Aircraft Type and Registration:	Boeing 777-236, G-VIIO
No & Type of Engines:	2 General Electric GE90-85B turbofan engines
Year of Manufacture:	1999
Date & Time (UTC):	16 August 2004 at 2317 hrs
Location:	Off the coast of the USA during climb
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 15 Passengers - 334
Injuries:	Crew - 5 (Minor) Passengers - 1 (Serious)
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	16,796 hours (of which 3,755 were on type) Last 90 days - 186 hours Last 28 days - 83 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

History of the flight

The aircraft was on a scheduled flight from Orlando Airport in the USA to London Gatwick Airport. Push back was at 2133 hrs with departure delayed until 2247 hrs due to ATC delays. The departure ATIS weather was reporting a surface wind of 140º/05 kt, visibility 7 km in light rain with cloud FEW at 1,500 feet and BKN CB (broken cumulonimbus) at 3,000 feet, OAT 24ºC and Dew Point 20ºC. The remnants of a hurricane were shown on the SIGMET (Significant Meteorological Information) chart centred some 350 nm north of Orlando.

The aircraft commander was the handling pilot for the flight and following departure, the aircraft was climbed towards the planned cruising level of FL370. The weather radar was set to 5º UP for departure and adjusted during the climb in order to scan the area ahead. No significant turbulence was encountered during the climb; the only weather returns were to the left of the aircraft's track and no closer than 50 nm. The area ahead of the aircraft shown on the weather radar displayed only green weather returns, the lowest level of precipitation returns depicted on the display, with the previously mentioned weather to the left painting either amber or red.

The aircraft was required by ATC to alter heading 10º to the right for other traffic and the commander checked the weather radar which continued to show green returns with the aircraft climbing in smooth air conditions. He discussed the requirement for the seat belt signs with the non-handling pilot and, given the length of time the passengers had been confined to their seats (almost 2 hours) and the smooth air conditions during the preceding 10 minutes, it was agreed they could be switched off. Shortly afterwards, with the aircraft climbing in IMC within cirrus cloud, the sky began to lighten. As the aircraft emerged from the cloud and as it was approaching FL320, it encountered severe turbulence. The indicated airspeed was seen to decay by approximately 20 kt, a momentary stick shaker activation occurred and the seat belt signs were selected ON. During the turbulence, a passenger suffered a broken ankle and five crew members received minor injuries.

Post turbulence encounter actions

The presence and position of the turbulence was reported to Jacksonville area control and was monitored by other aircraft in the area. The Cabin Service Director established the number and extent of the injuries and professional medical advice was sought on the treatment of the injured and whether the aircraft should divert. Following these discussions and consultation with the injured persons, it was agreed to continue to the planned destination of London Gatwick. The remainder of the flight was uneventful and the commander declared a medical emergency to Gatwick and was given an expeditious arrival routing.

Guidance to pilots on turbulence

The UK Civil Aviation Authority published an Aeronautical Information Circular (AIC) 81/2004 (Pink 66) entitled 'the effect of thunderstorms and associated turbulence on aircraft operations'. In the section dealing with the use of weather radar the document states:

> *'The significance of radar returns of given intensity usually increases with altitude, but the strength of the echo is not an indication of the strength of any turbulence'.*

Discussion

The crew had a difficult decision to make in balancing the risks of a potential turbulence encounter with the physiological needs of the passengers. Apart from the extensive presence of green radar returns indicating light to moderate precipitation, there was no associated weather indicated on the weather radar which might have warned the flight crew of the presence of the severe turbulence which, although short in duration, was severe. The person who suffered a broken ankle was standing with others waiting to use the toilet facilities. The maximum vertical accelerations were +2.367g and -0.352g. After the incident the commander was briefed by the operator not to switch off the seat belts sign whilst the aircraft was flying through green returns depicted on the weather radar.

INCIDENT

Aircraft Type and Registration:	Boeing 777-21H, A6-EMF	
No & Type of Engines:	2 Rolls-Royce Trent 877 turbofan engines	
Year of Manufacture:	1996	
Date & Time (UTC):	19 February 2005 at 1415 hrs	
Location:	Birmingham Airport, West Midlands	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 14	Passengers - 294
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Right-hand engine pylon panel 427AL delaminated	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	44 years	
Commander's Flying Experience:	10,684 hours (of which 1,920 were on type) Last 90 days - 186 hours Last 28 days - 34 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries by the AAIB	

Synopsis

On takeoff, the outer skin of panel 427AL on the inboard side of the right engine pylon, separated, falling onto the runway. The part of the panel remaining on the aircraft exhibited signs of heat damage to its forward edge.

There have been two other failures of a similar pylon panel 418AR, on the inboard side of the left engine pylon, one in 2003 and another more recently on 3 June 2005. These panels also showed evidence of heat damage at their forward edge. The aircraft manufacturer, Boeing, is examining the panel from the most recent event to try to determine the cause of the delamination.

The operator has introduced a repetitive inspection of the pylon panels on this particular aircraft (A6-EMF), until the cause of the panel failures has been identified. The aircraft manufacturer is not aware of any reports of problems with these panels on any other Boeing 777 aircraft.

History of the flight

Prior to departing on a scheduled passenger flight from Birmingham to Dubai, a routine inspection of the runway for debris was under way at Birmingham prior to A6-EMF's ('MF) departure. The inspection began at the 'A1' hold at the far end of the runway, with the 'checker' vehicle progressing towards the threshold of the active Runway 33. Prior to completing this inspection, the driver was instructed to leave the runway at holding point 'F1' to allow 'MF to be cleared for takeoff. The next aircraft was given conditional clearance by ATC to line up after 'MF's departure but was brought to a halt short of the runway, as the crew could see a large piece of debris on the runway itself, which they thought might have fallen from the departing Boeing 777. The debris was recovered and confirmed as being a metallic part from an aircraft (Figure 1).

After being appraised by ATC of the situation, the crew decided that they would continue the flight at a reduced speed until it could be verified that the debris had come from their aircraft. However, when climbing through FL260, with an airspeed of 260 kt, a vibration developed that grew progressively worse with increasing altitude. The climb was stopped at FL280 and a diversion was made to London Gatwick, which required the jettisoning of 20 tons of fuel to avoid exceeding the maximum allowable landing weight. The landing was completed uneventfully and, on inspecting the aircraft, it was observed that panel 427AL on the left side of the right engine pylon was missing its outer skin (Figure 2). There was no other damage to the aircraft.

Panel 427AL construction

The construction of the panel is typical of many on the Boeing 777 aircraft, comprising an aluminium honeycomb core sandwiched between skins of 2024 T81 aluminium. The skins are bonded using BMS 5-137 primer and BMS 5-90 adhesive, which have a curing temperature of 340-360ºF (171-182ºC) and a design service temperature of up to 350ºF (177ºC). The panel is attached to the pylon by 40 screws around its periphery. The area of the pylon in which the panel is located was designed to be exposed to a maximum temperature of 300ºF (149ºC).

Further investigation

The damaged panel 427AL was returned to the operator immediately for repair, and thus could not be examined by the AAIB, but photographs showed evidence of apparent heat damage to it's forward edge (Figure 2). The aircraft manufacturer believed the most likely source of heat to be a leak of core air from the engine.

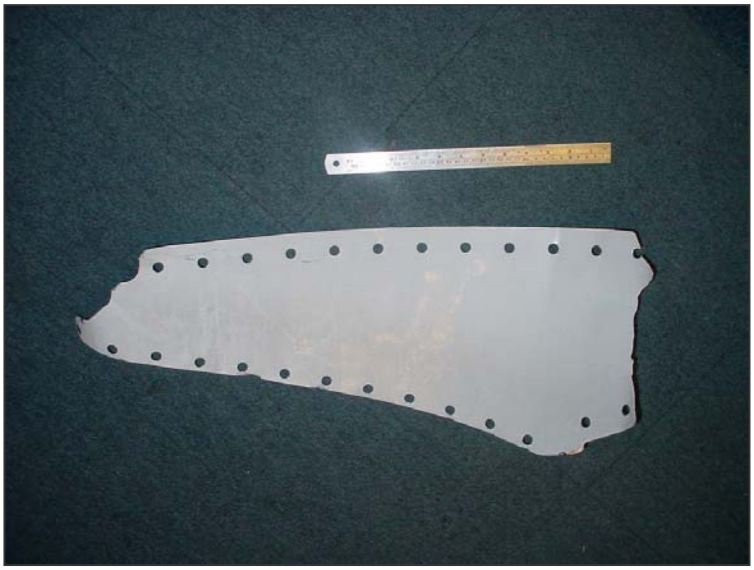
In early 2003 there was a report of this aircraft having experienced delamination of a similar panel, 418AR, on the inboard side of the left engine pylon. The panel also exhibited evidence of heat damage to its forward edge. On examining the panel, the aircraft manufacturer concluded that it had been exposed to temperatures of up to 350ºF (177ºC). Whilst this is within the acceptable service temperature range for the adhesive, exposure of the panel to such temperatures would cause some reduction in the strength of the adhesive bonds which, combined with the harsh environment of aerodynamic loads, high sonic vibration loads, and cyclic thermal stresses, would have increased the likelihood of the panel delaminating.

