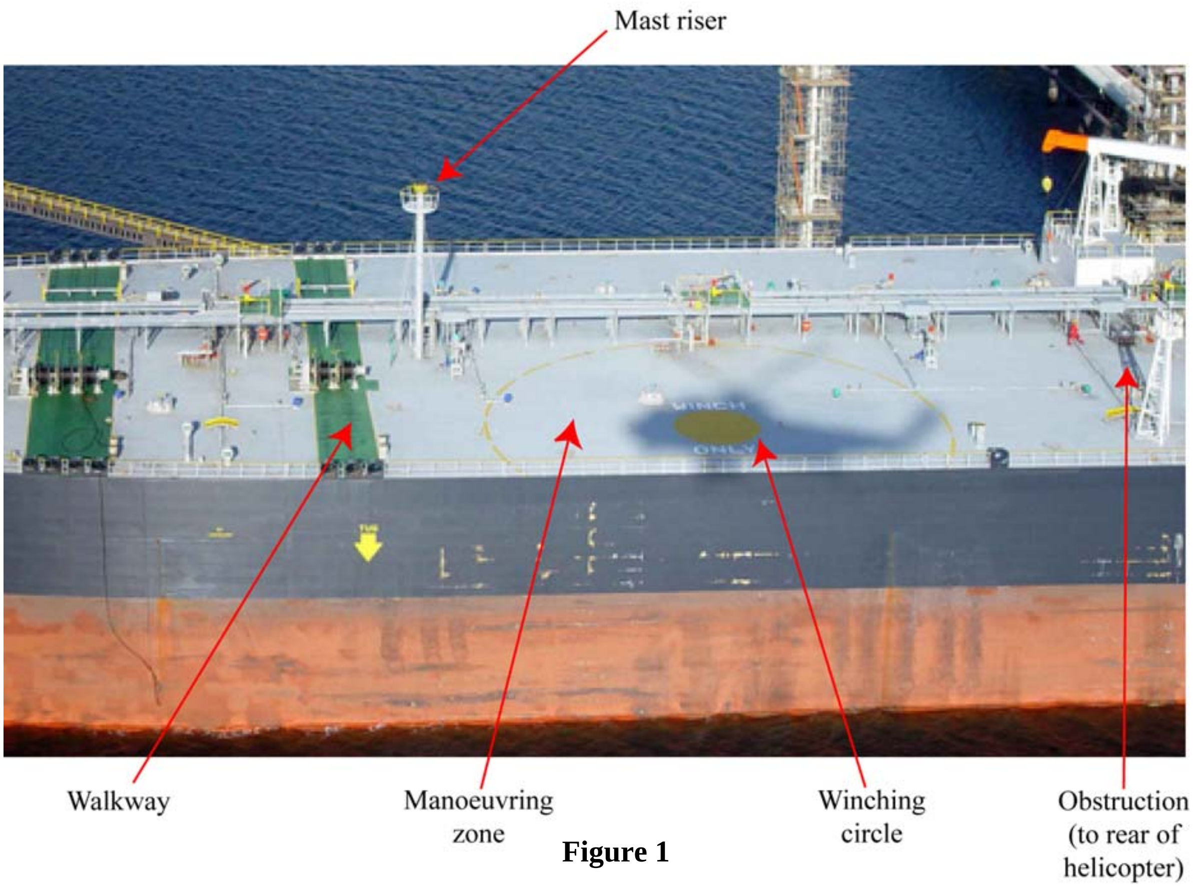


Figure 1

Tanker deck

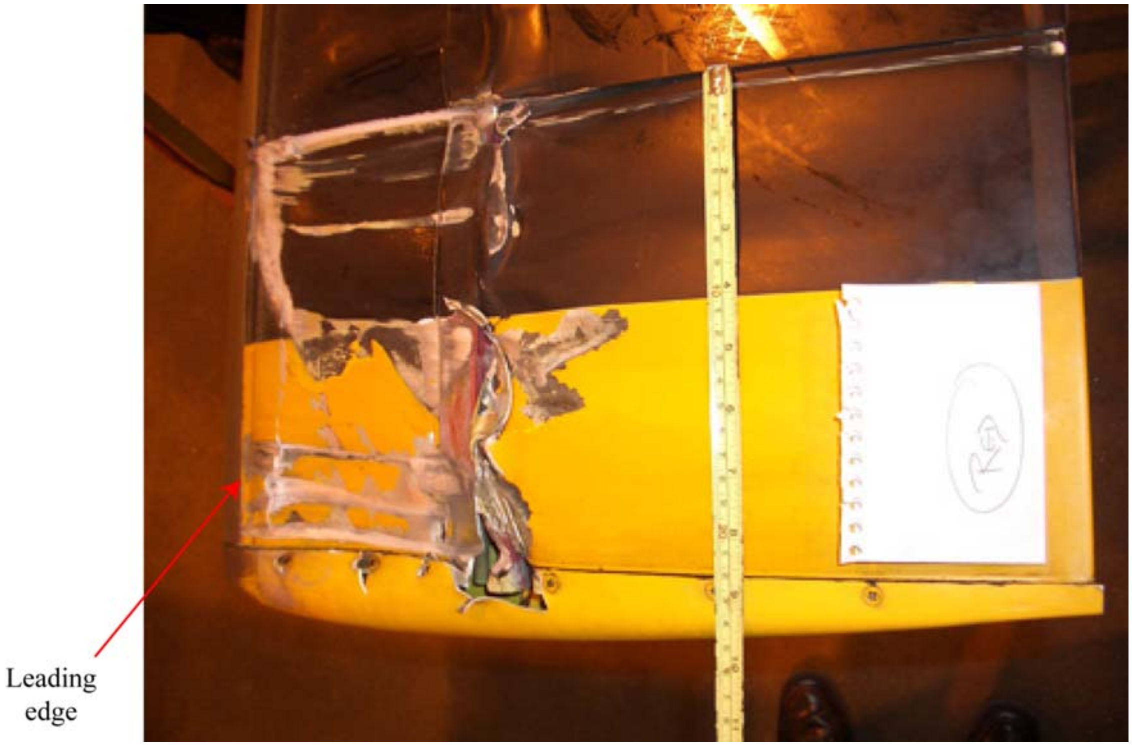


Figure 2

Red blade - lower surface

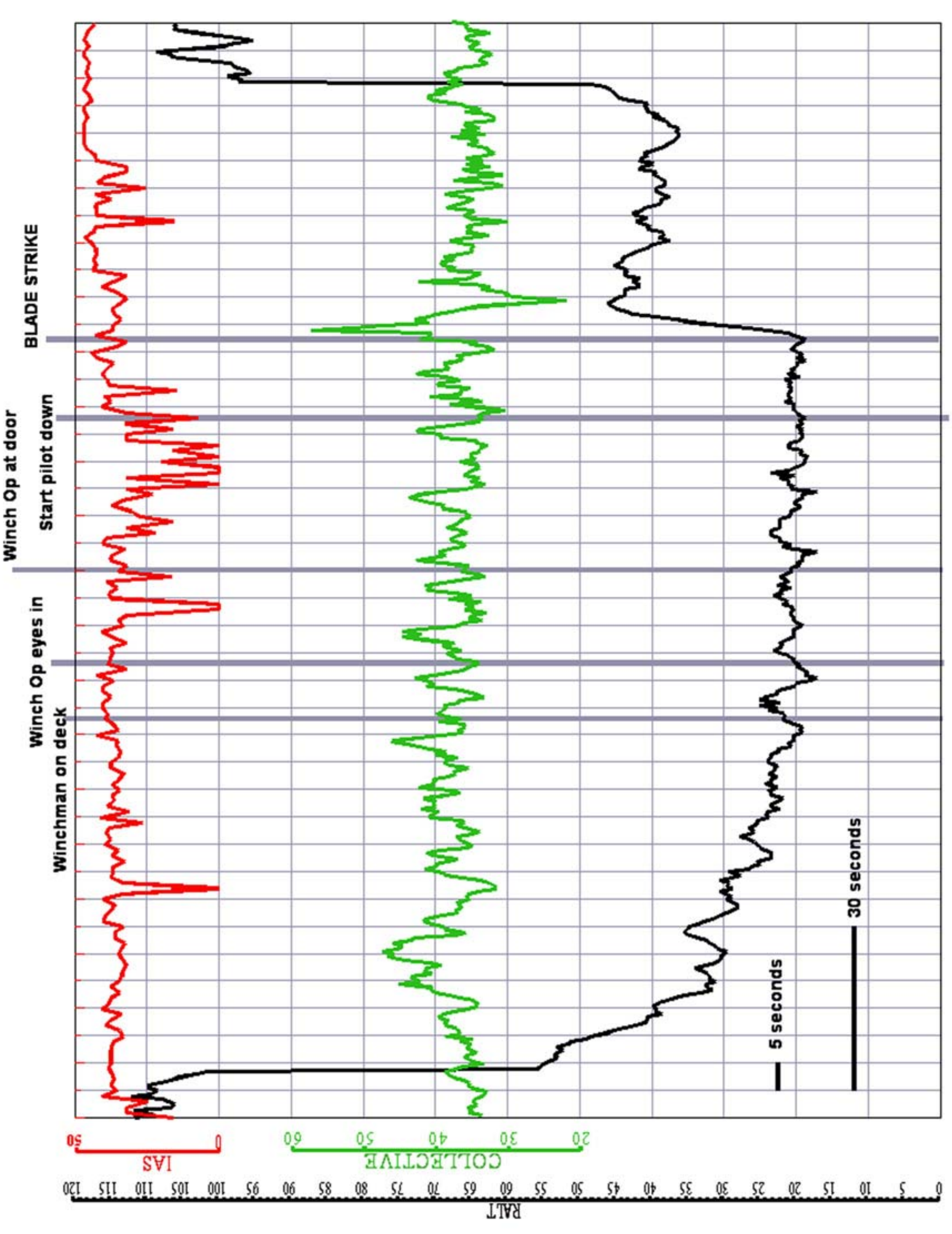


Figure 3

Relevant FDR parameters and related crew activities

Aircraft Type and Registration:	Agusta A109E, G-HIMJ	
No & Type of Engines:	2 Pratt & Whitney Canada PW206C turboshaft engines	
Year of Manufacture:	2003	
Date & Time (UTC):	14 March 2004 at 1600 hrs	
Location:	Colney Park Heliport, Leeds Bradford Airport, Leeds	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	All three landing gear units badly damaged. Wrinkling of the aircraft structure. Tail rotor drive shaft failure. Damage to the tail rotor drive shaft tunnel and engine drive shaft. Failure of four bolts securing lower attachment lug bracket of main rotor gearbox aft left brace assembly	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	54 years	
Commander's Flying Experience:	2,958 hours (of which 614 were on type) Last 90 days - 46 hours Last 28 days - 26 hours	
Information Source:	AAIB Field Investigation	

History of flight

The pilot reported that the aircraft lifted into the hover and made a normal departure into wind towards the west. Shortly after takeoff, at approximately 300 feet, a whining noise became audible. This was followed by a bang. The pilot realised that something serious had happened, but he did not know what this was, since all indications were normal and he still had control of the helicopter. He therefore elected to land immediately. He selected a nearby field and when flaring the helicopter near the ground, and applying the collective lever, the fuselage began to spin about the rotor axis. Upon landing, the helicopter stayed upright, although it was spinning and it rotated two or three times before stopping.

It was evident that the tail rotor and its control system remained intact but its drive system was no longer functional.

Significant aircraft features

The aircraft has a conventional layout with a main rotor gearbox mounted on a horizontal plate above the cabin section. The plate normally carries main rotor system torque reaction loads, whilst lift loads and moments applied by the rotor head are transmitted by four brace assemblies attaching the upper part of the gearbox to the top of the cabin structure. A drive shaft takes power from the front of each engine to respectively the left and right sides of the combiner gearing forming the rear of the main-rotor gearbox. These engine output drive shafts pass through holes in a titanium alloy bulkhead to reach the freewheels and input pinions of the combiner gearbox. The tail rotor drive shaft exits aft from the rear of the combiner gearing, between the input drive shafts.

The two forward main rotor gearbox brace assemblies slope upwards and aft from their forward attachments on the cabin roof and are angled at approximately 30 degrees to the longitudinal axis of the aircraft when viewed in side elevation. The rear brace assemblies have axes nearer the vertical when so viewed. The lower ends of both forward and rear brace assemblies are mounted close the edges of the cabin roof structure and slope inwards to their attachments near the top of the gearbox when viewed in front or rear elevation. (See Figure 1.)

The lower end of each brace assembly terminates in a fork fitting through which passes a bolt, also passing through a ball-joint within the lug of a steel attachment bracket. Each of these brackets incorporates four bolt holes which enable the former to be bolted to the main cabin roof structure through similarly spaced holes in a matching abutment bracket integral with the upper fuselage structure. Each abutment bracket is orientated in such a way that once the steel attachment bolts are installed, their axes lie approximately parallel with the axis of the corresponding brace assembly. In this way, tensile loads in any of the brace assemblies should result in evenly distributed purely tensile loading of each of the four corresponding attachment bracket securing bolts.

G-HIMJ was a sub-variant of the A109E design which, amongst other differences, utilised modified forward main rotor gearbox brace assemblies, incorporating vibration dampers, in place of the plain rigid brace assemblies hitherto employed. Whilst in service, the dampers in G-HIMJ were found to have become defective and the braces were temporarily replaced by components of the rigid design, owing to a supply problem with damper equipped brace assemblies. This was a standard procedure should damper equipped brace assemblies not be available. Subsequently, replacement brace assemblies, incorporating dampers, were fitted and these were in use at the time of the accident.

The tail rotor drive shaft consists of a tubular aluminium alloy forward section with Bendix couplings and a splined connection on the forward end, allowing slight relative longitudinal movement. This section is splined to the rear of the rotor brake unit, itself mounted on the output shaft as it exits the rear of the combiner section of the main rotor gearbox. The shaft then passes through a structural tunnel of sheet titanium alloy, positioned between the two engines. The tunnel has a constant cross-section over most of its length, but increases in cross sectional area at its forward end.

Aircraft history

The aircraft was nearly 12 months old at the time of the accident, having flown 276 hours and recorded 327 landings. The records showed that only routine maintenance had been carried out involving no dismantling or re-assembly of significant structure.

Post accident examination

Examination of the aircraft revealed that the forward section of the tail-rotor drive shaft had failed at a point some 6 inches aft of the rotor brake. Damage to the No 1 engine output drive shaft indicated that it had come into rotational contact with part of the adjacent bulkhead structure. Further examination revealed severe heat damage and cracking of the titanium alloy tail-rotor shaft tunnel at the junction between the tapered front section and the parallel-sided mid section. The lower attachment of the rear left brace assembly securing the main rotor gearbox to the aircraft structure had failed. The failure took the form of fracture of the four bolts connecting the steel attachment bracket to the aircraft structure.

The aircraft systems were partly dismantled to enable both ends of the failed forward tail-rotor drive shaft to be removed and to assist access to the lower attachments of both the rear brace assemblies of the main rotor gearbox.

Detailed examination

The tail rotor drive shaft had evidence of overheating at the point of failure and rotational scoring marks in the same area. Most of the fracture faces appeared to have deformed in a soft state, apparently as a result of coming into repeated mutual contact after failure. The short forward section of the shaft incorporated only one small fracture face which appeared not to have suffered further smearing and damage after failure. This face had the characteristic fibrous appearance of fractures which have occurred on light alloy structural and mechanical components which have failed under load when the components are known to have been subjected to fire or severe overheat at the time of failure. In addition, the internal painted surface showed evidence of heat discolouration. There was also some evidence consistent with torsional deformation of the shaft occurring whilst hot.