The operator conducted an inspection of its Boeing 777 fleet after this more recent occurrence, but no other aircraft were found with evidence of heat damage or delamination of the pylon panels.

Further panel delamination event

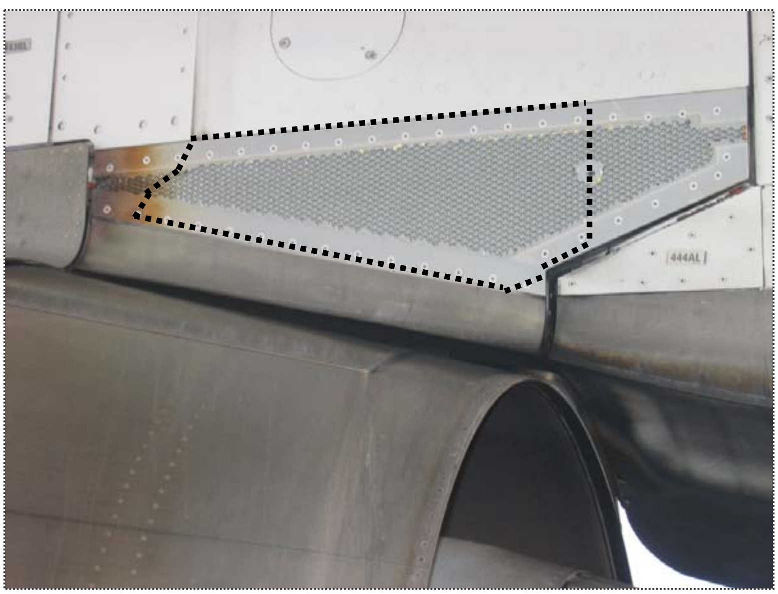
On 03 June 2005, 'MF experienced another occurrence of a pylon panel delaminating during takeoff at Islamabad in Pakistan. This latest event involved another failure of panel 418AR, similar to the event in 2003, and this panel was sent to the aircraft manufacturer for examination. The operator has since introduced a repetitive inspection of the pylon panels on this aircraft, until the cause of the panel failures has been identified. The aircraft manufacturer is not aware of any reports of problems with these panels on any other Boeing 777 aircraft.

Should any further relevant information become available, it will be included in an addendum to this Bulletin.



Section of outer skin of right engine pylon panel 427AL found on the runway

Figure 1



Delaminated panel 427AL showing heat damage at forward edge.
Recovered section indicated

Figure 2

INCIDENT

Aircraft Type and Registration:	DHC-8-311 Dash 8, G-JEDE
No & Type of Engines:	2 Pratt & Whitney Canada PW123 turboprop engines
Year of Manufacture:	1999
Date & Time (UTC):	29 November 2004 at 0914 hrs
Location:	London City Airport, London
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 32
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to skin of fuselage in tail section
Commander's Licence:	Airline Transport Pilot's License
Commander's Age:	64 years
Commander's Flying Experience:	17,500 hours (of which 1,400 were on type) Last 90 days - 59 hours Last 28 days - 19 hours
Information Source:	AAIB Field Investigation

History of flight

The aircraft and crew were engaged on their second of four sectors for that day from the Isle of Man to London City Airport (LCY). After an uneventful cruise, the first officer flew an ILS approach to Runway 10 which has a LDA of 1,319 metres. The 5.5º glidepath was intercepted from an altitude of 2,000 feet and manually flown with landing flap (15º) set. Although the first officer was the handling pilot for this sector, it is a company requirement for the commander to land the aircraft at LCY and handover of control was achieved at the ILS decision height of 430 feet. At this point the speed was V_{REF} +17 kt (108 kt). On taking control, the commander progressively reduced engine power and achieved V_{REF} +5 kt before entering the flare. He maintained the 5.5º glidepath using the precision approach position indicators (PAPIs) but on entering the flare reported heavy 'sink'. As the commander pulled back on the control column, the nose of the aircraft rose rapidly and the first officer called "six degrees pitch" in accordance with company Standard Operating Procedures (SOPs). The 'LDG ATT SIX DEG' message was also displayed on the advisory display unit. The first officer's call was not heard by the commander and almost simultaneously a firm landing was made. During the roll out the 'TOUCHED RUNWAY' red warning light on the flight deck was observed to be illuminated.

Aircraft damage

Examination of the aircraft revealed evidence of a light scrape mark on the aft underside of the fuselage adjacent to the tail-scrape detector. Both the white frangible plastic cover and the detector were completely abraded away. The substantial freight floor above the region of the detector prevented initial access from being gained to the internal structure. The airframe damage was however, in the light of information supplied by the manufacturer, judged to be sufficiently slight to enable the aircraft to be ferried elsewhere for repairs. No control problems were reported during the ferry flight or during the subsequent landing. Internal examination carried out after removal of the freight floor was reported as confirming the absence of structural damage other than that visible externally to the skin.

Examination of the runway close to the western threshold revealed a fresh white mark, parallel to the runway axis, close to the centreline, identified as having been made by the cover of the tail-scrape detector. Fragments of the plastic material of the latter were recovered from that area. The position of the white mark was noted to be significantly nearer the threshold than the general touchdown region denoted by the concentration of tyre markings.

Weather

The meteorological report for LCY at 0850 hrs described a surface wind of 360º/8 kt with good visibility and little cloud. The crew reported that there was little turbulence on the approach but considered that the recently glazed building to the north of the runway may have induced some turbulence at their touchdown point. Other crews landing that morning did not report any turbulence but there is anecdotal evidence of turbulence when the wind is stronger from the same direction.

Company procedures

The company Operations Manual Section 2.2.1.23.1 entitled Precision Approach Diagram describes the company's approach speed procedure. It states that the speed is to be reduced to 120 KIAS prior to the final approach fix. This speed should be maintained to decision height at which point it should then be reduced to V_{REF}. Section 8.3.22 states that:

> *'Whenever practicable, all pilots should aim to fly stabilised instrument approaches in terms of IAS, approach configuration, power setting and rate of descent from 1,000 feet above DA/MDA.'*

Section 2.2.1.26.3 also notes that when conducting 5.5º approaches:

> *'The descent rate associated with the steep approach may require engine power to be maintained in the landing flare.'*

Company training emphasised the importance of maintaining stabilised power settings on the approach which in practise involved tapering the speed gradually towards V_{REF} having passed decision height. Although not written down, it was common practise to maintain V_{REF} +5 kt until touchdown when there were no runway performance issues.

Flight Recorders

The aircraft was fitted with a Solid State Flight Data Recorder (FDR)[1] capable of recording a range of flight parameters into 52 hours worth of solid state memory (for the number of parameters recorded) when power was applied to the aircraft. The aircraft was also fitted with a Cockpit Voice Recorder (CVR)[2] which recorded crew speech and area microphone inputs encrypted and compressed into solid state memory (two hours of combined low-quality and 30 minutes of separate high-quality recordings), again when power was applied to the aircraft.

A time-history of the relevant parameters during the incident is shown in Figure 1. For comparison, data, typical of other landings recorded on the FDR, is also presented in Figure 1 (time-aligned for main-wheel touchdown), for a non-event landing, carried out by G-JEDE, two days earlier into LCY. The data presented for the incident starts five seconds before the first officer hands over control to the commander with the aircraft on the glideslope; 450 feet above the ground (radio altitude); V_{REF} +17 kt (108 kt) IAS; descent rate of 1,100 ft/min; with just under 15% torque on the No 1 engine and just over 10% torque on the No 2 engine; both reducing.

At the time the commander took control, the torque on both engines had reduced to 12% and 9% respectively; however, they started to reduce even further and more rapidly three seconds later, reaching a minimum of 3.5% and 2% over a ten second period. A change in the elevator angle and corresponding 4º nose up change in aircraft pitch is also evident just before the minimum-recorded torque is reached. Also, the descent rate slowed to 900 ft/min and the airspeed began to reduce.

Ten seconds before the tail struck the ground, the torque on each engine began to increase (reaching 10% and 7% at the time of the tail strike) while the propeller speed remained nominally the same. The descent rate remained at 900 ft/min and the airspeed continued to reduce.

[1] L3 (Fairchild) F1000 FDR: *Part Number S800-2000-01, Serial Number 02557.*
[2] Allied Signal Solid State Memory CVR: *Part Number 980-6022-001, Serial Number 0639.*

Four seconds before the tail struck the ground there was a large positive elevator deflection (trailing edge up) to 60% full deflection, pitching the aircraft nose-up. The maximum calculated pitch rate was 5º/second and the maximum positive pitch attitude was just under 9º, occurring just after the elevator deflection was reduced, and a fraction of a second before the tail struck the ground. The airspeed at the time of the tail strike was 91 kt (V_{REF}).

The nose gear touched down four seconds after the tail strike with the airspeed at 80 kt.

Effects on environmental conditions

The United Kingdom Aeronautical Information Publication (UK AIP) entry for LCY 2.20 paragraph 4 states, '*pilots are warned when landing on Runway 10 or Runway 28 in strong wind conditions, of the possibility of building induced turbulence and/or windshear*.' LCY's Operations Department produced a set of Aerodrome Safeguarding Procedures in July 2004 in order to assess the effects of proposed building development on airfield operations. Paragraph 5.8, entitled Wind Assessments, states that:

> *'Any new developments proposed … should include an appropriate assessment of any potential implications the development may have by providing for unusual changes to wind conditions with regards the airfield operation at LCY following the completion of the development. These assessments should be carried by a competent authority in consultation between the developer and LCY.'*

Existing building development at LCY required no such wind assessment.

Analysis

Data from the FDR suggests that at handover of control from the first officer to the commander, the aircraft was on the glideslope and 12 kt slower than that specified in the company SOPs. The commander then reduced engine torque to an unusually low level in order to reduce the speed to V_{REF} as soon as possible. Comparison with three other landings at LCY showed that this was the only occasion that engine torque was significantly reduced after handover of control. The effect of this was to destabilise the power on the final stages of the approach and, although the torque started to increase 10 seconds prior to the tail strike, it never attained the levels normally achieved on LCY landings. This low power setting combined with an airspeed close to V_{REF} provided the aircraft with less energy than normal approaching the flare. Without significant power increase and with the onset of sink, the pitch angle had to be increased rapidly to reduce the rate of descent, resulting in the tail strike.

The company SOP regarding speed control on the precision approach into LCY required the aircraft to decelerate from 120 KIAS at decision height to 91 KIAS at touchdown whilst maintaining a 5.5º approach. It is difficult however, to reconcile achieving this whilst maintaining a stabilised approach. Analysis of other approaches into LCY on this airframe reveal that commanders have chosen to fly stabilised approaches and accepted landings at speeds sometimes considerably higher than V_{REF}. There is anecdotal evidence of the commander's air speed indicator over reading which may have led to commanders maintaining higher landing speeds. The Landing Distance Available (LDA) at LCY is such that there are no performance issues with this type of aircraft if touchdown is achieved at the correct point and this probably influences commanders to accept the higher touchdown speeds. When aiming to land at V_{REF} from this type of steep approach, the company advice to *'maintain engine power in the flare'* is significant. This extra energy combined with the increased lift from the propeller slipstream over the wings allows the rate of descent to be reduced without a large increase in pitch angle.

Although the commander considered that the aircraft may have been subject to the wind effects from proximate buildings, this is unlikely with such a low wind speed. However, the effects of wind around existing buildings have not been studied and the airport's proactive stance towards future development and their effect on wind conditions is to be commended.

Follow up actions

As a result of this incident the commander received three days of line training with a company type rating examiner (TRE) and was released back to line flying.

For reasons unconnected with this incident, the company no longer operates this type of aircraft and has withdrawn all operations from LCY.

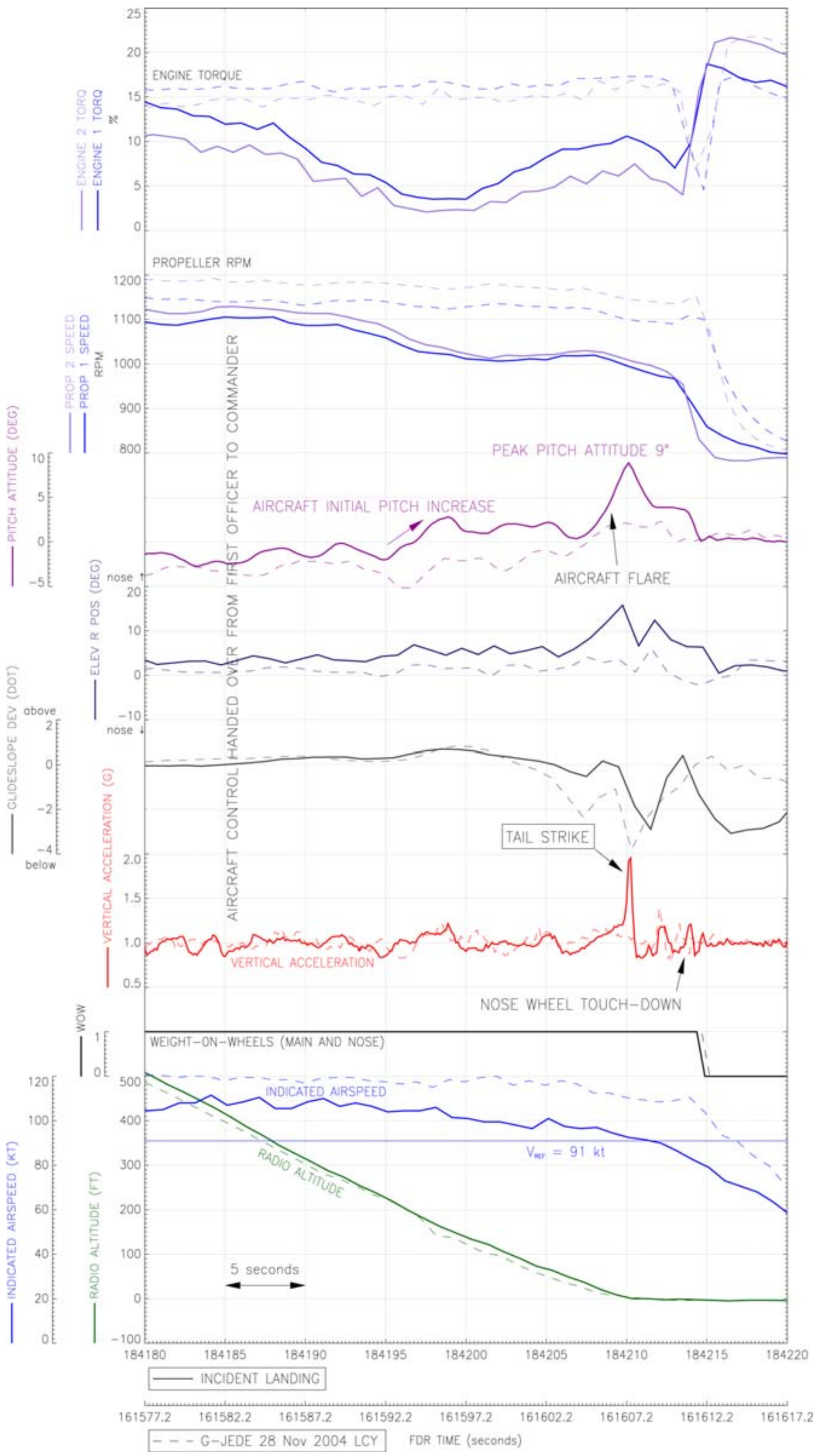


Figure 1

FDR Parameters for G-JEDE on 29 November 2004

INCIDENT

Aircraft Type and Registration:	i) Dornier 328-100, G-BZOG ii) Embraer EMB-135BJ Legacy, HB-JEA
No & Type of Engines:	i) 2 Pratt & Whitney Canada PW119B turboprop engines ii) 2 Rolls Royce Allison AE3007-AIE turbofan engines
Year of Manufacture:	i) 1998 ii) 2002
Date & Time (UTC):	1 February 2005 at 1650 hrs
Location:	Manchester International Airport, Manchester
Type of Flight:	i) Not applicable ii) Public Transport (Passenger)
Persons on Board:	i) Crew - 1 Passengers - None ii) Crew - 2 Passengers - 1
Injuries:	i) Crew - None Passengers - N/A ii) Crew - None Passengers - None
Nature of Damage:	i) Sharp cut in composite right wing tip leading edge ii) Superficial grazing of right winglet
Commander's Licence:	i) N/A ii) Airline Transport Pilot's Licence
Commander's Age:	i) N/A ii) 49
Commander's Flying Experience:	i) N/A ii) 6,100 hours (of which 1,100 were on type) Last 90 days - 90 hours Last 28 days - 40 hours
Information Source:	AAIB Field Investigation

Synopsis

The Embraer Legacy, with one passenger on board, was taxiing on the general aviation (GA) apron at Manchester International Airport. While moving forward slowly, with the assistance of a marshaller and two wing walkers, its right winglet struck the right wingtip of a parked Dornier 328. Separation of the aircraft revealed only superficial damage to the winglet and the Embraer was able to return to its base the following morning. The wingtip of the Dornier required replacement before further flight.