The lower attachment bolts of the rear left brace assembly were examined. The nuts and the fractured end faces of the separated threaded portions of the bolts remaining within the nuts revealed evidence of fatigue in all four fracture faces. Similar fatigue failure evidence was present on the corresponding fracture faces of the bolt shanks. The latter remained within the brackets after failure so their pre-impact locations could be determined. Two adjacent pairs of bolts had fatigue evidence across at least 95% of each of their cross-sections whilst the remaining two each had fatigue evidence across some 65%.

The corresponding four bolts in the attachment of the rear right brace assembly were examined. A torque wrench was used to assess the value required to begin further tightening of the bolts in question. One bolt was tightened until approximately the correct minimum torque value of 100 lbf inches was reached and required ¾ of a turn to achieve that torque figure. This bolt also required an initial 51 lbf inches torque to initiate rotation whereas the other three bolts rotated when peak torque values of less than 40 lbf inches were applied.

Non destructive examination of the bolts from the lower attachment of the rear right brace assembly was carried out. No evidence of cracking was found. Metrology carried out on both the failed and intact bolts confirmed that all were within the manufacturer's dimensional tolerances.

Further metalurgical analysis

An exercise in fatigue striation counting was carried out on the fracture faces of the bolts. This identified evidence of a number of fatigue cycles considerably fewer than the total number of flight cycles recorded on the aircraft since new.

Airworthiness follow-up action

The manufacturer stated that they had previously been informed that one attachment bolt had failed on the corresponding bracket of another 109E aircraft some time before the accident. The cause of the failure was not fully investigated by the operator and it was assumed at the time that this was a one-off event. After the accident to G-HIMJ, however, the manufacturer issued a Bolletino to all operators of relevant types which required an initial inspection, within five operating hours, to confirm that no bolts securing the brace assembly attachment brackets had failed. The Bolletino then required sufficient dismantling, within 25 hours operation, to enable the torque settings of all such bolts to be checked.

As a result of this Bolletino 12 loose bolts were identified affecting five aircraft: these bolts were related to one forward and five rear attachment brackets. When these returns were analysed, however, no particular pattern of build sequences or service use could be identified.

Design history of bracket

The 109 Series aircraft was originally developed with the lower attachment brackets for the gearbox brace assembly manufactured from aluminium alloy. It is understood from conversations with manufacturer's personnel that failure of one of these brackets occurred some years ago, in flight, whilst they were operating such a machine. The aircraft was reportedly able to remain airborne and under control for a period after the failure. It appears that the tail rotor drive was not affected on this occasion. Examination of the failed component reportedly indicated that it had suffered a fatigue fracture. As a result of this finding, it was realised that the fatigue spectrum of the bracket was insufficiently understood. The component was therefore replaced both on in-service examples of the type and on newly built aircraft by a geometrically similar component manufactured from a steel alloy. Being a material of considerably greater ultimate tensile strength (UTS) it is very much less susceptible to fatigue cracking under the same loading conditions compared with a geometrically similar aluminium alloy component.

It is understood that the rear left hand bracket normally carries the highest peak load of the four brace assembly lower brackets securing the main rotor gearbox.

Fatigue behaviour of bolted joints

The attachments between the brace assemblies and the airframe utilise bolted joints uniting the steel lug brackets and the main structure. This is atypical of traditional aeronautical practice in that the bolts are loaded in tension rather than shear. The presence of a ball joint within the attachment lug at the lower end of each brace assembly, combined with the orientation of the joint face, ensures that only axial loading is applied to the bolt group.

To achieve a satisfactory fatigue life in any such bolts requires them to be tightened to a level which creates within them a tensile stress exceeding that to which they would be subjected as a result of carrying only their working load applied via the brace assembly. Under such conditions, the elasticity of the two mating faces loaded in compression ensures that the tensile load in the bolts remains unchanged through a large range of varying tensile loads in the brace. The information for assembly of such a joint would thus be expected to require a specified bolt torque value which ensured significantly higher static bolt tension when assembled than the figure due solely to any repeated flight loads. Without such tension, the joint would have a severely limited fatigue life. This would not only result from the unsatisfactory joint characteristics but may also have been exacerbated by a modified load spectrum as a consequence of a changed dynamic response resulting from the altered stiffness of the rotor system locating structure.

Analysis

The loss of tail-rotor drive was clearly the result of the rotating drive shaft coming into contact with the titanium tunnel through which it passed. This created frictional heating evident in the form of cracking and discolouration of the titanium tunnel as well as the hot failure evidence visible on the shaft. This contact resulted from the failure of the rear left brace assembly attachment which allowed greater than normal displacement of the upper end of the gearbox under load. This permitted sufficient misalignment of both the tail-rotor drive shaft and the engine output shafts to bring the former and one of the latter into contact with fixed titanium alloy structure.

Some of the load normally carried by the failed brace assembly attachment is assumed to have been transferred to the remaining three brace assemblies and some to have transferred into a bending moment applied to the torque plate attaching the underside of the main rotor gearbox to the cabin roof structure. Use of the less rigid forward brace assemblies, incorporating dampers, permitted greater displacement of the gearbox and hence greater misalignment of the engine input and tail-rotor drive shafts connected to the gearbox on G-HIMJ than would be the case had the rigid brace assemblies been in use. In this way, the immediate consequence (loss of tail rotor drive) on the incident to G-HIMJ apparently differed from the more benign effects of the bracket failure experienced on an earlier 109 Series aircraft being operated by the manufacturer.

Examination of the bolt fractures made it clear that one pair of bolts on the failed attachment fractured almost entirely in fatigue, whilst the remaining pair initially continued to carry load. Thereafter, the remaining pair of bolts apparently alone supported the load previously shared with the failed bolts and a load, moreover, further accentuated in magnitude and accompanied by a major bending element, owing to the offset of the bolt reaction from the load axis of the brace. These remaining bolts appear to have finally failed in overload after fatigue cracks had propagated approximately half way across the section, a failure sequence consistent with most of the fatigue damage and all the overload failure occurring in this bolt pair after fracture of the first pair of bolts.

The unusually short in-service life of this failed joint contrasts with the reported generally trouble-free nature of these joints on other 109E aircraft. There was no obvious cause for this early failure. The presence of lower than normal torque settings on the bolts of the corresponding right brace bracket attachment is, however, significant. If one or more of the bolts of the failed attachment had similarly been installed with low torque and hence low pre-load, it is possible that a loading cycle could have been applied in service to one or more of the bolt group. This contrasts with the assumed design condition of bolts pre-loaded to a level at which a steady tension force is retained therein, as a result of elastic deformation of the joint faces, regardless of the presence or absence of tensile flight loading in the brace.

Since the rear left brace assembly is subjected to the highest design loading of the four braces, the bolted joint of its lower bracket (the failed joint) would be likely to suffer the onset of fatigue damage before the corresponding bolts of the rear starboard joint, if broadly similar and insufficient installation torque values had been applied to both bolt groups.

The evidence of fatigue failure in this low-hours machine, combined with the low number of recorded flight cycles, thus strongly suggests that the failed bolts must have been incorrectly torque tightened. There is no record of the joint being dismantled during the short service life of the aircraft and the extensive dismantling of mechanical components required to gain access to this area virtually precludes the possibility of such activity occurring without it being recorded.

It is understood that correct setting of the torque values on the bolts in question, at installation, is sufficient to ensure that appropriate torque, and hence tension, remains in those bolts throughout their service lives. It must therefore be assumed that the low torque values noted in the rear right brace assembly attachment bolt group existed from manufacture, or that they were lower than the specified values at installation. These low torque values indicate that an assembly quality failure occurred when this aircraft was manufactured and in the absence of any evidence of a pre-existing defect in the failed left side joint, it must be assumed that a similar assembly error occurred in that position causing the observed fatigue damage.

The level of cyclic loading occurring once per flight, if distributed equally between the group of incorrectly torque tightened bolts, would have been of insufficient magnitude to create rapid fatigue damage, which suggests that those bolt torques and hence pre-load values varied between the four bolts. This inequality, taken in conjunction with the relatively high stiffness of the bracket, would result in not only the static preloads but the peak values of the cyclic operating loads being very unevenly distributed between the four bolts in the joint.

It would thus be expected that a high proportion of the peak repeated loading initially applied to the joint would be reacted by one bolt. Under such circumstances the cyclic loading on that bolt would be high in relation to the UTS of the material and thus able to rapidly initiate and sustain cumulative fatigue damage. Thereafter, either shortly before or immediately after failure of the first bolt, a second, adjacent bolt would sustain an excessively high cyclic loading as a result of the cyclic loading of the brace. This would produce conditions conducive to rapid fatigue initiation and progression in that bolt. Once the second bolt failed, very high tensile and some bending stresses would be present in the remaining pair, now offset from the load axis, and subjected to consequent mechanical advantage. This would lead to rapid failure, a significant part of the cross-section failing in overload. This was the observed condition of the fracture faces of two adjacent failed bolts.

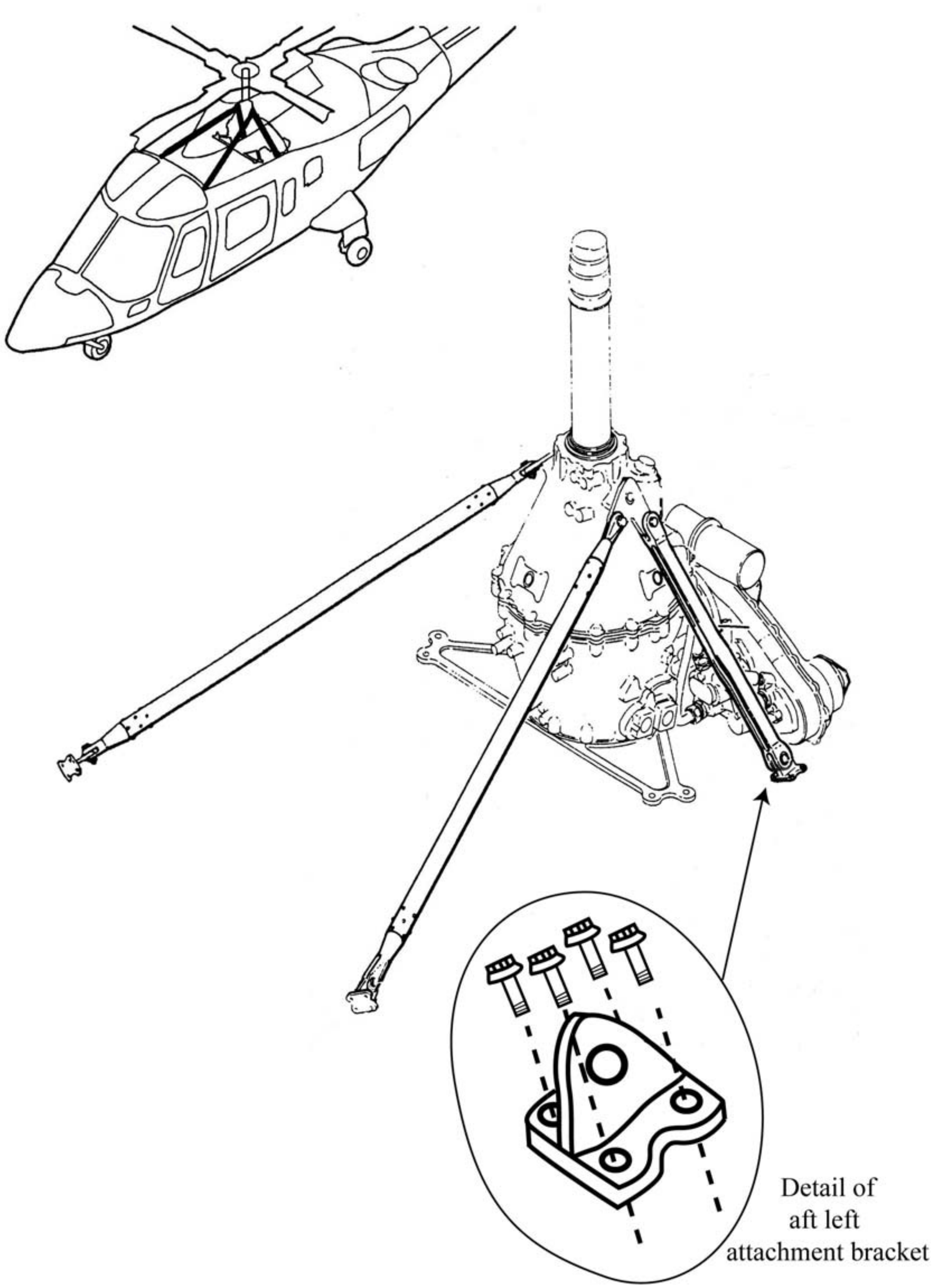
The important function of the failed joint emphasises the need to ensure that the fatigue life can be predicted (or exceeds the life of the remainder of the airframe). The orientation of the bolted joint, in relation to load direction, dictates that this can only be realised with robust control of bolt assembly torque values achieved during initial build and on any subsequent refitting of the bolted joint. The manufacturer stated, however, that an evaluation of the lower right attachment residual strength, in the event of failure of the lower left attachment, would still provide a positive margin of safety. This evaluation was valid for the design manoeuvre case.

Conclusion

The evidence is consistent with incorrect torque tightening of the bolts of the failed joint at manufacture of the aircraft. The installed bolt tension is of critical importance to the integrity of attachment between the lower brackets of the brace assemblies and the cabin structure of the 109 Series aircraft.

Following this accident Agusta have reviewed the assembly process and issued revised guidance to the production team. In addition, the production documents have been revised to include identification of the torque wrench used, the calibration expiration date and the torque values applied to the bolts.

Figure 1



AAIB Bulletin No: 5/2005 **Ref: EW/C2003/07/06** **Category: 2.3**

Aircraft Type and Registration:	Robinson R44 Raven I, G-OUEL	
No & Type of Engines:	1 Textron Lycoming O-540-F1B5 piston engine	
Year of Manufacture:	2002	
Date & Time (UTC):	30 July 2003 at 1004 hrs	
Location:	Carlenrig, Teviothead, near Hawick, Scotland	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	Helicopter destroyed	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	41 years	
Commander's Flying Experience:	96 hours - (of which 20 were on type) Last 90 days - 6 hours Last 28 days - 4 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The helicopter departed on a VFR flight from a private site near Hawick in Scotland to route to Barton Airfield in Manchester. Initially it flew southwards at 1,500 feet amsl but as it approached hills, whose tops were reportedly covered by an area of low cloud, it turned away from the planned route and probably entered cloud. As the turn continued the helicopter accelerated, entered a rapid descent and the main rotor blades struck the tailboom. Most of the tailboom detached, the rotors virtually stopped and the helicopter impacted the ground at the bottom of a valley, fatally injuring the pilot.

A number of military aircraft were operating in the area at the time of the accident but none of these could have influenced the safe progress of the flight. No signs of pre-accident malfunction of the helicopter were found, but full determination of its pre-impact serviceability was prevented by extensive post-crash fire damage. The available evidence indicated that the accident followed a main rotor blade strike on the tailboom, probably caused by excessively low rotor RPM. The control loss and low rotor RPM may have resulted from spatial disorientation and mishandling of the controls but the possibility that aircraft malfunction had contributed to the accident could not be eliminated.

History of the flight

On Sunday 27 July 2003 the pilot, accompanied by an instructor, carried out a short local flight in G-OUEL from Wycombe Air Park (Booker) and the next day he flew solo from Wycombe to a private site 3 nm north-east of Hawick, Scotland, to visit friends. He planned to return to Wycombe, via Barton Airfield, on the outskirts of Manchester, two days later. He told a friend that he had 'an enjoyable flight to Hawick' and that his only problem was preventing the helicopter 'wobbling' when he attempted to fold his map.

On Tuesday 29 July, when the weather improved in the evening, the pilot carried out three short flights in the Hawick local area. The first was to refuel from a trailer bowser located at a farm strip at Midlem. The second was his return flight back to the private site. The third flight was 'a gentle 12 minute sight-seeing trip, with no steep turns or abrupt manoeuvres', carrying three friends around the local area. The pilot subsequently spent a quiet social evening with his friends before retiring to bed at about 2200 hrs.