History of the flight

When the Embraer Legacy arrived earlier in the day, the GA apron was empty except for a number of light aircraft, which were parked on its eastern edge. However, at 1600 hrs, one hour before the intended departure of the Embraer, a Dornier 328 arrived and partially blocked its path. Handling agent staff attempted to tow the Dornier clear, but a raised flowerbed at the edge of the apron prevented them from moving it more than a few metres.

After start-up, the Embraer taxied with the assistance of a marshaller, who walked ahead of the aircraft and communicated with the cockpit using hand signals. Because of the proximity of the Dornier on its right hand side, and light aircraft parked at the edge of the apron on its left, a 'wing walker' was provided at each wing tip in order to assist the marshaller in providing manoeuvring guidance to the captain. Although the co-pilot of the Embraer was able, with some difficulty, to see the right winglet out of the cockpit side window, the curvature of the window pane and wing sweep made an accurate assessment of wingtip clearance impossible from the cockpit.

Shortly after moving off, the marshaller signalled for the Embraer to turn left in order to increase the distance between it and the Dornier. During this manoeuvre, which increased the effective speed of the right wingtip, the right hand wing walker realised that the winglet of the Embraer would hit the wingtip of the Dornier and attempted to communicate this to the marshaller by raising his right hand in a 'halt' gesture to the marshaller. The marshaller raised both arms to the captain, who stopped the aircraft immediately, but not before the right winglet had struck the Dornier. The pilots of the Embraer shut the aircraft down. The captain of the Dornier, who was onboard his aircraft at the time of the collision, was aware of an unusual movement, but characterised it as less violent than a gust of wind and, when told of the collision, judged that the Embraer must have been moving very slowly on impact.

The tip of the Embraer's winglet had made a clean impact into the composite structure of the Dornier's wingtip. As a result, damage to the Embraer was limited to a small area of leading edge erosion tape, and some paint. There was no apparent structural damage. The wing tip of the Dornier was cleanly penetrated for a distance of approximately six inches but damage was confined to the composite tip fairing, and had not reached the structure of the tip, nor the electrical system installed in the wingtip.

Recorded information

Recorded data from the flight data recorder indicates that at the time of the collision the Embraer aircraft was moving at a speed of 4 kt.

The apron and associated buildings are overlooked by a system of security cameras which record one frame every second. Footage from one of these cameras showed clearly the actions of the ground crew before and during the impact and confirmed their statement of events. It was not clear, however, if the marshaller or wing walker had at any time used conventional hand signals to indicate that the aircraft should stop, namely: repeatedly crossing the arms above the head at a speed which indicates the urgency of the stop.

A full description of the meaning of signals for the guidance of aircraft on the ground is given in CAP 393 *Air Navigation: the Order and the Regulations*, Rule 47 (Section IX, Table B). A more concise description is given in CAP 637 *Visual Aids Handbook*, chapter 6 'Aerodrome signals'*;* and in General Aviation Safety Sense Leaflet 6C '*Aerodrome Sense'*.

Conclusion

The handling agent conceded that it is difficult to accommodate two large GA aircraft at once on the GA apron. Additional parking is available on a taxiway adjacent to the GA terminal and, if this is also full, larger GA aircraft are permitted to use sections of the nearby cargo apron.

It is pertinent to note that Rule 37 (2) of the Air Navigation Order states that:

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

In this instance the commander of the Embraer aircraft, in conjunction with the marshalling team, developed a plan which he believed would ensure safe guidance whilst taxiing on the crowded apron: the collision occurred despite these measures.

INCIDENT

Aircraft Type and Registration:	Shorts SD3-60-100, EI-SMB	
No & Type of Engines:	2 P&W PT6A-64ARE turboprop engines	
Year of Manufacture:	1984	
Date & Time (UTC):	6 April 2005 at 0105 hrs	
Location:	15 nm north of Edinburgh, Scotland	
Type of Flight:	Public Transport (Cargo)	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Air Transport Pilot's Licence	
Commander's Age:	36 years	
Commander's Flying Experience:	2,180 hours (of which 600 were on type) Last 90 days - 80 hours Last 28 days - 42 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent telephone enquiries	

The aircraft was conducting a Royal Mail cargo flight from Edinburgh to Kinloss at night. The weather was good with a surface wind from 180º/10-15 kt. Runway 12 was in use.

A few minutes after takeoff, whilst passing FL55, the commander smelt something unusual. A visual inspection of the cargo area, through the cockpit door, revealed a white vapour coming from under the cargo net and filling the cargo area. The commander assumed this vapour was smoke; however, there were no smoke or fire warnings on the central warning panel. ATC were informed that they had a fire on board the aircraft and an immediate return to Edinburgh was requested.

Whilst they were being radar vectored for an SRA approach to Runway 12 at Edinburgh a further visual inspection showed that the cargo section was now full of a dense white smoke. The check list for a Cargo Fire was completed and crew oxygen masks and goggles were made available. Once stabilised on finals for a visual approach, another inspection of the cargo area showed that the smoke had now cleared.

The aircraft landed without further incident and was brought to a halt on the runway and shutdown. The Airport Fire Service (AFS) were immediately in attendance and the crew evacuated the aircraft.

The aircraft was inspected by the AFS with a thermal imaging camera. This revealed no signs of heat or fire within the aircraft. All packages within the cargo hold appeared normal, were intact and showed no signs of damage. The AFS were unable to identify the contents of the cargo due to there being no shipper's declaration available from either the commander or the Royal Mail; however, such a declaration was not required since there were no dangerous goods on board.

The aircraft was taxied to stand where the cargo was off loaded for further investigation with Royal Mail personnel in attendance. During the unloading of the cargo there was nothing untoward found on the aircraft which would have caused the smoke in the cabin.

The cargo from the aircraft was taken by road to Inverness where it was held separately at the sorting office. Royal Mail personnel carried out a visual external search of all the packages before they were released for distribution/delivery. No evidence of any leakage or damage to packaging was found. It has therefore not been possible to identify the source of the smoke or vapour which caused the crew to believe that they had a fire on board the aircraft.

Aircraft Type and Registration:	Cessna T310R, N6834L	
No & Type of Engines:	2 Teledyne Continental TSI0-520-BB piston engines	
Year of Manufacture:	1981	
Date & Time (UTC):	30 March 2004 at 0840 hrs	
Location:	Near Laneshaw Bridge, Colne, Lancashire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Private Pilot's Licence and FAA Private Pilot's Certificate issued on basis of UK Licence	
Commander's Age:	57 years	
Commander's Flying Experience:	627 hours (of which 403 were on type) Last 90 days - 3 hours Last 28 days - 0 hours	
Information Source:	AAIB Field Investigation	

Synopsis

Fire in the aircraft's nose baggage compartment, which started in the vicinity of the cabin heater, caused the smell of smoke in the cockpit. This prompted the pilot to request a return to Leeds Bradford Airport six and a half minutes after he had taken off for a flight to Connaught (Knock) in Ireland. The aircraft successfully negotiated a level turn to the left at 3,400 feet onto a south-easterly heading but then started a rapid descent and a steep turn or series of turns where radio and radar contact was lost. This may have been the result of controlled flight or uncontrolled manoeuvres. The aircraft was seen to be flying slowly and 'not in trouble' a matter of seconds before it struck the ground. The aircraft crashed in a field at an elevation of 950 feet above mean sea level (amsl) approximately 0.5 nm to the south-south-east of the last radar return and within two minutes of loss of contact. Ground impact marks were consistent with an uncontrolled impact yet the positions of some of the controls suggested that the pilot may have been trying to make a forced landing, albeit with a tailwind, into a sloping field which may have appeared level from the air. Post mortem examination of the pilot concluded that there was no evidence of cabin air contamination which

could have had an incapacitating effect and that he died as the result of multiple injuries sustained at the time of impact. One Safety Recommendation is made to the FAA concerning the inspection of combustion heaters.