On Wednesday morning, the day he had planned to return to Wycombe, the weather was poor with low cloud and drizzle. The pilot rose at about 0630 hrs and watched the weather report on the television. He decided to take a western route via Carlisle once the weather improved and eventually departed the site at 0956 hrs. (Note: times quoted in this report are UTC/GMT, one hour different from UK Summer Time.)

The helicopter was fitted with a Global Positioning System (GPS) navigation system that recorded the time, position, groundspeed, track and GPS altitude every 30 seconds during the flight. The GPS recorded data was downloaded at the AAIB and converted to heights above mean sea level (amsl) and Ordnance Survey Grid; the last part of the route is shown at Figure 1.

The recorded data showed that G-OUEL passed down the western edge of Hawick and followed the general line of the A7 road at a ground speed of between 107 kt and 116 kt until it reached Teviothead (8 nm south-west of Hawick) around 6 minutes after takeoff. The average GPS altitude up to this point was approximately 1,500 feet (approximately 1,000 feet agl).

GPS altitude can be subject to substantial error but the recorded values suggested that for much of the flight, where the aircraft had apparently been flown approximately level, the GPS altitude had been accurate to within ±100 feet. The possible error in the recorded altitude could have increased somewhat when the aircraft was in a banked turn, as a result of antenna shielding effects, but it was judged unlikely that there would have been a major increase. The GPS used was designed to provide highly accurate groundspeed and track and it is likely that the errors in horizontal position would have been less than the altitude errors. The timings and routing were confirmed by a small number of witnesses who had either heard or seen the helicopter.

The GPS data showed that approximately 1 nm south of Teviothead, where the A7 road turns south, the aircraft's ground speed reduced to 98 kt. Over the next 30 seconds the aircraft climbed from around 1,500 feet to 2,400 feet; an average rate of climb of 1,800 feet per minute. In this time it turned right through 32° and the ground speed reduced to 50 kt. Over the next 30 seconds the GPS altitude increased approximately 200 feet to about 2,600 feet, the right turn continued through a further 83° and the ground speed increased to 86 kt. At the final data point, timed at 1004 hrs, the GPS altitude had decreased about 150 feet to approximately 2,450 feet, the right turn had continued through a further 130° and the ground speed had increased to 120 kt. No further data points were recorded.

Recorded radar data showed one possible contact for G-OUEL, timed at 1004 hrs and located close to the accident site, but no further contacts showing its flight path. The absence of radar returns was consistent with local terrain masking the helicopter at its relatively low level. There were no eye witnesses to the final minutes of the helicopter's flight and no witnesses saw the accident take place. Several people however, heard the helicopter. Witnesses, at a farm 1,200 metres north-east of the accident site, clearly heard the engine sound from G-OUEL as it passed low overhead. One of these witnesses heard the continuous sound of the engine suddenly stop with a bang, which she likened to a rifle shot. A person, driving south along the A7 road, saw smoke and flames rising from the accident site some distance away, but they did not see the events immediately before and thought it was a bonfire.

The wreckage of the helicopter was discovered later in the day by a local farmer. The helicopter had been destroyed and the pilot had received fatal injuries.

Other air traffic

Witnesses

A number of witnesses saw or heard helicopters and jet aircraft in the area on the day of the accident. Two witnesses, a farmer and his son, were in the cab of their tractor 2,500 metres north-east of the accident site. The son reported seeing a fast-jet fly low along Carlenrig Ridge, a ridge forming the northwest side of the valley above the accident site. He described it descending into the valley near Teviothead and following the A7 towards Hawick. The time was estimated by both to be around 1000 hrs. Shortly after this the farmer noticed light grey smoke rising vertically from the approximate area of the accident site. An estimated forty five minutes later (1045 hrs) they saw a second fast-jet fly the same route. This was followed, some ten minutes later, by a Chinook helicopter. The farmer's son could not identify the type of fast-jet aircraft and neither he nor his father could be certain of the time of their observations.

Military activity

The Ministry of Defence (MoD) provided information on the military flying activity taking place in the vicinity of the accident site for the relevant time. Planned training flights had either re-routed or abandoned low flying that day due to low cloud. Radar data, recorded from Scottish Radar at Prestwick, showed the progress of a Chinook helicopter along the A7 road 10 minutes after G-OUEL. The Chinook was transiting from Lossiemouth, near Inverness, to a military training area 20 nm south of Hawick. Twice during the flight the helicopter had been forced to climb due to low cloud. It had descended to low level in VMC north of Hawick and reached a position approaching Teviothead along the line of the A7; the same routing taken by G-OUEL. Due to low cloud to the south, towards Langholm, the helicopter commander elected to route further to the west and therefore passed north of the accident site along the adjacent valley. He did not see the accident site or smoke rising from the wreckage.

Two fast-jets were booked into the Low Flying Area (LFA) encompassing the accident site. While tracking north-bound along the A7 they were forced by bad weather to abandon their low level flight in the vicinity of Hawick. Their approved time of entry into the LFA was 1030 hrs and, although the exact time at which they passed the accident site could not be determined, the aircraft had to negotiate bad weather and were delayed on their intended flight plan. They did not enter the low flying area until after 1030 hrs.

The radar recorded only one primary radar return in the vicinity of the accident site, at 1004 hrs. This was probably G-OUEL as it reached the highest point of its climb.

Weather

Aftercast

An aftercast obtained from the Meteorological Office showed the synoptic situation at 0600 hrs on the day of the accident as an area of low pressure centred just east of Middlesborough, with an occluded front lying over the English-Scottish borders. This low and the occlusion moved slowly east during the morning as high pressure began to build from the west, producing a light, rather moist, north-easterly air flow over the area. The weather was outbreaks of rain and drizzle at times with hill fog over much of the high ground. The surface visibility was 20 to 30 km deteriorating to between 2,000 metres and 8 km in rain and drizzle and 100 metres or less in hill fog. Mean sea level pressure was 1013 mb at 0700 hrs rising to 1015 mb by 1100 hrs.

Cloud was generally scattered or broken stratus with a base of 1,800 to 2,500 feet and broken strato-cumulus cloud with a base of 3,500 to 6,000 feet often deteriorating to broken or overcast stratus with a base of 1,200 to 1,800 feet. The wind was light from the north-east, between 5 kt at the surface to 15 kt at 2,000 feet altitude.

During the morning there was a great deal of layer cloud over the English/Scottish borders below 10,000 feet amsl. Much of the layer cloud was drifting in from the North Sea in the light north-easterly winds. The lower layers were patchy but at times extensive, causing transitory hill fog as areas of cloud followed by gaps moved across the area.

Actual conditions observed at 0950 hrs at Carlisle Airport, approximately 24 nm south of the accident site, gave a variable surface wind averaging 360º/05 kt, visibility greater than 10 km, broken cloud at 1,500 feet, ambient temperature of 19ºC with a dewpoint of 16ºC and a QNH of 1014 mb.

In-flight observation

The commander of the Chinook helicopter provided a report on the conditions encountered as he transited the route flown by the pilot of G-OUEL. He reported that, having crossed the high ground to the south-east of Edinburgh, the low cloud began to break up, providing a large circular clear area some 15 nm in diameter centred approximately 30 nm south-east of Edinburgh. The ground below and ahead was clearly visible and he was able to carry out a descent in good Visual Meteorological Conditions (VMC). Approximately 4 nm south of Hawick, flying at 500 feet agl and heading 220°M, he could see the cloud covering the hill tops of the high ground to the south. Although the Teviot valley south of Teviothead was, in his opinion, just about passable, there was better weather to the west and he elected to route over Eskdalemuir Forest.

The visibility was approximately 10 km below the base of the cloud, which he estimated was at about 1,600 feet amsl. The wind at this altitude, as computed by the aircraft's navigation system, was north-easterly at less than 10 kt. No turbulence or showers were encountered and the crew did not see or detect any other aircraft activity in the area of the crash site.

Witness observations

The farmer, working with his son north-east of the accident site, stated that the weather that morning had included patches of drizzle coming down from the direction of Eskdalemuir Forest, to the west of his position. Comb Hill (see Figure 1) was visible from time to time, with its top in cloud. There was no wind and the light grey smoke he saw in the area of the accident site rose vertically before spreading out and taking on a gentle south-westerly drift.

Medical and pathological information

A post-mortem examination found that the pilot had died of multiple injuries. No evidence of any pre-existing disease was found and a toxicological investigation revealed no evidence of any condition which may have caused or contributed to the accident.

Pilot's flying experience

The pilots flying log-book and licence were not recovered. The hours quoted below are therefore estimated from other available information.

The pilot carried out training for his Private Pilot's Licence/Helicopter (PPL/H) on the Enstrom helicopter, which included instrument flying appreciation. He completed the requirements and was issued with his JAR PPL/H on 24 September 2002. He amassed 76 hours on the Enstrom before carrying out a type conversion onto the R44. His R44 rating was issued on 17 January 2003. At the time of the accident he was estimated to have flown 20 hours on the R44.

Aircraft description

General

The Robinson R44, manufactured in the USA, is a single-engined helicopter of conventional layout (Figure 2) with a maximum gross weight of 2,400 lb. At the time of the accident the manufacturer had constructed approximately 1,500 R44s, in three versions, over a 10 year period. The primary fuselage structure is constructed of welded steel tubing covered with a riveted aluminium skin and is fitted with a skid landing gear. The tailcone is a monocoque aluminium structure. There are two front and two rear seats; the pilot normally occupies the front right seat. The GPS receiver fitted to G-OUEL incorporated a moving map display; it was mounted on the central frame of the forward transparency. V_{NE} (the never exceed indicated airspeed) at G-OUEL's weight and altitude at the time of the accident was 130 kt (100 kt when operating at power above Maximum Continuous.)

Powerplant and transmission

The aircraft is powered by a 6-cylinder petrol piston engine with a maximum take-off power rating of 225 shp for the R44 Raven I (de-rated from the basic engine capability of 260 shp). Fuel supply for this model is via a carburettor. A pulley sheave carried on the horizontal engine output shaft drives 4 vee-belts which transmit power to an upper sheave when the belts are tensioned. Tensioning is effected by an electric screwjack clutch actuator which, when activated, raises the upper sheave and automatically sets and maintains the required tension. An over-running clutch within the upper sheave transmits power forward to a main rotor (MR) gearbox and aft to a tail rotor (TR) driveshaft and allows the rotors to continue to turn in the event of an engine stoppage. The MR gearbox contains a spiral-bevel gear set that drives a vertical MR shaft.

Rotors

The main rotor has two all-metal blades, each of which is attached to a MR hub by a coning pivot hinge (Figure 3). The hub is mounted to the top of the MR shaft by a horizontal teeter pivot hinge located above the coning hinges. The design places the main rotor centre of mass close to the teeter hinge point under normal operating conditions to minimise vibration and improve rotor stability. The provision of coning hinges permits a lighter blade design by reducing flapping bending moments near the blade roots. Teetering travel is limited by contact of the blade spindles with elastomeric stops on the rotor shaft. Pitch-change bearings for each blade operate in an oil bath contained in a blade root housing that is sealed by a neoprene boot; nominal blade pitch angles are 2-3° with the collective fully down and 14.5-16.5° with the collective fully raised. No blade drag hinges are provided.

The MR diameter is 33 feet and the MR blade tip speed is 705 feet/second at the normal maximum rotational speed of 102% (408 RPM). Rotation is anti-clockwise viewed from above. Each blade is fitted with a tip weight, around 3.5 feet long, carried within the outer portion of the stainless steel leading edge spar. Substantial tensile loads generated in the blades by centrifugal forces limit the bending and torsional deformation of the blades in normal operation. As with all conventional helicopters, this centrifugal rigidity is essential for the correct operation of the rotor.

The TR driveshaft, running in the tailboom, transmits power to a TR gearbox containing a spiral-bevel gear set that drives a horizontal TR shaft. The TR has two all-metal blades carried on a hub which is attached to the TR shaft by a teeter hinge.

Control

The MR is controlled by varying the blade pitch angles (Figure 4) by means of a pilot-operated collective lever and cyclic stick, each connected to the MR blades by mechanical rod and bellcrank linkages. Three hydraulic servo jacks, powered by a hydraulic pump driven by the MR gearbox, provide boost to reduce control forces. Directional control is by yaw pedals, connected to the TR blades by mechanical rod and bellcrank linkages, which vary the collective pitch of the TR blades.

The engine power output required to maintain rotor RPM varies with flight control inputs and aircraft manoeuvres. Coarse adjustment of power output as a function of collective lever position is provided by a correlator mechanism acting on the engine carburettor throttle. The throttle is connected to a twistgrip on the collective lever but is normally controlled in flight by an electronic governor that acts to maintain rotor RPM. The governor moves the whole throttle system, including the twistgrip, but a clutch in the linkage between the governor and the system allows the pilot to over-ride governor activity by means of the twistgrip. The R44 Pilot's Operating Handbook (POH) specified that flight with the governor selected off is prohibited, except in the case of in-flight malfunction of the system or for emergency procedures training.

The rotor speed limitation, power on, published in the POH was 101-102%. Low rotor RPM warnings, in the form of an amber caution light and a horn, activate when rotor RPM decreases to 97% or below. The MR and its control system is designed so that with the collective lever fully lowered, aerodynamic forces on the MR blades in the resultant auto-rotative descent maintain normal rotor RPM without engine power input. A manoeuvre that increases the load factor above 1g, such as a flare or a banked turn, causes a change in relative airflow that increases the auto-rotative forces on the MR blades and thus increases the rotor RPM. Normal RPM can be maintained by increasing the collective setting while the load factor is above 1g. Similar effects in powered flight cause a reduction in the engine power required while the load factor is above 1g.

The operating sense of the throttle twistgrip requires the left hand to be rotated away from the pilot (ie clockwise, viewed from the front) in order to manually open the throttle. This is the conventional sense for a helicopter throttle as it enables the wrist to naturally rotate the throttle open as the left arm is raised to increase the collective setting, when operating the throttle manually. However, the operating sense is opposite to that of a motorcycle throttle. Several instructor pilots reported that pilots, and in particular motorcyclists, operating this type of helicopter throttle control commonly did not find the direction of manual twistgrip rotation required in response to a rotor RPM excursion to be instinctive. It was also reported that there was a common tendency for pilots under stress to apply a fixed grip to the twistgrip and inadvertently preventing the governor from maintaining the RPM within the governed range.

In order to prevent or eliminate ice build-up in the engine induction system, warmed air can be diverted to the intake by a pilot-operated carburettor hot air control that operates in conjunction with a hot air assist system correlated with the collective lever setting. Excessive induction system heating results in unnecessary power loss. The aim is to adjust the amount of hot air such that the induction system temperature, as indicated on a cockpit gauge, is maintained above the level at which ice can form. It is intended that the necessary manual control setting is made immediately after takeoff and that the amount of hot air is then varied automatically by the assist system as the collective lever setting, and thereby the engine power output, is changed. It was reported that the correlation tends not to be exact and that further manual adjustments are commonly necessary to maintain the required temperature.

Aircraft history

G-OUEL (Serial Number 1235) had been imported new to the UK in 2002 and subsequently operated by the same company until the time of the accident. Records indicated that it had been maintained in accordance with Maintenance Schedule CAA/LAMS/H/1999, Issue 1, Amendment 1, and did not suggest that there had been any significant problems with the aircraft that could have been relevant to the accident. The last maintenance check, a 50 Hour Inspection, had been carried out on 24 June 2003, at which point the airframe and engine had each accumulated 247 flight hours since new.