History of the flight

The pilot was flying solo in his privately owned aircraft from Leeds Bradford Airport to Connaught (Knock), Ireland. Although there was no significant cloud for his departure the visibility was 4,000 metres. At 0814 hrs he requested clearance to taxi. ATC advised him that they had not received his flight plan, which had been faxed to them earlier, so the pilot resubmitted it from the aircraft using his mobile telephone. Due to a further delay, resulting from a problem with the telecommunication links between Leeds Bradford and Manchester ATC, N6834L was eventually cleared to taxi at 0825 hrs, 11 minutes after the pilot's original request. As the aircraft taxied past one of the maintenance company's hangars, an engineer in an office noticed that the pilot was repeatedly looking down inside the aircraft. The engineer made particular mention of this to his colleague because the aircraft was negotiating a sharp right turn on the taxiway at the time. The pilot was known to use the cabin heater when it was cold and operating its controls, that are positioned low on the instrument panel, may have been occupying his attention at that time.

The aircraft completed a power check before lining up on Runway 32, was cleared to take off at 0831 hrs and carried out a normal takeoff and turning left towards Keighley, a Visual Reporting Point (VRP) 9 nm to the west. Two minutes after departing the pilot was instructed to transfer to the Leeds ATC Approach frequency, which he did. Having been restricted, initially, to an altitude not above 2,000 feet on the QNH, the pilot was cleared to climb further to an altitude of 3,400 feet. He then requested, and was given, a Flight Information Service. Six and a half minutes after departing from the airport the pilot informed Leeds ATC that he would like to return. During his exchange with ATC he advised the controller that this was because there was a smell of smoke in the cockpit. N6834L was cleared to return to the airport via Keighley, not above an altitude of 2,000 feet. In response to the controller's request, the pilot confirmed that he was the only person on board the aircraft. When making this radio transmission, at 0838:20 hrs, the pilot sounded distracted. No further transmissions were received from the pilot.

The Leeds radar controller, who had displayed on his radar screen both primary and secondary information from the aircraft, saw it make a left turn while it maintained an altitude of 3,400 feet. According to secondary radar information, it stayed at this altitude until 0838:52 hrs. Thereafter, there was only primary radar contact (without altitude information) until 0839:26 hrs. Recordings of the radar information, retrieved some time later from the Great Dunn Fell, Clee Hill and Claxby radar heads showed the aircraft's track until it disappeared from the radar screen (see Figure 1).

Having seen the primary radar contact disappear the radar controller, who was also controlling two other aircraft, waited for two further sweeps (16 seconds) of the radar before transmitting a radio check to N6834L at 0839:43 hrs. There was no reply. The controller made three further attempts, without success, to establish radio contact with the pilot and asked another aircraft if they had heard any transmission from N6834L. At 0841:00 hrs the controller again transmitted a radio check but there was no reply from the pilot in N6834L.

The last radar contact placed the aircraft in the vicinity of Wycoller Country Park, 15 nm west of Leeds Bradford Airport. A driver in a car park on the eastern edge of the country park, whose broken down car was being repaired at that time, heard what sounded like the noise of an aircraft or 'an old tractor engine' coming from the direction of a hill half a mile to his east. The noise reminded him of a car engine running on dirty petrol. He looked up and saw very low in the sky a slow moving, white coloured, light aircraft, heading in a north-westerly direction as if it was taking photographs or just "messing about". "It appeared to be flying level and did not seem to be in trouble". After glancing at the aircraft the driver turned away and continued talking to the mechanic repairing his car. He then heard a noise "like farm machinery tumbling down a gulley". Both he and the mechanic looked up and the mechanic remembered seeing the nose of an aircraft digging into the ground with its tail somersaulting over the top. The driver's recollection was of a large amount of dust and debris travelling down the hillside in a westerly direction. Just before the crash the mechanic recalled hearing the noise of an engine which was "spluttering or failing, as if it was running out of fuel". He said that this sound had lasted for two to three seconds.

The driver and mechanic ran approximately 800 metres to the scene of the accident and, as they ran, the mechanic called the emergency services on his mobile telephone. That call was timed at 0841:03 hrs. As they approached the wreckage they were aware of a very strong smell of fuel. However, despite the aircraft being severely disrupted, there was no fire. The pilot, who had been thrown about 10 metres clear of the main body of the aircraft, did not appear to have survived the accident. The emergency services arrived approximately 10 minutes later.

Pathology

The post-mortem report concluded that the pilot died as a result of multiple injuries sustained at the time the aircraft struck the ground. There were no predisposing medical conditions which might have caused or contributed to the accident and the toxicology examination revealed no drugs, alcohol or evidence of cabin air contamination which could have had an incapacitating effect.

Meteorological information

The synoptic situation at 0600 hrs on 30 March 2004 showed high pressure centred over Norway and Poland feeding a generally light south-easterly flow over Lancashire.

The weather in the area of the accident included mist and haze up to 500 feet agl, especially in valleys, with further layers of thin haze up to around 6,000 feet amsl. There were possible patches of broken stratus cloud, as the valley fog thinned and lifted, between 100 and 500 feet agl and further isolated patches of thin strato-cumulus cloud above 5,000 feet with cirrus cloud above 20,000 feet amsl. The surface visibility was between 4,000 metres and 6 kilometres, generally improving to 7 to 12 kilometres by 0900 hrs, and the surface wind was 080º/5-10 kt. At 3,000 ft amsl the wind had veered to 140º/15-20 kt.

The Aerodrome Meteorological Report (METAR) at Leeds Bradford Airport at 0820 hrs gave a surface wind of 050º/4 kt, a visibility of 4,000 metres in mist, no significant cloud and a surface temperature of +5ºC. A further meteorological observation at Leeds Bradford at the time of the accident reported a surface wind of 060º/6 kt, a visibility of 4,000 metres in mist and, again, no significant cloud.

This reflects the visibility recalled by one of the witnesses at the car park adjacent to the crash site. Shortly before the accident he could not see the top of a hill that was 3,800 metres away to his south, whereas he had been able to see it about 45 minutes earlier. The top of the hill is 800 feet higher than the elevation of the car park.

Pilot qualifications and experience

The pilot started flying in 1993 at the age of 47. Two years later, having completed 100 hours of flying, he gained his UK Private Pilot's Licence (Aeroplanes) with a rating for single engine aeroplanes (Landplanes). Two months after that he added an Instrument Meteorological Conditions (IMC) rating to his licence.

Between March and May 1996 he undertook a course of instruction in N6834L, which he had recently purchased, and was issued of a rating for multi-engine aeroplanes (Landplanes). His logbook indicated that, in July 1996 after another course, he passed the flight test for an IMC (multi) rating. This however, was not recorded in his licence; a possible oversight by the examiner. His logbook also contained annual signed entries for Certificates of Experience, valid until 24 July 2000.

The pilot started making the first of many flights between Leeds and Knock, in 1996. In 1999, following a number of incidents in Ireland over a two year period, the pilot was directed by the Irish

Authorities not to fly in their airspace until the latest of those incidents had been investigated. The Irish Aviation Authority (IAA) also communicated with the Civil Aviation Authority (CAA) expressing their concern that the pilot might place himself and others in jeopardy if his standards of airmanship and lack of appreciation of the limitations of his licence continued at the levels they had encountered. There is no record of any action taken by the CAA in response to those concerns beyond a copy of a draft letter acknowledging the IAA's communication and mention of a possible interview that was to be arranged with the pilot. The IAA subsequently lifted their ban on the pilot in May 2002.

Between December 2001 and March 2002 the pilot undertook a course of instruction in Florida, USA culminating, on 27 March 2002, in the issue of a FAA Private Pilot's Certificate with ratings for 'single and multiengine land instrument airplanes'. The licence was '*issued on the basis of and valid only when accompanied by'* the pilot's UK licence and that '*all limitations and restrictions on the UK pilot licence apply'*. The pilot's UK rating had lapsed, therefore his FAA certificate ratings were not valid from the moment it was issued.

The pilot resumed his regular but infrequent flights between Leeds Bradford and Knock in May 2002 and returned to Florida in October 2002 for further instruction on the PA-28 and PA-23. While there he completed an instrument competency check on the PA-28. He had further periods of instruction in Florida in May 2003 (PA-28 and PA-23) and February 2004 (PA-34 and Cessna 172), during both of which he completed instrument competency checks. In the latter period of training he completed 2.7 hours of flying. In between his visits to Florida he continued to fly between the UK and Ireland. The accident flight was his first since returning to the UK from his last period of instruction in Florida. His most recent flights within the British Isles had been to Knock on 26 October 2003, returning to Leeds Bradford on 8 November 2003.

The pilot always used the same instructor when he was flying in the USA. This instructor confirmed the hard work that the pilot put into his flying reflecting, he said, the ability of someone who had come to flying late in life. In particular, the instructor commented that the pilot was able to deal with a situation when given the time to think it through in advance but could not deal so well with a problem presenting itself unannounced.

Radar information

Radar returns from three radar heads were available for the accident flight, each with differing amounts of coverage. The returns from the Clee Hill radar appeared to be the most accurate for the latter part of the flight with a final point 0.5 km from the accident site. No height information was available for this point as it was only a 'primary' radar return.

The recorded radar data was used to ascertain much of the aircraft's track over the ground and its altitude (Figure 2). During the course of the investigation an aircraft was flown over the position of the accident site at an altitude of 1,500 feet on the QNH; approximately 550 feet agl. At that altitude it was clearly visible on both primary and secondary radar but this begged the question as to why the accident aircraft had not been visible on secondary radar for the last 34 seconds that it 'painted' a primary radar return.

Another Cessna T310R, G-GOTX, which was involved in an accident in Humberside earlier in the same month disappeared from the radar screen when it was at an altitude of 3,200 feet amsl. In that case it was considered possible that the altitude recorded on radar was influenced by static pressure errors caused by the manoeuvres that that aircraft appeared to carry out. N6834L was not, apparently, conducting complex manoeuvres so it is probable that another factor was responsible for the lack of received altitude information. It is possible that the N6834L entered a high rate of descent, its radar transponder failed or that electrical power was removed from the transponder.

The radar recordings showed that the aircraft completed a level turn at an altitude of 3,400 feet amsl and it is possible that it then started a very rapid descent. Two minutes and 11 seconds elapsed between the last secondary radar altitude information and a witness to the accident dialling the emergency services on his mobile telephone. Allowing at least 15 seconds for the witness to react to the situation before making that call means that the aircraft descended at an average of 1,280 feet per min (fpm) before striking the ground. This is not an overly rapid rate. However, the aircraft may have descended from 3,400 feet to 1,500 feet, or lower, in the 34 seconds that it remained as a contact on primary radar. That would result in a rate of descent, during that period, of 3,350 fpm or greater.

GPS data

The aircraft was fitted with a panel-mounted Trimble TNL 2000T GPS unit that sustained damage in the accident. This unit has a limited memory only capable of recording a position fix of the 'last known point', date and time when electrical power is removed from the unit (Figure 1).

The 'last displayed position' refers to that which would be shown on the GPS display, updated once every second from position fixes made five times per second. The 'last known position is the latest (and last) of these implying that the displayed position could be up to 0.8 seconds older than the last position fix.

The date and time that power was removed from the unit was recorded as 30 March 2004 at 0839:05.672 hrs UTC; very close to the time and position at which transmissions were no longer received from the aircraft's radar transponder. The recorded GPS altitude at the last fix (3,187 feet amsl) was close, within the unit's tolerance of ±900 feet, to the aircraft's reported altitude of 3,400 feet. At this stage the sequential positions recorded from the Clee Hill radar indicated a track of approximately 120ºM, towards the airport.

Emergency procedures

The Pilot's Operating Handbook specifies an emergency procedure for *Inflight Cabin Electrical Fire or Smoke.* It lists the immediate action memory items as:

1. *Electrical Load – REDUCE to minimum required.*
2. *Attempt to isolate the source of fire or smoke.*
3. *Wemacs – OPEN.*
4. *Cabin Air Controls - OPEN all vents including windshield defrost.*
   CLOSE if intensity of smoke increases.

This is followed by the non-memory action to:

5. *Land and evacuate airplane as soon as practical.*

In supplementary information the manual states that:

> *if the smoke increases in intensity when the air controls are opened, they should be closed as this indicates a possible fire in the heater or nose compartment.*

It also advises that:

> *when the smoke is intense, the pilot may choose to expel the smoke through the foul weather window (in the pilot's side window), but cautions that the foul weather window should be closed immediately if the fire becomes more intense when the window is opened.*

It is not clear whether the pilot had managed to identify the source of the smoke.

Aircraft history

N6834L had been built by Cessna in Wichita in 1981 as a T310R, serial number 310R-2137 and had operated in the USA, and then in Belgium, until 1996, with 2,868 hours logged. After its change of ownership and move to the United Kingdom in 1996, the aircraft continued to be operated on the US register, maintained by a maintenance company at Leeds Bradford Airport under FAA Regulations.

Up to the date of this accident, N6834L had logged 3,287 flight hours, 420 in the eight years since the change of ownership, flown almost exclusively by the new owner. The rate of utilisation was high in the earlier years and much lower in the last two years. The aircraft had last been flown on 8 November 2003; over 4 months before the accident flight.

As delivered by the manufacturer in 1981, the aircraft had an avionics fit suitable for operation in IFR, including a two-axis autopilot system. During the period to 1996 a number of additional items were added, under the FAA STC (Supplemental Type Certificate) system. These included a weather radar system, graphical engine monitors, a Trimble TNL-2000 GPS navigation system and a Precise Flight speedbrake system.

Accident site

The aircraft struck the ground in a field of rough grass on sloping moorland (Figure 3). The initial point of impact was on the right wing tip tank and a long ground scar showed the initial impacts of the right engine, the nose, fuselage, the left engine and the left wing. There was separation at this point of both propellers, both engines and both tip tanks, as well as fragmentation of the nose section. The remaining portions of the fuselage, wings and empennage came to rest around a stone wall after travelling 100 metres and the engines were found 135 metres from the initial impact.

Measurements from the ground marks showed that the aircraft was travelling in a direction of 300ºM when it struck the ground, approximately 30º nose down and with a banked 45º to the right. Examination showed that the landing gear and wing flaps were retracted at the time of impact. Aerial photographs taken a few days after the accident showed extensive damage to the grass around the initial impact, demonstrating that there had been large amount of fuel onboard at the time of the accident. The pattern of the damage to the vegetation indicated that, as would be expected, the bulk of this fuel was in the main tanks, at the wing tips. The nature of the impact, at speed into soft ground and the fragmentation of the tip tanks, meant that there was no post-crash fire.

Examination for fire and smoke

The wreckage was examined closely for evidence of smoke or burning preceding the impact. As there had been no post-crash fire, it was clear that any marks of heating or combustion found in the wreckage would have occurred before the aircraft hit the ground.

There was no evidence of any electrical arcing, sooting or other heating or combustion found around the instrument panel or any part of the cabin. There were, however, items recovered from varied locations around the wreckage site which exhibited fire and heat damage. All of these items would have been located in the nose section of the fuselage. They included items of clothing and baggage, the manual tow-bar, pieces of the nose structure itself and components from the aircraft heating and ventilation system, including the combustion heater which showed a distinct pattern of fire damage. There was no fire damage found on any item from any other area of the aircraft.

Detailed wreckage examination

Flight controls

The primary flying control cables (ailerons, elevator and rudder) were traced through the wreckage and there were no indications of pre-existing damage. The wreckage was too damaged for reliable measurements from the aircraft trim mechanisms; in this aircraft the autopilot system also works through these trim actuators. Both panels of the additional speedbrake system, mounted in the aft bay of the engine nacelles, were found to have been in the retracted position at impact. Parts of the 'foul weather' window were identified but its position at impact could not be determined.

Engine and propeller controls

The throttle quadrant was found intact, although separated from its normal mounting in the cockpit. There were signs of impact to the control levers and thus the positions of the throttle (power) and mixture levers, having freedom to move, could not be treated as reliable. However, both propeller speed levers were found fully aft in the 'feather' position, beyond the gate mechanisms which prevent inadvertent 'feather' selection. In this aircraft, movement of a propeller speed lever to 'feather' requires that the lever be moved inboard. There was no damage on the gates. It is likely therefore, that these lever positions represented a deliberate selection by the pilot at a very late stage in the flight.