Accident site

The wreckage of the helicopter was located in hilly countryside around 1 nm south-west of Teviothead. The main wreckage was at Ordnance Survey position NT395039, 666 feet amsl, in a steep-sided valley orientated north-east to south-west. The valley had a relatively flat base around 150 metres wide containing a small river and numerous drainage channels. The ground was generally moderately firm and covered with tall grass and areas of high, dense bracken. The valley was between hills that, in the vicinity of the accident site, rose to 1,181 feet amsl on the south-east side (around 0.5 nm south of the main wreckage site) and to 958 feet amsl on the north-west side. The terrain 1.9 nm south of the site rose to 1,683 feet.

Examination of the site showed that components of G-OUEL had been spread over a trail around 400 metres long and 100 metres wide that ran north, diagonally down the south-east face of the valley and across the valley floor. The southern end of the trail was at about 800 feet amsl. It was possible that some of the lighter items could have been repositioned by the wind prior to the site examination but the evidence indicated that this had not generally occurred.

The items in the southern part of the trail largely consisted of multiple white paint flakes, in a trail around 200 metres long, together with a number of pages from a Pooley's Flight Guide, both of which had clearly originated from the helicopter. The Pooley's pages were A5 sized loose-leaf paper sheets, normally held in a ring binder. A number of pages from the guide were found distributed over a 100 metre wide area of the trail. They were generally undamaged, with no signs of having been pulled or torn out of a binder, but most had been spattered with a red oily fluid. It was found that they constituted 52 consecutive pages from near the front of the guide and included two bands of consecutive pages with particularly heavy fluid contamination.

A manufacturer's component dataplate, identified as part of the anti-collision beacon mounted on the top of the aft part of the tailboom, was found 90 metres along the trail. Portions of 'danger' and aircraft registration lettering decals from the tailboom were found a little further along the trail.

These were followed, at 250-320 metres, by a MR blade fragment and a number of large and small pieces of the tailboom, together forming the whole tailboom with the exception of its forward 2 feet, with the tail rotor and its gearbox attached. These items were followed by a part of the aircraft compass and a headset. Between 300 and 400 metres along the trail were several portions of the TR driveshaft and TR control rod from the tailboom. None of the above items had been fire damaged.

The main wreckage, essentially consisting of the helicopter with most of both MR blades but absent most of the tailboom, was located 380 metres along the trail, embedded deeply into the ground. Ground marks and wreckage examination showed that it had impacted the ground with high vertical speed and very low horizontal speed while rolled onto its right side. There were no appreciable ground marks from the MR blades, apart from where the outer portion of one blade (designated Blade A) had become impaled in the ground. This was apparently the result of motion along the longitudinal axis of the blade, without significant rotation.

The main wreckage had been subjected to extensive fire damage, with most of the composite and aluminium components destroyed, except for some on the right side that had been embedded into the ground. The MR had remained outside the fire area and the GPS receiver had been thrown clear and was virtually undamaged. A 1:250,000 scale and a 1:500,000 scale aviation map with a track line from the departure point to Carlisle drawn on it were found at the site. Fire damage to vegetation alongside a drainage channel adjacent to the main wreckage was consistent with a substantial quantity of fuel having flowed from the wreckage into the channel and burnt.

Examination indicated that all parts of the aircraft were present in the trail, with the exception of the tip portion of MR Blade A. It could not be located by extensive searching and digging but was subsequently recovered by members of the public, apparently from an area of bracken around 200 metres west of the main wreckage. The blade fragment located with the tailboom parts originated from the fracture area. The remains of all four cabin doors were identified in the wreckage, in each case with the door handle in the closed and locked position and generally with the two latch pins protruding, although some latch pins had fractured. The position of the doors was consistent with their having been closed, with the exception of the forward right door, which was found lying under the forward fuselage. The evidence suggested that this door had opened and over-rotated around 180° before the fuselage had struck the ground.

Following on-site examination, the wreckage was taken to the AAIB Headquarters at Farnborough for detailed inspection.

Detailed wreckage examination

It was clear from markings and damage characteristics that the tailboom had sustained three strikes from MR blades on its left side (Figure 5). One of these strikes, around mid-way along the tailboom, had been particularly heavy. The strikes had separated the boom into 7 major parts and a large number of smaller fragments. Severe localised flattening damage to the TR driveshaft and the TR control rod in the area of the heavy tailboom strike was also indicative of a MR blade strike.

Both MR blades had suffered surface gouging, consistent with contact with the tailboom, in a region between around 2.3-4.3 feet from the tip for Blade A and 4.9-7.4 feet from the tip for Blade B (Figure 4). Neither blade had sustained appreciable leading edge damage from the ground impact. The inner portion of Blade A had buckled, consistent with its end-on ground impact. The fracture of the blade, 3.5 feet from its tip, was at the inboard end of the tip weight fitted within the blade spar. The blade had a pronounced, smooth forward bend in the plane of the blade outboard of the fracture and this, together with the spar fracture surface characteristics, indicated that the fracture had resulted from in-plane bending overload. The evidence, in conjunction with that from the markings on the blade and on the tailboom and from the distribution of the detached parts, was fully consistent with the fracture having resulted from overload caused by inertial effects when the blade struck the tailboom. Blade B was intact; it exhibited marked upward bending deformation along its length.

Markings showed that the pitch change horn of each MR blade had contacted the MR hub while the blades had been coned upwards around 21° and the blade pitch angle had been around 27° leading edge up. Both elastomeric teeter stops had been impacted by the blade spindles and virtually severed. The main rotor shaft beneath the stops had a small imprint from the spindle on each side but was otherwise undeformed.

The TR blades were undamaged, with no signs of rotation at ground impact. Light scoring and minor deformation of the tailboom and slight paint scraping on the left side of both TR blades showed that both blades had made light rotating contact with the boom over a few revolutions.

Flight control and engine control systems were examined as far as possible but extensive destruction of the main fuselage prevented a full assessment. Parts of the flight control runs and most parts of the servo actuators had been destroyed by fire damage, but most control run pivots remained, with no signs of disconnection. The throttle linkage remained intact. The belt drive clutch actuator had suffered major damage but it appeared unlikely that the screwjack setting would have changed from that at ground impact; comparison with another R44 with similar flight time to G-OUEL indicated that the setting was consistent with the drive having been engaged.

Engine strip examination at the manufacturer's UK agent found no signs of mechanical failure prior to ground impact. However, most of the accessories had been destroyed by fire and no evidence as to the pre-impact state of the carburettor or magnetos was available. Analysis of a sample of fuel from the bowser used to refuel G-OUEL before its departure on the accident flight found that it generally conformed to the specification requirements for aviation gasoline. It marginally exceeded the requirement on an existant gum test but was within limits on a repeat and both results were within the repeatability of the test method. The results were consistent with the effects of sample ageing before testing and were not considered relevant to the operation of the engine.

The evidence suggested that neither the engine nor the rotor system transmission had been rotating at appreciable speed at ground impact. However, there were signs that both had been rotating at the time that significant disruption in the engine bay and in the transmission bay behind the MR gearbox had occurred. Heavy local machining of the engine oil cooler by the engine starter ring indicated engine rotation. Transmission rotation was indicated by the wrapping of a steel reinforcing wire from a MR gearbox cooling air hose around the MR gearbox input shaft. The wire remained intact and snagged on the shaft and the evidence indicated that the shaft had stopped after having made around 15 turns from the point at which it had first picked up the wire. These effects were consistent with a MR blade strike having caused deformation of the rear part of the fuselage or with a blade strike or excessive vibration having disrupted the engine and/or MR gearbox mounts. The rotational speed of the engine or transmission at the time could not be determined but the evidence suggested that both had made only a limited number of turns before stopping.

Previous research and analysis

FAA Technical Panel

The R44 configuration and MR design was similar to the Robinson R22 two-seat helicopter. Both types had suffered a number of cases of MR blade strike on the fuselage or tailboom in flight. On 19 July 1994 the Federal Aviation Administration (FAA) chartered a Technical Panel (TP) to research solutions that would reduce the potential for fatal accidents involving in-flight main rotor contact with the airframe (referred to as rotor/airframe contact accidents) of R22 and R44 helicopters. The need for the review arose from 34 fatal rotor/airframe contact accidents, 31 of which involved the R22 and three the R44. The seven member panel, in conjunction with the manufacturer and other expert bodies, conducted a comprehensive study that particularly addressed the design and behaviour of the main rotor system.

The TP convened on 8 August 1994 and, following a review of the accidents, recommended initial action on 30 December 1994. These recommendations addressed the provision to pilots of information on the conditions leading to fatal accidents, prohibiting flight in turbulence and developing pilot training requirements and the legislation to support them.

A revision of the Basic Helicopter Handbook to cover fatal accident causal factors was initiated in February 1995. After completing the initial study the TP continued its research to support FAA action. From the Executive Summary dated 30 April 1996, the flight testing of a fully instrumented R44 undertaken in July 1995 and a computer based simulation programme produced no evidence of rotor instability. Some of the earlier recommendations were refined and a recommendation was made by the TP to mandate the fitting and use of a rotor speed governor on all R22s; it was already required for continuous use on the R44 helicopter.

The TP concluded that:

> *"Accident investigators had not definitively determined the primary causal factors of any of the 34 reported R22 and R44 rotor/airframe contact accidents. Based upon the results of the research and study by the TP, the actions recommended by the TP will reduce the potential for rotor/airframe contact by eliminating some of the conditions that have accompanied those accidents and will help prevent excursions beyond the limit of the flight envelope. Those actions have mandated increased minimums in flight experience and training for those helicopters, reduced the operating flight envelopes, and will reduce pilot workload in the aircraft. Beyond the recommendations put forth in this report, the TP proposed no further action on the part of the FAA."*

Flight Testing

The flight testing mentioned above was carried out by the manufacturer with participation by the FAA. It investigated MR blade flapping angles, rotor RPM decay and helicopter pitch and roll rates resulting from a variety of manoeuvres and initial flight conditions, such as cyclic pushovers and sudden power reduction.

The manufacturer's report on the testing stated that R44 rotor head clearances allow the MR hub to teeter up to 15.1°; the teeter stops make initial contact at 7.4° and compress at larger angles. The clearances also allow for upward blade coning of around 16°; droop stop contact occurs at 1.2° downward coning. Blade contact with the tailboom would occur at a downward flapping angle (teeter angle minus upward coning angle) of approximately 15°.

The maximum aft flapping angle during the flight tests was 7.2°, given by a teeter angle of 8.2° with a 1° upward coning angle, producing a blade/tailboom clearance of 26 inch. The greatest aft teeter angles occurred with a forward helicopter centre of gravity. This condition also produced higher right roll rates during pushover manoeuvres, up to 41°/second. A high roll rate manoeuvre, where the bank angle was reversed from 45° left to 45° right at 117 kt with maximum continuous power applied, produced a maximum right roll rate of 62°/second. The lowest rotor RPM experienced was 80%, in a test where the engine power was chopped in level cruise at 105 kt and the collective was maintained at its original setting for 1.1 seconds after the chop and then fully lowered in a further 0.9 seconds.

The report concluded that the R44 met or exceeded the FAA requirements for rotor blade clearance and for rotor RPM decay associated with specified time delays in reducing the collective after sudden power loss. It concluded that the rotor system would not stall, exceed teeter limits or contact the airframe when the helicopter was flown within its approved limitations.

Main rotor-airframe strike

Information from the POH, from discussions with the aircraft manufacturer and from research findings indicated that, for a helicopter with a teetering MR, an in-flight MR blade strike on the fuselage or tailboom could result from either a MR stall or a reduced load factor condition. The factors involved are as follows:

Main rotor stall

The lift and drag forces generated by airflow over each section of the MR blades are a function of the relative speed of the airflow over the section and its angle of attack (AOA), the angle between the blade chord and the airflow (Figure 4). Increased lift and drag forces are generated by increasing AOA, up to a critical aerodynamic stall angle (around 15° for the R44), beyond which the airflow separates from the upper surface of the section. This results in a sudden reduction in lift and large increase in drag on the section.

An increased AOA is required in order to maintain the lift if MR RPM reduces. The AOA is also increased by an increase in the sink rate of the section (the descent rate of the section relative to the airflow). In the event of part of a blade reaching the stall angle, the drag increase tends to reduce the MR RPM and the loss of lift tends to increase the sink rate. Reduced centrifugal loading on the blades due to decreased RPM also allows increased torsional deformation of the blades, tending to increase blade pitch angle and thus the blade AOA. The combined resultant increase in the AOA tends to rapidly deepen the stall and extend it over a greater portion of the blade, thereby further increasing the torsional drag on the MR. For a piston-engined helicopter such as the R44, where the engine is mechanically connected directly to the rotors, a reduction in MR RPM causes a corresponding reduction in engine RPM. The maximum output power of the engine decreases in direct proportion to the reduction in its RPM. The increase in drag and reduction in the power available can cause the power required to drive the rotors to rapidly exceed the maximum output power of the engine. In this case continuing RPM reduction results.

The process of RPM reduction in a blade stall condition is very rapid and can only be reversed by immediate lowering of the collective lever, thereby reducing the pitch angle of the blades and thus their AOA. For the R44 the RPM reduction is reportedly irreversible below about 72%, ie full lowering of the collective lever will not prevent continuing rapid RPM reduction.

The speed of the airflow over a blade section is the resultant of its speed due to rotation and its speed due to motion of the helicopter. Thus, in forward flight the retreating blade (on the left side of the aircraft) experiences a lower airspeed than the advancing blade (on the right), with the speed difference increasing as the aircraft's forward speed increases. This causes the retreating blade to descend, thereby increasing its angle of attack, and the advancing blade to rise, thereby reducing its angle of attack. The effect results in equalisation of the lift on each side of the MR disc and in rotor blow-back (or 'flap-back'), where the rotor disc tilts back.

In the event of excessive blade AOA in forward flight, the retreating blade can stall first and thus cause asymmetric MR stall. The loss of lift associated with the stall causes the aircraft to sink and the resultant upward relative airflow on the tail surfaces pitches the fuselage nose down. With a teetering rotor, the combined effects of excessive MR blow-back and fuselage nose down pitching, possibly accentuated by aft cyclic control input made by the pilot to counteract the nose-down pitching, can cause the MR blades to strike the fuselage or tailboom, generally on the left side. As MR RPM reduces below normal, the likelihood of a strike is increased because of the greater out-of-plane bending excursions of the blades that can result from the loss of MR stiffness associated with the reduced centrifugal loading.

Information was obtained on an overseas R44 accident in 2004. The accident reportedly probably resulted from MR/fuselage contact due to low rotor RPM, possibly following engine power loss due to induction system icing. Evidence provided by a video recording being made by one of the helicopter's occupants at the time of the accident showed that extremely violent airframe vibration immediately preceded the MR/fuselage contact. It appeared that this was due to severe MR imbalance associated with excessive flapping excursions of the MR blades at low RPM.

A reduction in the engine power delivered to the rotors would cause the rotor RPM to decrease until corrective action were taken; it is intended that in the event of power loss the pilot should rapidly lower the collective lever fully, enter auto-rotation and carry out an engine-off landing. Practising this procedure forms a substantial part of pilot training. An excessively low MR RPM condition can quickly result from insufficiently rapid full lowering of the collective lever.

Possible causes of power loss include engine mechanical failure, engine induction system icing or malfunction of governor, ignition, fuel supply or transmission systems. Insufficient power could also result from mishandling of the throttle or governor; movement of the throttle by the governor can be inadvertently over-ridden by the pilot. In the absence of power loss, low RPM can also be caused by MR over-pitching, where the collective lever demand is maintained at a level at which the power required to drive the rotors exceeds the maximum power output of the engine.

The R44 POH notes that in conditions where low rotor RPM can occur, the effects can be accentuated by high density-altitude, aggressive manoeuvring, high forward airspeed or atmospheric turbulence.

Reduced load factor

For a helicopter with a teetering MR, such as the R44, the fuselage is effectively hung beneath the MR disc. The orientation of the fuselage relative to the disc is determined by acceleration forces on the mass of the fuselage (its weight, in 1g flight) and by aerodynamic forces on the fuselage. Reduction in the load factor below 1g, due to manoeuvring, reduces the stabilising force due to gravity.

A substantial reduction in load factor, as would be caused by an abrupt forward movement of the cyclic stick in forward flight (pushover), can result in excessive flapping of the MR disc relative to the fuselage. In the event of the pilot applying substantial aft cyclic control to reload the MR while the helicopter is pitching forward, the MR disc may tilt aft relative to the fuselage before it is reloaded. The main rotor torque reaction will then combine with tail rotor thrust to produce powerful right rolling and right yawing moments on the fuselage. With reduced MR lift there is less lateral control available to stop the right roll, which is likely to prompt a substantial left cyclic control input by the pilot. In this situation the MR blades can flap far enough for the blade spindles to forcibly contact the teetering stops on the MR mast. Such mast bumping can be vigorous enough to deform the mast (mast pinching). Severe pinching can fracture the mast and separate the MR from the aircraft. MR blade contact with the fuselage and/or tailboom can also result. The effect of a pushover type cyclic stick movement can be accentuated in conditions of high forward airspeed, turbulence or excessive sideslip. The R44 POH advises:

> *"To avoid these conditions, pilots are strongly urged to follow these recommendations:*
>
> 1) *Maintain cruise airspeed greater than 60 KIAS and less than 0.9* V_{NE} *[117 kt in G-OUEL's case].*
> 2) *Use maximum "power on" RPM at all times during powered flight.*
> 3) *Avoid sideslip during flight. Maintain in-trim flight at all times.*
> 4) *Avoid large, rapid forward cyclic inputs in forward flight, and abrupt control inputs in turbulence."*

Discussion

It was apparent from wreckage markings and distribution that G-OUEL's tailboom had suffered several strikes by the MR blades and that most the tailboom had detached in-flight as a result and subsequent ground impact was inevitable. The absence of ground marks from the MR blades together with the lack of appreciable ground impact damage to the blade leading edges indicated that the rotor had stopped, or very nearly so, by the time the helicopter reached the ground. The ground impact, made with substantial vertical speed, was non-survivable. Extensive destruction of the helicopter in the ground fire meant that insufficient evidence was available for all details of the in-flight break-up sequence to be positively determined.

Witness markings on the MR hub were not consistent with the effects of ground impact and showed that both MR blades had suffered gross upward coning in flight. This was supported by the marked upward bending of Blade B, which had suffered little ground impact damage. Such severe coning could only have occurred in a situation of gross MR underspeed and consequent large reduction in the centrifugal loading on the blades. In such a condition substantial vertical excursions of the MR blades ('blade sailing') are likely; the severe coning therefore probably occurred close to the time of the MR blade/tailboom strike. Additionally, it appeared that the in-plane bending of Blade A, that had probably resulted from a tailboom strike, was unlikely to have occurred with the high tensile loads in the blades that would have been present at normal rotor RPM. This feature thus also signified that MR RPM had been relatively low at the time of the strike.

The excessive coning caused rupture of the elastomeric boot that sealed the pitch change bearing for each blade. It appeared likely that oil released from the bearings had caused the red staining on the Flight Guide pages released from the helicopter and therefore that the pages had been released close to the time of the MR blade/tailboom strike. The position at which the pages were found was also consistent with their having been released close to the time of the strike and then drifted in the prevailing light north-easterly wind. This was also the case for the trail of paint flakes, likely to have been generated by the break-up of the tailboom. The tailboom parts would have experienced more ballistic throw and less drift than the pages and the paint flakes, having a lower drag to weight ratio. Overall the wreckage trail characteristics indicated that G-OUEL had been tracking approximately north at the time of the MR blade strike.

The reasons for the release of the Flight Guide pages could not be determined. The position of the forward right cabin door in the wreckage indicated that it had opened before ground impact and this was supported by the release of two items of cabin equipment along the trail. The pages could have been sucked out when the door opened; the lack of damage to the pages indicated that they had probably been carried loose from the ring binder. The door latching mechanism was simple, with a design that appeared likely to provide positive latching of the doors in normal circumstances, and no evidence was found to indicate that R44 cabin doors had any tendency to come open. The reason for the door coming open could not be positively established but it appeared that it could have been due to deformation of the fuselage by abnormal loads. It was possible that such loads could have resulted from excessive aerodynamic loads imposed by violent manoeuvring associated with the MR blade/tailboom strike, or from the direct effects of a strike on the fuselage, or from excessive vibration. The evidence from another accident indicated that severely low rotor RPM could result in extremely violent vibration because of MR imbalance caused by excessive excursions of the blades.

Background evidence indicated that there were two possible reasons for the MR blade/tailboom strike. Some mast bumping had occurred on G-OUEL, but it appeared that this could have been associated with excessive blade coning. The absence of gross mast bumping indicated that a reduced load factor condition had probably not been responsible. However, as described above, there was evidence of severe MR underspeed and it was likely that this condition had led to the strike.

In such a case, the stalled rotor would continue to rapidly loose RPM, down to an insignificant level, following the strike and the aircraft's subsequent trajectory would effectively be ballistic, under the influence of gravity and aerodynamic drag. Thus the lack of appreciable horizontal speed when the main wreckage struck the ground indicated that the horizontal speed at the time of the strike had been relatively low. The lateral dispersion of the items in the wreckage trail was quite low, even allowing for the gentle prevailing wind, suggesting that aircraft had been no more than a few hundred feet above the ground when they had separated from the aircraft. It was therefore judged, although not positively established, that the aircraft's altitude when the strike occurred had probably been in the order of 900-1,200 feet amsl.

There were several possible reasons for a significant rotor underspeed, as described earlier. Although no signs of aircraft malfunction prior to the MR blade strike were found, the severe ground-fire destruction prevented the pre-accident serviceability of the engine or it accessories, the fuel supply system or the transmission system from being positively established. There were signs of engine and transmission rotation at the time when disruption had occurred, probably due to the MR blade strikes or to rotor imbalance. No definitive indication of the rotation speed at this point were available, but the evidence of only limited rotation following the disruption suggested that it had been low. Little evidence was available in relation to other possible causes of power loss, such as inadvertent over-riding of the governor by the pilot or engine induction system icing. The flight conditions were probably conducive to induction system icing and some reports suggested that the 'hot air assist' system, even if correctly set at takeoff, would not necessarily maintain the system free of icing without further adjustment en route. Thus the possibility of a loss of power, from a variety of causes, could not be dismissed.

In the event of significant rotor RPM reduction, due to a loss of power or an excessive collective pitch demand, it is intended for the low rotor RPM warnings (97%) to prompt a rapid lowering of the collective lever to restore normal RPM. It was clear that in some situations the rate of RPM reduction could be rapid and even a relatively short delay would result in a severe rotor underspeed; however, the ground fire damage prevented the serviceability of G-OUEL's low rotor RPM warning system from being verified.

A detailed assessment of the operational factors that could have led to a low rotor RPM situation was made. G-OUEL's pilot knew the A7 road between Hawick and Carlisle well and following the road in good weather would have been a simple task. His initial transit had been stable at approximately 110 kt groundspeed and 1,500 feet amsl and appeared to have been uneventful.

However, whilst the weather at his departure point had improved during the morning, low cloud was still in the vicinity of the high ground further south on his intended track to Carlisle. When the Chinook approached Teviothead some 10 minutes after G-OUEL, low cloud beyond this point caused the experienced RAF helicopter pilot, with his navigator, to decide not to continue south down the A7 but to route to the west of the high ground. At low level, the presence of low cloud on the route was only apparent on approaching Teviothead.

The right turn initiated by G-OUEL just south of Teviothead indicated that G-OUEL's pilot had also decided to divert from the original routing and to either land, turn back or route further west. The turn took G-OUEL along the spur of a hill that rose fairly steeply to 1,180 feet amsl and the aircraft climbed at a high rate to around 2,400 feet amsl, with the groundspeed reducing to 50 kt. Given the reported stratus cloud, with a base estimated by the Chinook pilot as around 1,600 feet amsl, it appeared likely that G-OUEL would have entered either the side or the base of the cloud during the climb. Such an entry into cloud could have been inadvertent, possibly coinciding with a distraction such as studying or refolding a map, or could have been made because of concern about terrain clearance.

Radar returns from G-OUEL, except for one approximating to the accident site position, were not recorded because of the relatively low level of the flight, and thus information on the helicopter's progress was not available. However, the GPS record suggested that between the end of the climb and the last GPS data point the aircraft accelerated to around 120 kt, without major height variation, while continuing the right turn through a further 240° onto a south-easterly track. It was likely that either the MR strike or the ground impact caused disconnection of the GPS antenna and the end of data recording. Thus a high rate manoeuvre, such as a descending, tightening right turn, would have to have occurred following the last GPS data point in order for the aircraft, less than 30 seconds later, to be on a northerly track some 1,200-1,500 feet lower when the MR strike occurred. The available evidence suggested possible scenarios for the final flight path, as follows:

Spatial disorientation

In cloud, it would have been necessary for the pilot to fly by sole reference to the flight instruments. The R44 is responsive to control inputs but, like all helicopters, is inherently unstable. Although G-OUEL's pilot had received basic instrument flying familiarisation training, his experience level made it unlikely that he would have been in a position to accurately control the aircraft in IMC. With the absence of outside visual references, physical sensations can produce compelling perceptions of the aircraft's attitude and manoeuvres that differ markedly from those indicated by the flight instruments and spatial disorientation can occur. This tends to be more likely when recent and/or total instrument flying experience is low and in a high stress situation, such as unintended entry into IMC by a relatively inexperienced pilot.

In the event of unintended IMC entry it would be appropriate to maintain a moderate airspeed while attempting to regain VMC or, having done so, while manoeuvring to remain clear of cloud. Given this, G-OUEL's acceleration to 120 kt (ie close to V_{NE}) following the climb, suggested that it was not fully under control at this point. The characteristics of the flight path described above, particularly the high airspeed and the rapid descent that followed, were consistent with the effects of spatial disorientation. It was thus possible that the accident had resulted from loss of control due to spatial disorientation following unintended entry into IMC.

Attempt to regain VMC

With the layers of stratus cloud that were apparently present, it is possible that the pilot climbed through the lower cloud and emerged between cloud layers with a limited, poorly defined horizon. The line feature formed by the river running through the valley could have been visible to the pilot, possibly intermittently, on the right side of the helicopter. This could have led him to conduct a relatively high speed, turning descent using minimum collect pitch in order to attempt to regain VMC. Such a manoeuvre was consistent with the fairly rapid altitude loss between the last recorded data point and the rotor strike, as described above. During the descent it was possible that the helicopter entered an area of denser cloud and the pilot lost sight of the river.

Low rotor RPM

In either of the above scenarios it would be expected that large cyclic and/or collective control inputs would be made at some point in an attempt to arrest the descent and possibly to reduce airspeed. An excessive, sustained collective demand could cause 'over-pitching', whereby the power required to drive the rotors exceeds the power available from the engine, and a consequent rapid reduction in rotor RPM. It was also possible that low RPM could result from over-riding of the governor action by the throttle twistgrip. One possible scenario would be manual closure of the throttle in an attempt to contain a substantial rotor overspeed resulting from a vigorous flare and/or turn with the collective lowered. A subsequent increase in the collective setting without first operating the twistgrip to open the throttle and allow the governor to act could lead rapidly to the low rotor RPM situation that precipitated the rotor strike. Both MR blades were at a high pitch angle at the time when they left evidence of excessive upward coning, but some disruption of the pitch change mechanism had occurred and there was no evidence as to the pitch angle immediately prior to this low RPM situation. Overall, there was insufficient evidence to determine why the low rotor RPM situation had occurred.

Conclusions

It was likely that the helicopter had entered IMC during a turn away from an area of low cloud on its planned route. Shortly afterwards control had been lost and the aircraft descended rapidly, possibly as the result of spatial disorientation. An excessively low rotor RPM had probably resulted and led to contact of the main rotor blades with the tailboom, causing most of it to detach, stoppage of the rotors and non-survivable ground impact. Rapid reduction in rotor RPM to a hazardous level can result from small delays in applying appropriate control inputs. The control loss and low rotor RPM may have resulted from mishandling of the controls but the possibility that aircraft malfunction had contributed to the accident could not be eliminated.

Safety Recommendations

Section 4 of the R44 Pilots Operating Handbook 'Normal Procedures' and Section 10 'Safety Tips' provide information on the rotor blade stall hazard created by low rotor RPM. However, the danger of rotor blade stall resulting from the application of rapid and excessive collective pitch is not covered. The following Safety Recommendation is therefore made:

Safety Recommendation 2005-021

It is recommended that the Robinson Helicopter Company consider including in the R44 and R22 Pilot's Operating Handbooks, a specific warning highlighting the possibility of a rapid and excessive collective pitch demand causing a hazardous loss of rotor RPM, together with guidance on the appropriate handling of the collective lever.

Following a considerable number of previous R22 and R44 accidents resulting from main rotor blade/fuselage strikes, concern has been expressed not only over the adequacy of rotor blade to fuselage clearance but also the maximum time delay that can safely be tolerated in reducing the collective pitch after a sudden power loss. Although the FAA Technical Panel assessments had concluded that FAA requirements in these regards were met or exceeded, it was clear that rotor RPM decay in the event of sudden power loss could be rapid. It was noted that a delay of as little as two seconds in selecting the collective lever fully down after activation of the low RPM caution on the R44 could result in an appreciable reduction in rotor RPM to a level that was not significantly above the RPM at which any further decrease was irreversible. The behaviour of the R22's rotor system is apparently similar. Federal Aviation Regulation (FAR) Part 27.143 concerning pilot reaction times states that:

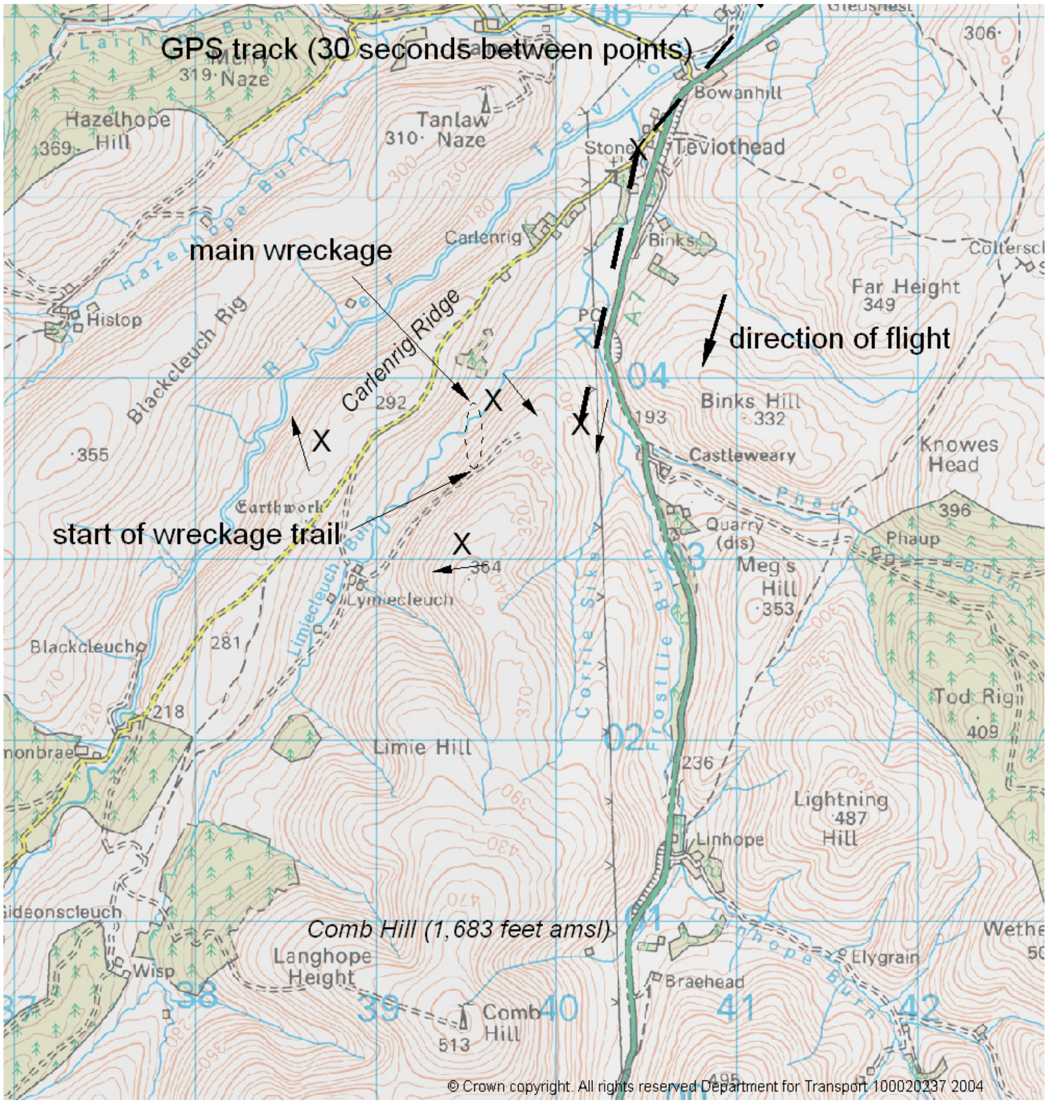
> *'No corrective action time delay for any condition following power failure may be less than - For the cruise condition, one second, or normal pilot reaction time (whichever is greater); and for any other condition normal pilot reaction time.*

It is therefore questionable that pilots, particularly of relatively low experience, should be expected to consistently and reliably react within, what appears to be, an unrealistic timescale.