Propellers

The propellers were taken to an overhaul facility for examination. The general damage to the blades indicated that there had been some degree of rotation of both propellers at impact but there were no distinct indications that there was substantial power being transmitted. Mechanical damage to the left propeller hub indicated that, at impact, this propeller was at, or very close to, the 'feather' position. In contrast, the mechanical damage to the right propeller indicated that it had been within the normal operating range of a rotating propeller but close to the 'fine pitch' end of the range.

Engines

Both engines were too damaged for functional testing. However, a strip examination showed that both were mechanically intact, with no sign of pre-impact distress. The colour and condition of the ignition plugs was consistent with normal operation and the magnetos were tested satisfactorily.

The cockpit fuel selectors were found in their respective 'LEFT ENGINE OFF' and 'RIGHT ENGINE OFF' quadrants, consistent with the selector valves themselves and the sense of the control movement (a cable 'pull' will move selector and valve to different positions). However, the disruption to the airframe means that this evidence of fuel selection is not fully reliable.

Instruments and avionics

The avionics systems in the aircraft were too badly damaged in the ground impact for functional testing. However, it was noted that, where the ON/OFF switches could be tested on individual navigation and communication units, the selection was always found in the ON position. The HSI (Horizontal Situation Indicator) and RMI (Radio Magnetic Indicator) gyro instruments were both found with headings of 120ºM, corresponding to the likely heading of the aircraft when power was removed from the GPS and, probably, the radar transponder.

Both the HSI and RMI instruments are electrically 'slaved' to remote gyros and would thus stop operating with the loss of electrical power. However, the aircraft's two artificial horizon instruments were both vacuum-driven, as was the directional gyro mounted in front of the right-hand pilot seat. The altimeters and airspeed indicators were conventional pressure instruments. These would have continued to function without electrical power.

The Cessna T310R electrical system diagram shows that electrical power could be removed either by the Avionics master switch (mounted on the circuit breaker panel to the left of the pilot) or by use of the three 'ganged' Master switches (left alternator, battery and right alternator) mounted low on the instrument panel. These three Master switches would routinely be exercised by the pilot at the start and end of each flight and selection to OFF would remove electrical power from certain instruments and the navigation and communications systems. In addition, electrical power would be removed from other aircraft systems, including the cabin heater, flaps, landing gear and speedbrakes. The engine and propeller controls would not be affected.

Effects of fire

Because of the disruption to N6834L in the impact, another Cessna T310R, manufactured in 1978, was examined by the AAIB. This examination confirmed that the pattern of heat damage to the contents of the nose compartment in N6834L was consistent with a fire centred under the combustion heater. It also confirmed that the aircraft's electrical systems would not have been affected by the fire as the electrical looms in the nose were routed under the floor on the left-hand side of the nose compartment, separated from the combustion heater by the nose leg bay. The only aircraft system that would have been affected by a localised fire around the combustion heater, in this example T310R, would have been the right pitot pressure line, routed through the combustion heater compartment. In N6834L, however, this pitot line did not exist as the aircraft had a single (left) pitot probe.

Heater system

N6834L was equipped with a combustion-type cabin heater (model 8259JR-2, manufactured by South Wind) mounted in the nose compartment. This arrangement is common in aircraft with twin piston engines.

In this design, the heater is supplied by ambient airflow, through flexible ducting and a dedicated ventilation fan, and delivers heated air into the cabin through further flexible ducting into controllable heat outlets. The heated cabin air, which is not recirculated, exhausts overboard.

The layout and functioning of the cabin heating and ventilation system can be seen at Figures 4, 5 and 6. Figure 4 shows the position of the combustion heater in the nose of the aircraft and the routeing of the heating and ventilation air flows into the cabin. Figure 5 shows the principal components of the system (combustion heater, ventilation fan, centrifugal fan and fuel pump), as configured for a bench test. Figure 6 illustrates the internal functioning of the combustion heater.

The heater depends on the aircraft's fuel system for its fuel supply. The fuel to each engine is normally drawn directly from the main tank (tip tank) on that side, via a fuel selector valve. The fuel line to the cabin heater is drawn from a point on the fuel line between the right tank and the right selector valve, so the position of either fuel selector will not affect the heater, for which the dedicated fuel line has a separate electrically-operated solenoid.

Fuel and combustion air are supplied from a pump and centrifugal fan respectively, driven by a single motor, and the fuel and air are introduced into the core of the heater, where they are ignited by a single ignition plug. The combustion core is surrounded by a jacket that acts as a heat exchanger for the warm air being supplied to the cabin. The combustion air is exhausted downwards from the heater directly to the outside, through a short exhaust pipe.

The pilot's control of the combustion heater is by means of a variable thermostatic valve and a three-position switch. In the HEAT position, the fuel supply solenoid is energised to open, the motor for the fuel pump and the combustion heater is powered, the igniter operates and the ventilation fan is powered. With the switch at FAN, only the ventilation fan is powered. At OFF, all the circuits are de-energised. The design of the heater also ensures that the fuel and combustion air continue to be provided only if the heater is operating correctly and selected to HEAT.

A Cessna Service Bulletin, MEB95-9, applies to these heaters. This Bulletin was issued in June 1995 and covered the inspection of the aluminium fuel lines to the heater, looking for evidence of fuel leaks and corrosion. Corrosion beyond 'minor pitting' would require the fuel line's replacement with a stainless steel line. Inspection was required within the earlier of 100 hours of operation or 12 months calendar time. There was no requirement for repeated inspections.

In addition, specific inspections for this model of heater are specified in an FAA Airworthiness Directive from 1981, AD81-09-09. This AD required an initial inspection and overhaul within 50 hours of heater operation and then a repeat every 250 hours of heater operation, with a further provision for overhaul every 1,000 hours of heater operation.

Heater system examination

The combustion heater, examined in detail by the AAIB with a representative from the heater manufacturer present, showed extensive external heating damage (Figure 7).

The outer casing (or 'jacket') showed that the fire within the nose compartment was predominantly under the heater, towards the aft end. This is the area of the assembly closest to the fuel line from the aircraft to the fuel pump assembly, the fuel line attaching the fuel pump to the heater and the fuel drain line from heater itself. The connection in the leading edge of the right wing showed that the fuel supply line had not been replaced by the stainless steel line as provided for in the Cessna Service Bulletin MEB95-9.

Disassembly of the heater showed a normal pattern of internal combustion, with no leaks of the burner assembly other than an anomalous hole (approx ⅜" across) on the aft end plate. This hole had been made with considerable force and there was no mechanism that would have created it other than the aircraft's impact with the ground. It was also noted that there had been no recent maintenance in this area of the aircraft.

Therefore, all the mechanical damage to the heater was found to be consistent with the ground impact and all the heat damage was found to be consistent with an external fire, centred in the area immediately below the heater, while the aircraft was still in the air.

This external fire had, in particular, badly affected the electrical wires which provide the control system harness for the heater. Expert examination of the ruptured and melted ends of these wires indicated that there may have been some electrical arcing but there was no indication that this initiated the fire.

The examination showed three items of evidence indicating that the heater was not continuing to operate at the time of the impact with the ground:

1) the combustion blower had no scoring marks to denote rotation at impact,
2) the damage to the wiring, which occurred before impact, would have prevented further supply of fuel and combustion air as both the fuel pump and supply solenoid require positive electrical supply and,
3) the overheat switch on the heater body had 'popped', also preventing further supply of fuel and combustion air to the heater.

Combustion heater regulations

The current certification requirements for combustion heaters in this category of light aircraft are detailed in Part 23 of the Federal Aviation Regulations (FARs - in the USA) and CS-23 (Certification Standards - in the European Union). These codes are, on this topic, essentially identical and require that the compartment surrounding a combustion heater be treated as a 'fire region' if *"… the heater fuel system has fittings that, if they leaked, would allow fuel vapours to enter this region."* (FAR 23.859) These requirements include the means of fire detection and suppression, with further requirements for fireproofing and are the same requirements as those for larger Transport Aeroplanes (FAR Part 25 and CS-25).

However, FAR 23.859 had been amended in October 1980 (Amendment 23-27). Previous to that time the certification requirements for combustion heaters in light aircraft were lower and did not include, for instance, any requirement for the means of fire detection and suppression. As this aircraft type was certificated well before 1980, the later requirements of Amendment 23-27 did not apply.