The following Safety Recommendation is therefore made:

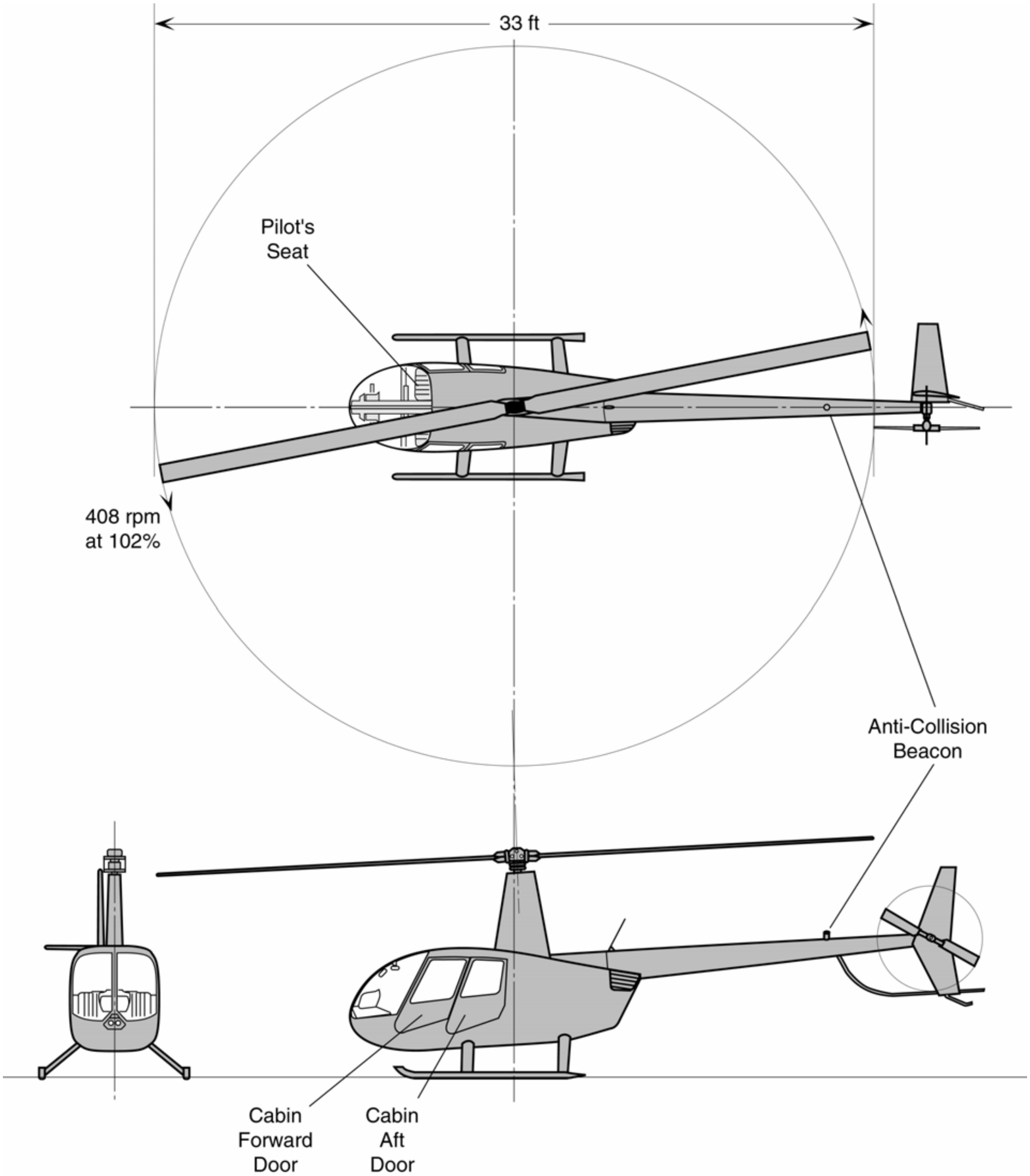
Safety Recommendation 2005-022

It is recommended that the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) reassess the 'corrective action time delay' in reducing the collective control after sudden power loss on a single-engined helicopter, with the aim of ensuring, as far as possible, that the minimum reaction time required is realistically within the capability of an average qualified pilot.



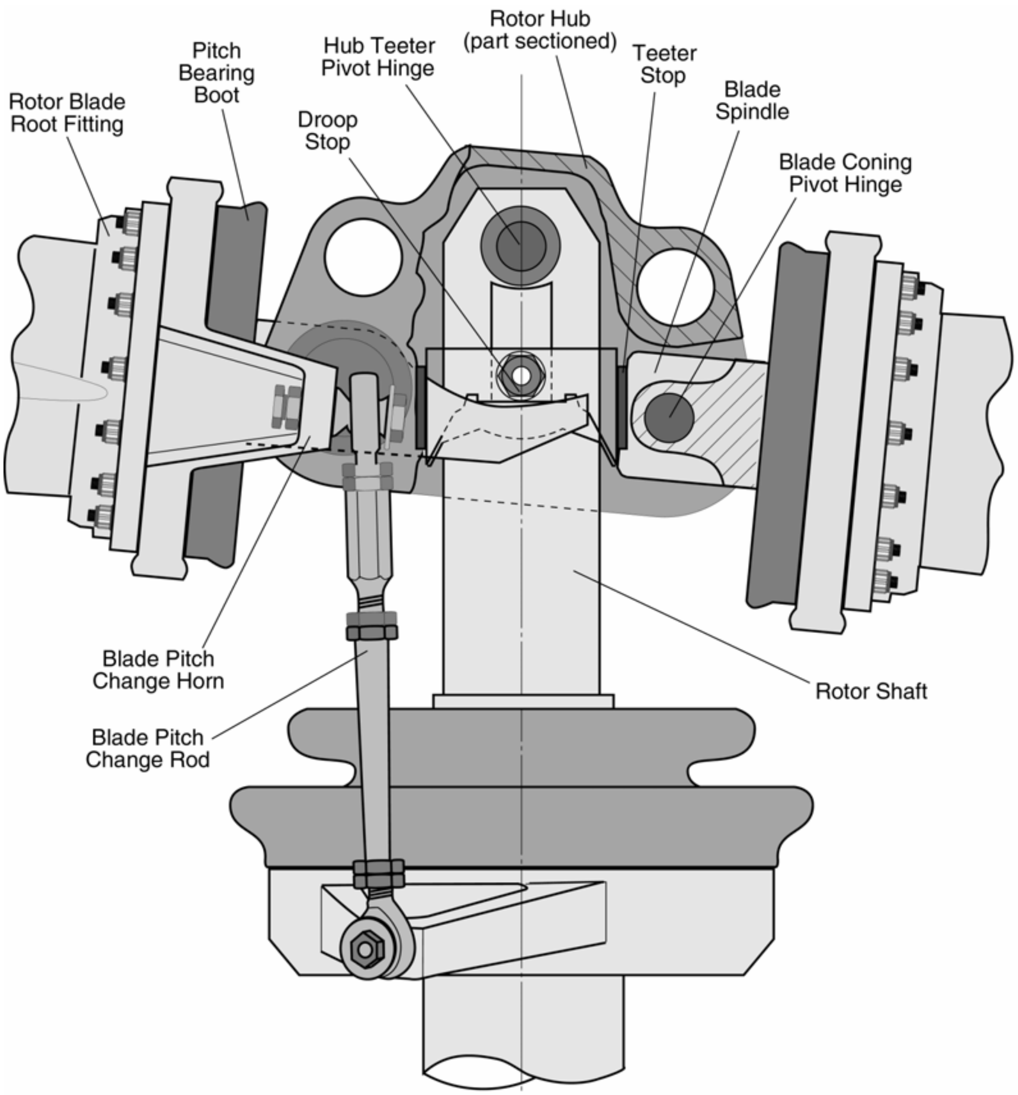
Final GPS track of G-OUEL and wreckage site location

Figure 1



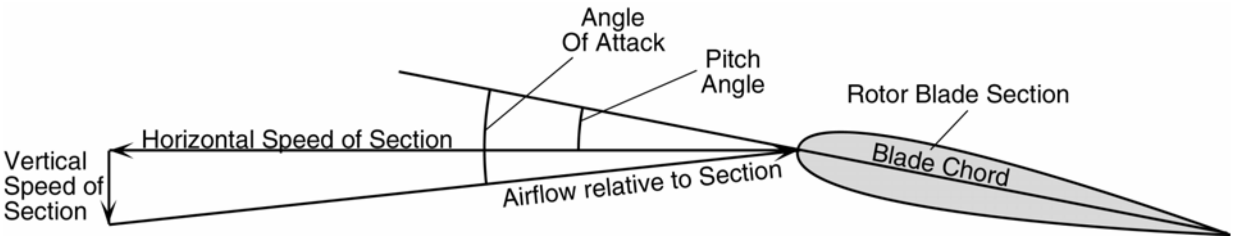
Robinson R44 - General arrangement

Figure 2



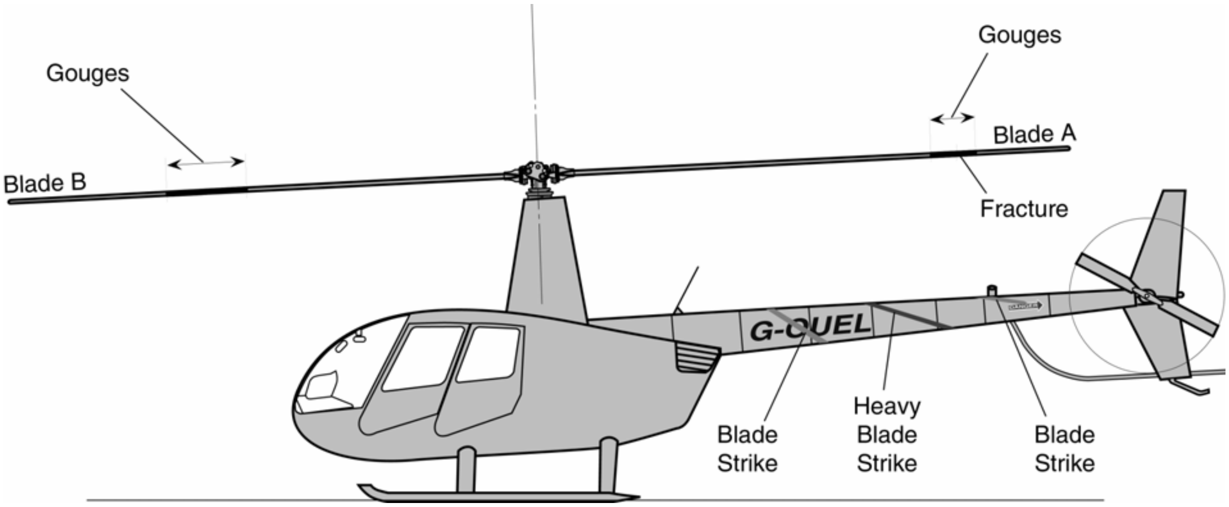
Robinson R44 Main Rotor Head

Figure 3



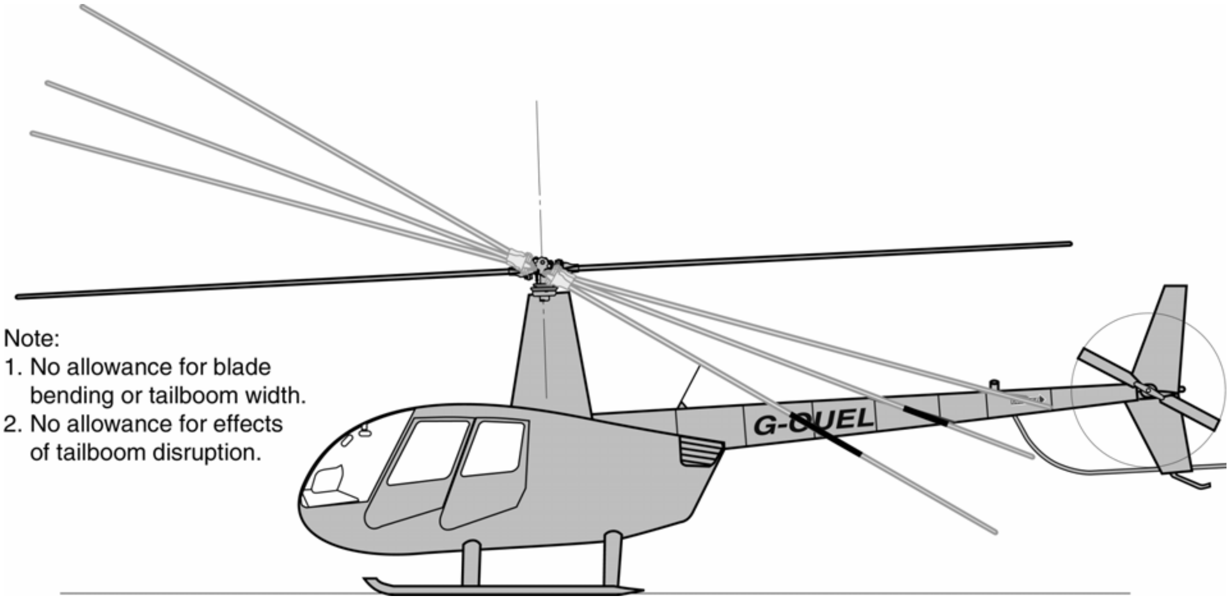
Rotor Blade Angles

Figure 4



G-OUEL - Main rotor blade and tailboom marks

Figure 5



Note:
1. No allowance for blade bending or tailboom width.
2. No allowance for effects of tailboom disruption.

Schematic of possible main rotor blade strikes on tailboom

Figure 6

AAIB Bulletin No: 5/2005 **Ref: EW/C2004/04/03** **Category: 3**

Aircraft Type and Registration:	1) Slingsby T50 Skylark 4, BGA identification number 1116 2) Schempp-Hirth Ventus cT, BGA identification number 3259
No & Type of Engines:	1) None 2) 1 Solo 20.5 shp piston engine (removable)
Year of Manufacture:	1) 1963 2) 1987
Date & Time (UTC):	26 April 2004 at 1444 hrs
Location:	Approximately 1.4 nm west of Lasham Airfield, Hampshire
Type of Flight:	1) Private 2) Private
Persons on Board:	1) Crew - 1 Passengers - None 2) Crew - 1 Passengers - None
Injuries:	1) Crew - None Passengers - N/A 2) Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	1) Destroyed 2) Destroyed
Commander's Licence:	1) BGA Gliding Certificate 2) BGA Gliding Certificate
Commander's Age:	1) 46 years 2) 68 years
Commander's Flying Experience:	1) 65 hours (of which 18 hours were on type) 2) Approximately 10,270 hours (of which at least 1,500 hours were on type)
Information Source:	AAIB Field Investigation

Synopsis

The Ventus and Skylark gliders collided while gliding at approximately 4,000 feet agl a short distance west of Lasham Airfield. Both were severely damaged. Visibility was generally in excess of 5 km, but was variable and decreased with height. The investigation concluded that the gliders had approached each other about 28° off head-on, probably while both were flying straight and level. Following the collision, the pilot of the Skylark parachuted to the ground with no injuries. The pilot of the Ventus was injured in the collision and was still in his aircraft when the main wreckage impacted the ground.

Safety recommendations have been made regarding international co-operation and action to improve the conspicuity of gliders and light aircraft, a study to assess means of improving light aircraft conspicuity, the adoption of measures likely to be cost-effective and operational advice to glider pilots concerning flight in IMC or marginal VMC conditions.

History of flight

On the day of the accident, Lasham Gliding Society was operating both aerotow and winch launches. The Ventus was launched at 1130 hrs, using an aerotow. It remained continuously airborne until the collision with the Skylark. At the time of the collision, at least 11 other gliders were airborne from Lasham Airfield. No one saw the collision, although two airborne witnesses saw a descending parachute and an aircraft in an uncontrolled descent. On the ground, a witness saw one aircraft spinning towards the ground, another aircraft descending with part of one wing missing. This latter witness also saw a parachute and raised the alarm at the aerodrome.

The surviving pilot, in the Skylark, was undergoing a course to complete the requirements for a Silver Gliding Certificate and had been at Lasham since about 0800 hrs on the morning of the accident. He had received a weather briefing from one of the gliding instructors and, at about 1030 hrs, was informed that the conditions appeared suitable for an attempt at a five-hour duration flight to complete the Silver Certificate requirements. He prepared his aircraft and had an uneventful winch launch at 1233 hrs; he released his glider at about 1,200 feet agl and initially headed towards the north. Over the next two hours, he remained within about 8 nm of Lasham and was always confident that he could recover to the airfield. He considered that the weather was bright but hazy and that the wind appeared light and variable throughout his operating heights. The visibility became somewhat "murkier" as he climbed.

He then headed for the area between Alton and Lasham and, as he did so, noticed two red gliders thermalling (ie circling in a thermally induced column of rising air) in a position above and to his right. Ahead of him, he saw a cumulus cloud and, as he approached the area beneath the cloud at approximately 3,000 feet agl he saw a white glider thermalling below the cloud base but about 1,000 feet above him. The white glider in the thermal was in a left turn and, the pilot of the Skylark joined the thermal in the same direction. Once established in the thermal, the pilot looked for the glider above him but being unable to see it, he presumed that it had left the thermal. At the time, he still had visual contact with the two red gliders, which were well away from his geographical position.

After about five minutes, having achieved a height gain of about 1,000 feet, he decided to leave the thermal and head in the general direction of Basingstoke. As he levelled his wings at approximately 4,000 feet agl, with airspeed between 45 and 50 kt and on a heading of about 270°M, the pilot looked to the left for the red gliders. He could not see them and looked forward. He was then confronted with a white glider, which he later stated "seemed to fill my windscreen". He recalled that its wings appeared level and that he could see directly into a towing hook recess in the nose of the glider. The glider was slightly above him and about 10° to his left.

The surviving pilot recalled that everything happened very quickly and his immediate instinct was to push forward on the control column. He was not sure that he managed to do so before he heard a "big bang" behind his head. He had instinctively closed his eyes and when he opened them, his aircraft appeared stable but was descending and he could see green fields directly ahead. The pilot could not remember releasing his canopy but recalled releasing his harness and then being thrown forward out of the aircraft. After a few moments of tumbling, he pulled his ripcord and his parachute deployed. He then saw his own aircraft descending but with part of one wing detached and with no tail section. He also saw an aircraft canopy descending and saw the white glider. It appeared intact but not in control and it struck the ground shortly after his own aircraft. After a successful parachute landing, the pilot ran to a nearby house, where he telephoned the airfield to advise them of the collision. He then ran to the site of the crashed white glider and found that other personnel from the Gliding Society were already there.

The surviving pilot subsequently confirmed that he had not entered cloud during his flight and did not consider that the position of the sun was a factor at the time of the accident.

Aircraft descriptions

Ventus

The Schempp-Hirth Ventus cT is a single-seat motor-assisted glider with a 17.6 metre (57.7 feet) wingspan (Figure 1). It is configured with a mid wing and a T tail. The fuselage and empennage (fin and tailplane) are primarily constructed of glass-fibre reinforced plastic (GRP) and the wings of carbon-fibre reinforced plastic (CRP). A bay in the fuselage immediately behind the cockpit contains a small powerplant, consisting of a petrol reciprocating engine driving a propeller, which can be deployed into the airflow to maintain altitude. The landing gear consists of a main wheel, retractable in flight, and a tail wheel.

Records indicated that the accident glider (Aircraft Serial Number 093) had been constructed in 1987 and had accumulated 2,545 flight hours and 723 launches at 7 February 2004. The flight time subsequent to this date could not be determined. It had been owned by the pilot involved in the accident for five years. The aircraft was designated as British Gliding Association (BGA) 3295 and had a valid BGA Certificate of Airworthiness, issued on 7 February 2004. The whole aircraft had a gloss white external finish, apart from black decals on both sides of the fin and the forward fuselage.

Skylark

The Slingsby T50 Skylark 4 is a single-seat glider with a 17.9 metre (58.7 feet) wingspan (Figure 1), constructed of a wooden framework covered generally with plywood and in places with fabric. It has a high wing and the tailplane is located near the base of the fin. The landing gear consists of a single non-retractable wheel fitted to the bottom of the fuselage and a tail skid.

Records indicated that the accident glider (Aircraft Serial Number 1384) had been constructed in 1963 and had accumulated 2,205 flight hours and 2,133 launches at 16 April 2004. The aircraft was designated as BGA1116 and had a valid BGA Certificate of Airworthiness, issued on 16 April 2004. The external finish was gloss cream paint on the fuselage and fin and gloss bright red paint on the wings, rudder and tailplane.

General view from the cockpits

As with most higher-performance gliders, the fuselages of both the Ventus and the Skylark types have relatively small cross-sections, with maximum dimensions in the order of approximately 2.1 feet wide and 2.7 feet high for both aircraft. Consequently, the pilot is semi-supine when seated in either aircraft. In both cases the cockpit, located forward of the wing, is faired with a single-piece clear transparent canopy that is unobstructed by any reinforcing frame members. For a seated pilot, the arrangements in both gliders provide a generally excellent unobstructed field of view, compared with many aircraft types, although there is inevitably some obstruction of the forward and downwards view by the nose of the glider and the instrument panel.

Wreckage examination

Examination of the accident sites showed that the Ventus and Skylark gliders had impacted the ground 474 metres apart and that components from both aircraft were scattered in two trails located in the area between them.

Ventus

The main wreckage of the Ventus was located in open country near the top of a rise, at Ordnance Survey Reference SU659423, 518 feet amsl. The terrain in the immediate area was flat, with moderately heavy soil covered with short grass interspersed with a number of saplings.

The evidence showed that the engine and the landing gear wheel had both been in the retracted position at ground impact. There was no fire.

The aircraft was generally intact but with severe damage to the forward part of the fuselage, extending over the entire cockpit area. An appreciable ground crater had been formed by the nose section, which had suffered considerable break-up and had detached. Additionally, the fuselage had completely fractured between the wing and the empennage, the fin and rudder had sustained fractures, the wing and tailplane leading edges had suffered impact damage and the outer part of the right wing had detached. Extensive spattered blood deposits were present on the external surfaces of the fuselage aft of the cockpit and on the empennage; the pattern of the deposits made it clear that these had occurred before ground impact.

Ground marking and wreckage characteristics showed that the Ventus had struck the ground while pitched about 90° nose down, travelling with high vertical speed and little or no horizontal speed. It was judged that the ground impact would not have been survivable. The damage was generally consistent with the effects of ground impact but it was clear from markings on the wreckage that some of the empennage and nose damage had occurred in the collision.

A number of items from the Ventus were found in a trail running from the main wreckage back to just north of the Skylark main wreckage position. These consisted of numerous components from the cockpit and several small pieces of GRP structure.

Detailed examination revealed multiple red paint deposits scraped onto the underside of the forward fuselage. The deposits were centred on the aircraft's centreline and extended over almost the whole length of the cockpit. They were angled 10° to the centreline, from right to left, forward to aft. There were also cream paint deposits scraped on the left side of the forward fuselage beneath the canopy coaming.

Skylark

The main wreckage of the Skylark was located in a field 474 metres on a bearing of 200°T from the Ventus, with severe impact damage. Components forming a significant proportion of the Skylark had been scattered in a broad trail running west for a distance of 255 metres from a point around 75 metres north of the main wreckage. The trail consisted largely of items from the cockpit and rear fuselage together with the canopy and most of the empennage and included the intact outer section of the right wing. Detailed examination indicated that the attachments for this wing section had failed in downward overload, indicative of excessive negative aerodynamic lift forces on the wing. Based on BGA information, it was judged likely that such a failure could result from the rapid aircraft nose down pitch that would result from the sudden loss of the tailplane. The evidence indicated that the canopy had been released before ground impact.

Scrape marks and heavy gouges that were not consistent with ground impact effects were present on the upper surface of the left wing, 4.9 feet outboard of the fuselage centreline. The markings passed across the top of the heavily-built wooden wing spar. They were angled 18° to the aircraft's centreline, from left to right, forward to aft. The spacing between two deep gouges matched that between two small steel brackets protruding from the underside of the Ventus beneath the aft part of the cockpit.

Collision evidence

The distribution of the wreckage, with estimated allowances for likely ballistic and wind drift effects, indicated that the gliders had collided close to Ordnance Survey Reference SU657420, approximately 400 metres south-south-west of the Ventus crash site.

It was clear from the markings on the two gliders that the underside of the nose of the Ventus had made forcible contact with the top surface of the Skylark's left wing in the area of its robust spar. This was followed by collision between the forward fuselage of the Ventus and the empennage of the Skylark, as indicated by geometric considerations and by a number of items of evidence. These included wreckage distribution features, the cream paint scrape on the Ventus and the findings, when the Skylark empennage parts were laid out in order, of particularly severe damage to the inboard part of the left tailplane and of GRP fragments embedded in a control mechanism in the tailplane root.

The evidence showed that the collision resulted in severe disruption of the Ventus' cockpit area and indicated that the pilot was gravely injured at this time.

Contact between the wings of the two gliders would have been inevitable had their roll angles been only a few degrees different. The absence of any sign of such contact, together with the central location of the markings on the Ventus, indicated virtually identical roll angles at the time of the collision, consistent with both gliders having been level in roll, as reported by the Skylark pilot. The available evidence suggested that neither glider had a substantially different pitch attitude or had been climbing or descending at an appreciable rate relative to the other at the collision point, but these parameters could not be quantified.

The angles of the collision markings showed that the Ventus had been tracking 332° relative to the Skylark at the collision (ie 28° from head-on, Figure 1). The Ventus travelled around 400 metres north-north-east from the collision point but, as there was no definitive evidence as to its manoeuvres after the collision, neither the absolute heading nor track of either glider when they collided, nor their altitude, could be established. Evidence of the speed of either glider was not available from the examination and the calculation of other collision parameters was based on an assumed Skylark airspeed of 45-50 kt, as reported by its pilot, and on the angles of the scrapes on the gliders. With this assumption, the Ventus' airspeed would have been 78-87 kt and the resultant closing speed 120-133 kt.

Weather information

The Meteorological Office provided an aftercast of the weather information. The synoptic situation at 1200 hrs showed a slack, slow moving area of low pressure centred over the Midlands. Relatively stable and dry conditions existed over Southern England with a light, mainly south-easterly airflow. Cloud was FEW cumulus, base at 5,000 feet amsl and BKN cirrus, base at 25,000 to 30,000 feet amsl. The wind was 060°/03 kt at the surface and 160°/03 kt at 4,000 feet amsl. The surface visibility was 15 km. There was a small inversion around 4,500 feet amsl. Just below this level, it was likely that the visibility would have been reduced, although this could not be quantified. At 1445 hrs, the sun was at 40° elevation and on a bearing of 236°T.

Other pilots airborne at the time provided information on the weather. It was generally agreed that the cloud cover had increased throughout the day but that the base was no lower than about 4,500 feet agl. The sun was high in the sky and towards the south-west. Visibility was generally greater than 5 km but was variable and decreased with height. Visibility appeared better in a horizontal direction rather than looking from air to ground. One experienced instructor was launched at 1156 hrs. He found that the cloud base was indistinct and that the soaring conditions were inconsistent. In the Alton area at around 4,700 feet, he considered that the horizontal visibility was poor and because of this he returned to the airfield, landing at 1301 hrs.

Recorded information

National Air Traffic Services Limited provided information on radar returns for the time and area of the collision. However, no useful information could be determined as to the manoeuvres of either glider prior to the collision.

Both gliders were carrying recording devices, which were subsequently examined to determine if any useful information could be obtained as to the flight profile of the gliders.

The Skylark had a data logger installed but investigation confirmed that the unit had not been switched on for the flight.

The Ventus had a number of items of navigation/recording equipment on board, including a GPS receiver and a small digital computer which could have recorded flight parameters. Both these items were found in the wreckage trail one to two days after the accident. Using information from the manufacturers, attempts were made to extract information from the two units. Unfortunately, the batteries from both units had depleted and no information had been retained.

Other information

Another glider pilot reported that he had spoken with the pilot of the Ventus by radio while they were both airborne. The pilots had spoken at about 1230 hrs when the Ventus was reportedly near Salisbury and heading west. A further contact at approximately 1315 hrs indicated that the Ventus was near Wincanton and heading north as the weather was deteriorating to the west. No further reported contact was made with the Ventus.

Lasham Aerodrome is located outside the Odiham Aerodrome Traffic Zone (ATZ) but within the associated Military ATZ. The collision occurred in Class G airspace which extends vertically from ground level to the base of the London Terminal Control Area at an altitude of 5,500 feet.

Most gliders operate under Visual Flight Rules (VFR) which in turn means they are flown in Visual Meteorological Conditions (VMC). In Class G airspace between 3000 feet amsl and FL100, VMC minima are 5 km visibility, plus separation from cloud by 1,500 metres horizontally and 1,000 feet vertically. Below 3,000 feet amsl, pilots are required to remain clear of cloud and in sight of the surface; at airspeeds less than 140 kt the minimum visibility requirement is reduced to 1,500 metres.

However, gliders may also be flown in accordance with the Instrument Flight Rules (IFR) in Class G airspace. To comply with the IFR below 3,000 feet amsl, glider pilots must either remain at least 1,000 feet above the highest obstacle within a distance of 5 nautical miles, or remain clear of cloud and in sight of the surface. Above 3,000 feet amsl or above the appropriate transition altitude, whichever is the higher, all aircraft should comply with Rule 30 regarding (quadrantal) flight levels but since gliders cannot normally transit in level flight, they are unable to comply with Rule 30. Moreover, since there is no legal requirement for a glider pilot to hold a licence, there is no legal requirement for a glider pilot to hold an instrument flying qualification. Nevertheless, almost all gliding activity in the UK is supervised by the BGA which publishes its own laws and rules. The Association has operational regulations that govern cloud flying and a training system which leads to progressive increases in privileges and achievements. In effect, the BGA's training system and awards are analogous to the licensing system for private pilots of powered aeroplanes.

The CAA and the BGA retain statistics of mid-air collisions within the UK. From 1987 to April 2004, there have been 28 collisions involving gliders; of these, 12 collisions resulted in fatalities. Eight of the collisions involved a glider and a General Aviation (GA) aircraft, of which 6 were towing aircraft. One other involved a collision between a glider and a free fall parachutist and the other 19 were collisions between 2 gliders. The glider to glider collisions occurred predominantly while thermalling, with 13 of the collisions occurring during these manoeuvres. As a general comparison, there have been 20 collisions between two GA aircraft over the same period.

Over the past few years, trials have been conducted by various organisations in the UK and overseas to attempt to quantify the effectiveness of ways to increase the conspicuity of aircraft. The use of colour, reflecting surfaces, strobe lights and electronic surveillance devices are possible ways of achieving greater conspicuity. However, all have some inherent disadvantages.

The visual means are dependent on continuous vigilance by the pilot and are affected by the prevailing light and background conditions. Coloured surfaces produce a higher skin temperature when exposed to sunlight than would be the case with a white surface and this reduces the strength of the composite materials from which most modern gliders are constructed. Effective strobe lights require electrical power in quantities not normally available in gliders. Electronic surveillance devices set to provide adequate warning of a conflict between aircraft in transit would tend to provide frequent nuisance alerts for gliders thermalling, when a number of aircraft can knowingly be flown in close proximity, but it is the environment where most glider collisions occur.

Medical information

An autopsy carried out on the deceased pilot by an aviation pathologist indicated that the pilot had died from multiple injuries. The pathologist was unable to differentiate between injuries sustained during the collision and injuries resulting from the ground impact. There was no evidence of any toxicological factor which could have caused or contributed to the accident.

From 1 March 2003, the BGA aligned their medical standards with the UK National Private Pilot's Licence. These are based upon UK Driver and Vehicle Licensing Agency (DVLA) standards. Solo glider pilots are required to achieve Group 1 (private driver) standards. To instruct or to carry passengers, pilots are required to achieve Group 2 (professional driver) standards. With effect from 1 March 2003, pilots have been required to obtain a General Practitioner (GP) endorsement to their own declaration of fitness to fly. For pilots beyond the age of 65 years, this is required annually. Both pilots had complied with the applicable requirements.

Analysis

The collision occurred with both gliders flying in straight transit flight. Whilst the flight profile of the Ventus could not be positively determined, the assessed closing speed indicated that the pilot was transiting rather than repositioning within a thermal. The pilot of the Skylark had just left a thermal and had initiated a visual search, primarily to re-acquire previously seen gliders that he had assessed as possible conflictions. When he looked ahead, there was insufficient time to manoeuvre clear of the approaching glider.

The pilot of the Ventus had reported near Wincanton, some 53 nm west of Lasham approximately 90 minutes before the collision. There was no evidence to confirm the movements of the glider from Wincanton but the time available meant that its pilot had the flexibility to return direct to Lasham and operate in the local area or to delay his return. Therefore, it was not certain that the Ventus was the white glider seen high in the thermal by the pilot of the Skylark.

The forecast weather conditions were suitable for gliding. However, the actual conditions encountered by at least one experienced pilot resulted in him landing early. Nevertheless, many other pilots remained airborne, indicating that they considered that the conditions were suitable for gliding. The nature of the sport is such that weather conditions can change dependent on the area and/or the time. Within the overall supervision of the Chief Flying Instructor, the decision to continue gliding remains with individual pilots. The fact that one experienced pilot landed early while others remained airborne tended to indicate that conditions were variable. The surviving pilot considered that conditions were satisfactory but he was conscious that the visibility deteriorated with height and proximity to cloud.

Gliders are particularly susceptible to airborne collision for two main reasons. Firstly, their small cross-section makes it difficult to acquire and maintain visual contact. Secondly, they tend to congregate in airspace where there are rising air currents (especially thermals). The BGA is conscious of this potential danger and attempts to ensure that pilots are inducted with good lookout techniques from initial training. Very comprehensive written material is provided to every gliding instructor as part of the BGA Instructors' Manual. However, students are dependent on their instructor for the amount of information passed on. Following the accident, and after discussion between the BGA and the AAIB, it was agreed that the BGA would provide the material on lookout techniques to every pilot member of the BGA.

Evidence from the surviving pilot was that he was in straight transit flight at approximately 45 to 50 kt when the collision occurred. He also considered that the other glider was in straight transit flight. The assessment that the Ventus' airspeed was in the order of 83 kt indicated that it was flying at around normal cruising speed, rather than the lower speed that would be used for thermalling. Although this also indicated that the Ventus was in transit, there was no available evidence to determine for how long it had been so doing. The Skylark had just been established in straight transit flight and the reported visual lookout actions of the pilot were appropriate for the situation.

There is no way of knowing the visual lookout procedures of the pilot of the Ventus but, as a very experienced glider pilot, he would have been well aware of the need to maintain a regular lookout. The collision occurred at a time when the two gliders were close to head on to each other. In that situation, it would have been difficult for each pilot to acquire the other glider because of the small cross-section of each aircraft and the fact that, on a collision course, there would have been no relative movement between the two aircraft.

It appeared that neither pilot saw the other glider in time to initiate any effective avoidance manoeuvre. When the pilot of the Skylark became aware of the Ventus, his instinctive reaction was to initiate a descent but he was not sure that he was able to take any action before the collision. The Rules of the Air include the action to be taken when aircraft are on a collision course but, to be effective they are obviously dependent on acquiring the other aircraft in time to allow recognition, decision and action. In this case the late sighting meant that there was insufficient time for effective avoiding action to be taken.

Both pilots were entitled to be in that airspace and, as such would have been relying on the principle of 'see-and-avoid'. However, that principle was not effective in this case. While the nature of gliding would preclude stringent airspace rules and regulations, it would appear sensible to evaluate further means of increasing glider conspicuity and to require effective measures to be adopted. Various organisations within the UK (and abroad) have been involved in trials looking at different aspects of this subject but it would seem to be appropriate for one organisation to take the lead with a view to evaluating the various possibilities and determining the way ahead. During this accident investigation, a review of the statistics involving collisions indicated that the problem was not confined to gliders. Last year, the AAIB investigated a collision between a light helicopter and a microlight aircraft. The resulting report, contained in AAIB Bulletin 4/2005, concluded that the limitations of the human eye and lack of aircraft conspicuity were contributory factors to that accident.

Accordingly, it is considered that the organisation best placed to lead any study would be the CAA. However, it would be necessary to include other organisations, such as the BGA, in any study. Therefore, the following recommendation has been made:

Safety Recommendation 2005-006

It is recommended that the Civil Aviation Authority should initiate further studies into ways of improving the conspicuity of gliders and light aircraft, to include visual and electronic surveillance means, and require the adoption of measures that are likely to be cost-effective in improving conspicuity.

Safety Recommendation 2005-008

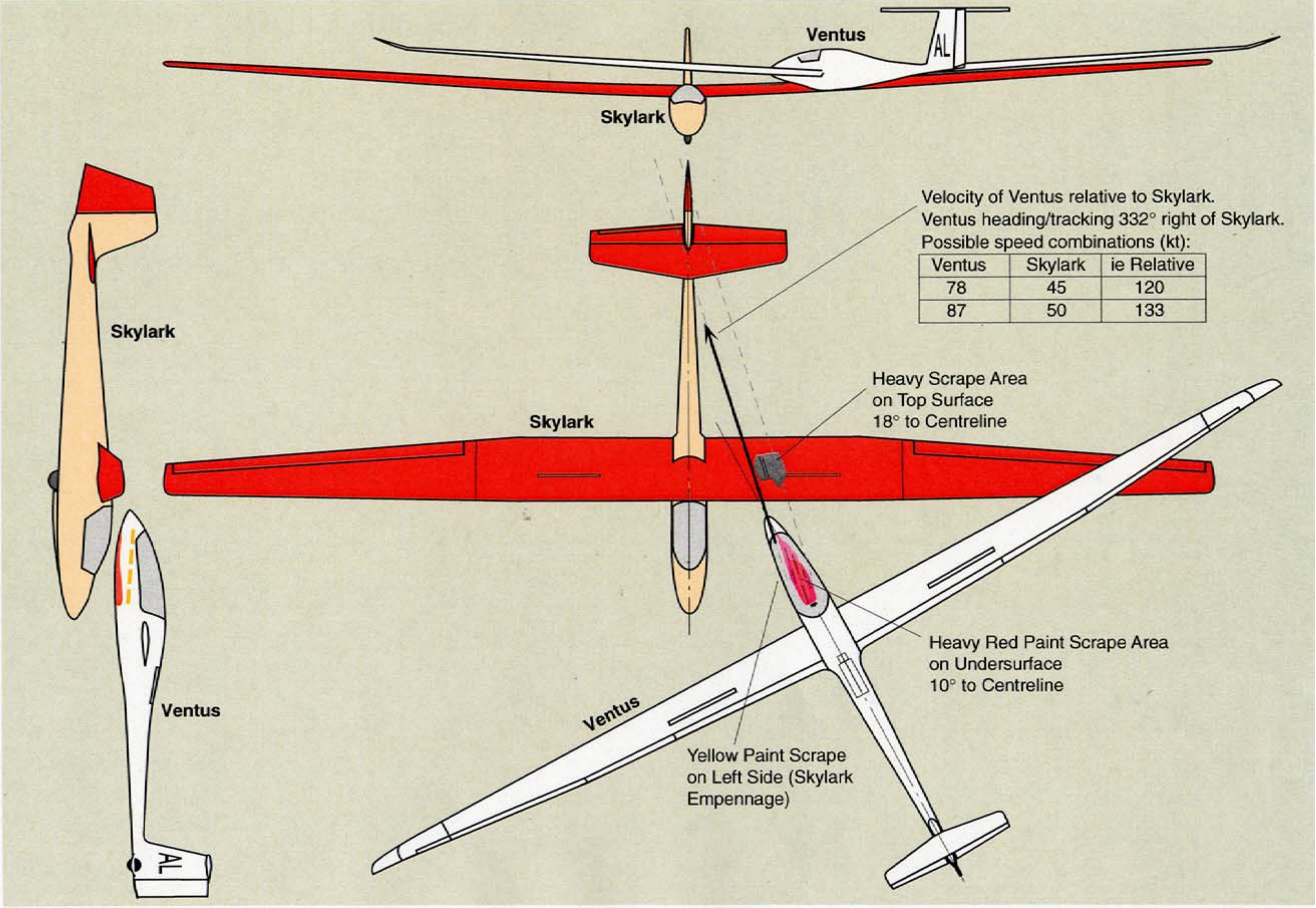
It is recommended that the Civil Aviation Authority should promote international co-operation and action to improve the conspicuity of gliders and light aircraft through visual and electronic methods.

Additionally, the 'see and avoid' principle requires every glider pilot to be able to see other gliders in sufficient time to take successful avoiding action. The extant BGA rules for cloud flying and thermalling help to minimise the risk of glider to glider collisions but other legitimate users of unregulated airspace, who may be flying faster aircraft than gliders, may need more time (and hence greater visibility) to take effective avoiding action around a single glider or, indeed, even greater visibility to manoeuvre around a group of thermalling gliders using the same 'see and avoid' principle. Consequently, although glider pilots may fly legally in weather conditions that are below VMC minima, they should not depend upon their own or other pilots' abilities to 'see and avoid' each other in marginal VMC conditions. It is difficult to define 'marginal' conditions and it is not easy to measure horizontal visibility in the air, particularly when approaching the diffused boundary between clear air and cloud base. The assessment of 'marginal' conditions is a matter of airmanship and so, it has been recommended to the BGA that:

Safety Recommendation 2005-046

The British Gliding Association should review its operational advice to and training for glider pilots with respect to flying in IMC and marginal VMC conditions.

VENTUS/SKYLARK COLLISION SCHEMATIC



Velocity of Ventus relative to Skylark.
Ventus heading/tracking 332° right of Skylark.
Possible speed combinations (kt):

Ventus	Skylark	ie Relative
78	45	120
87	50	133

Figure 1

RECENT AIRCRAFT ACCIDENT AND INCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

THE FOLLOWING REPORTS ARE AVAILABLE ON THE INTERNET AT http://www.aaib.gov.uk

1/2004	BAe 146, G-JEAK during descent into Birmingham Airport on 5 November 2000	February 2004
2/2004	Sikorsky S-61N, G-BBHM at Poole, Dorset on 15 July 2002	April 2004
3/2004	AS332L Super Puma, G-BKZE on-board the West Navion Drilling Ship 80 nm to the west of the Shetland Islands on 12 November 2001	June 2004
4/2004	Fokker F27 Mk 500 Friendship, G-CEXF at Jersey Airport, Channels Islands on 5 June 2001	July 2004
5/2004	Bombardier CL600-2B16 Series 604, N90AG at Birmingham International Airport on 4 January 2002	August 2004
1/2005	Sikorsky S-76A+, G-BJVX near the Leman 49/26 Foxtrot platform in the North Sea on 16 July 2002	February 2005

ABBREVIATIONS COMMONLY USED IN AAIB BULLETINS

ADELT	automatically deployable emergency locator transmitter
ADF	automatic direction finding equipment
AFIS(O)	Aerodrome Flight Information Service (Officer)
AFS	Aerodrome Fire Service
agl	above ground level
AIC	Aeronautical Information Circular
amsl	above mean sea level
APU	auxiliary power unit
ASI	airspeed indicator
ATC(C)	Air Traffic Control (Centre)
BMAA	British Microlight Aircraft Association
CAA	Civil Aviation Authority
CG	centre of gravity
°C,F,M,T	Celsius, Fahrenheit, magnetic, true
DGAC	Direction Général à l'Aviation Civile
DME	distance measuring equipment
EGT	exhaust-gas temperature
ETA	estimated time of arrival
ETD	estimated time of departure
FAA	Federal Aviation Administration (USA)
FIR	flight information region
FL	flight level
ft/min	feet per minute
g	normal acceleration
gall imp/US	gallons, imperial or United States
hrs	hours
hPa	hectopascal
IAS	indicated airspeed
IFR	Instrument Flight Rules
ILS	Instrument landing system
IMC	Instrument Meteorological Conditions
IR	Instrument Rating
IRE	Instrument Rating examiner
ISA	international standard atmosphere
kg	kilogram(s)
KIAS	knots indicated airspeed
km	kilometre(s)
kV	kilovolt
kt	knot(s)
lb	pound(s)
LDA	landing distance available
mb	millibar(s)
MDA	Minimum Descent Altitude
mm	millimetre(s)
mph	miles per hour
MTWA	Maximum Total Weight Authorised
NDB	non-directional radio beacon
nm	nautical mile(s)
NOTAM	Notice to Airman
OCH	Obstacle Clearance Height
PAPI	Precision Approach Path Indicator
PAR	precision approach radar
PFA	Popular Flying Association
PIC	pilot in command
psi	pounds per square inch
QFE	pressure setting to indicate height above aerodrome
QNH	pressure setting to indicate elevation above mean sea level
RPM	revolutions per minute
RTF	radiotelephony
RVR	runway visual range
SAR	Search and rescue
SSR	secondary surveillance radar
TAF	Terminal Aerodrome Forecast
TAS	true airspeed
TGT	turbine gas temperature
UTC	Co-ordinated Universal Time
V_1	Decision speed
V_2	Take-off safety speed
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VHF	very high frequency
VMC	Visual Meteorological Conditions
V_{ne}	never exceed airspeed
V_R	Rotation speed
VOR	VHF omni-range