Combustion heaters - previous occurrences

A number of accident and incident databases were researched to look for cases, particularly in the United States, where combustion heaters were considered to have been causal factors in aircraft accidents. Despite the mixed reputation carried by these heaters in light aircraft, there were very few accidents in which the Federal investigators had considered the heater as playing any part. The manufacturers of the heaters consider this to be due to the multiple 'fail-safe' design features of the heaters and, in the case of N6834L, there was evidence that the airborne fire was limited both in extent and duration.

Maintenance details

The aircraft's maintenance at Leeds Bradford Airport was carried out by a local company, operating under the appropriate FAA approvals. Because of the aircraft's lower rate of utilisation in the last two years, the major maintenance inputs had been for Annual Inspections, the latest being performed in July 2003. These Annual Inspections, as applied by this maintenance organisation, included items in the nose compartment of the aircraft but did not detail the form of inspection of the heater or require a check of its operation.

According to the aircraft's maintenance records, there had been an inspection of the combustion heater on 22 February 1996 after the aircraft's arrival. This included the application of the FAA Airworthiness Directive AD81-09-09. As the heater was inspected at 2,868 hours of flight time in 1996, at the current rate of utilisation, a specific inspection would not have been required for a further 250 hours of heater operation.

The hours of heater operation are normally recorded on a 'heater meter' in the nose compartment, linked directly to the electrical circuits of the combustion heater. In this accident the nose compartment had been considerably disrupted and the heater meter could not be identified within the wreckage and furthermore, the maintenance organisation had not made periodic note of the operating hours from the meter. The AD81-09-09 notes that *"In complying with this AD, if the owner or operator cannot document combustion heater operative time, the aircraft time must be used"*. According to this interpretation, the next AD inspection would have been required at 3,118 hours of aircraft time, which was reached in June 1999.

The aircraft maintenance records also did not show any record of the manufacturer's Service Bulletin on the heater fuel lines, MEB95-9, having been performed and the fuel line identified at the wing connection was of the original aluminium alloy type. The compliance period (100 hours of operation or 12 months, from June 1995) covered the move of the aircraft to the United Kingdom in early 1996 and its change of ownership. From the maintenance records, it appears that the omission of this Service Bulletin was unintentional.

As a result of these discrepancies, the AAIB conducted a series of interviews with the maintenance engineers who had performed the recent Annual Inspections (August 2003 and July 2002). Although, many months after the work, the engineers did not have a detailed recollection of the particular work they had performed on N6834L, they understood the inspection requirements in the area of the combustion heater and stated that an operational check of the heater would have been conducted at the same time as the required, and documented, engine runs.

The maintenance requirements for light aircraft registered under the CAA are broadly similar to those under the FAA. However, for all models of combustion heaters, there is a further requirement for UK-registered aircraft (CAP 747 Generic Requirement No 11, dated 28 February 2005, previously CAA Airworthiness Notice, No 41, Issue 9, 29 Oct 2001 - "*Maintenance of Cockpit and Cabin Combustion Heaters and their associated exhaust systems*"). This Airworthiness Notice ensures that, irrespective of operating hours, a combustion heater will be specifically dismantled and inspected at least every two years.

Analysis

Operations

The pilot continued to fly in the USA and UK in the honest belief that his FAA certificate, coupled with annual training and flying checks in the USA, qualified him so to do. He was however, not qualified to fly in the UK or USA unless he was under instruction. The instructor who trained him in the USA recognised his flying aptitude and indicated that his ability was consistent with someone initiating and pursuing an interest in aviation later in life. He also commented that the pilot was able to handle situations which he had previously thought through but was less able to deal with unexpected and unusual situations.

The aircraft engines, that cold morning, had probably been running for at least 17 minutes before the aircraft took off and it is possible that the pilot had started the heater while the aircraft was still on the ground; it is possible that he was operating the heater controls when he was seen to be looking inside the cockpit while taxiing.

The fire in the forward baggage compartment, six minutes after takeoff, would have been very alarming and the pilot's radio call to return to Leeds Bradford Airport was logical in the circumstances. Although he reported a smell of smoke in the cockpit to ATC there was no evidence from the post-mortem that he had inhaled any smoke or been incapacitated by it. He was, by all accounts, fit and healthy.

The visibility during the flight would not have afforded a good natural horizon and the pilot would not have been able to see Leeds Bradford Airport when he turned back and started his descent. Therefore, not only was there a need to action the procedure for a serious emergency, but he had to navigate and fly the aircraft primarily with reference to his flight instruments. Given the pilot's ability and previous incidents, this situation would have generated a very high workload. Additionally he had had little flying practice in the previous eight months and the flying he had carried out had been in the USA accompanied by an instructor on different aircraft types.

The indications from the Trimble GPS and its last recorded position suggest that the power to that piece of equipment was removed 21 seconds before the last primary radar contact was recorded. Following power removal to the GPS equipment, there were no further recorded secondary radar contacts and the pilot did not, apparently, make any further radio transmissions. The emergency procedure for '*Inflight Cabin Electrical Fire or Smoke*' includes reducing the electrical load to the minimum in an attempt to isolate the source of fire or smoke. The inference therefore, is that the pilot switched off the power to these pieces of equipment while still at an altitude of 3,400 feet and flying in a south-easterly direction.

It cannot be determined whether the pilot did this by isolating the avionics electrical bus or by selecting the three Master switches to OFF. However, familiarity with the location and function of the Master switches, lack of familiarity with the avionics bus switches and uncertainty as to the source of the smoke make it more likely that he selected the Master switches to OFF.

The aircraft probably developed, for a period of time, a high rate of descent after leaving an altitude of 3,400 feet; in the order of 3,350 fpm or more. However, neither the impact marks nor the witness report that the aircraft was glimpsed flying level just before the accident suggest such a high rate of descent at those moments.

Following the last primary radar contact the aircraft turned from a track of about 120ºM on to a track of approximately 300ºM, as indicated by the impact marks. That turn does not appear to have started before the last radar contact at 0839:26 hrs. With that in mind, the aircraft turned through 180º, 540º, 900º, or other multiples of 360º, in no more than one and a half minutes. The aircraft made good about 0.5 nm on a track of 150ºM between the last primary radar contact and the impact point. This puts the point of impact about 0.25 nm to the right of the aircraft's last known track. By simple formula, an aircraft flying at, say, 120 kt would need a 60º angle of bank to achieve a 180º turn and remain within 0.25 nm of the original track. If the aircraft had been flying at a slower speed the angle of bank required would have been correspondingly less. In the absence of more recorded data, a number of manoeuvres are conceivable, all of which would involve steep angles of bank.

The pilot had expressed his wish to return to Leeds Bradford. The rapid descent and turn towards the north-west was not communicated to the radar controller who transmitted four radio checks to N6834L between 0839:43 hrs and 0840:18 hrs. It is highly likely therefore, that the aircraft was still airborne when some, if not all, of these radio calls were made and there is no evidence from the post-mortem that the pilot was incapacitated. So, if the manoeuvre was intentional, it reflects a desire by the pilot to land the aircraft immediately. This possibility can be given further credence by the evidence that power was removed from some, if not all, of the avionics instruments.

In summary, the aircraft lost height rapidly and turned tightly, either because the pilot decided to land immediately or because he had lost control. The impact marks show that the aircraft struck the ground in an uncontrolled fashion and, with the one witness who saw the aircraft airborne stating that it did "not seem to be in trouble" shortly before the impact, it is possible that control may have been lost only moments before impact. From the air, the field where the aircraft impacted was sloping away from the aircraft's direction of approach and may have appeared flat. It is therefore possible that the pilot was trying to land on what he thought was a benign surface, although he made no PAN, MAYDAY or other radio call to that effect. The fact that the fuel supplies to the engines were found in the OFF position and that both propeller speed levers had been selected to the gated feather position adds weight to that hypothesis. With a surface wind of about 080º/5-10 kt the aircraft would have had a downwind component before it struck the ground.

Systems

The negative results of the post-mortem and toxicology examinations and the lack of recorded flight information, particularly towards the end of the flight, make it impossible to determine positively the process which led from the detection, by the pilot, of smoke in the cockpit to the impact with the ground. However, the technical examination showed a very high probability that the smoke detected by the pilot came from a fire centred around the area of the cabin heater.

There was no indication that the fire would have affected other aircraft systems and the apparent loss of electrical power, at the same time, to the GPS, radar transponder, the HSI and RMI navigational instruments could not be attributed to the fire. This is both because of the physical separation between these systems and the fire and the redundancy (battery, left alternator and right alternator) of the electrical supply. Although N6834L did not have systems, other than the heater system, routed through the heater compartment, examination of other similar types has shown that this area may, in some cases, be used for other systems.

One effect of the fire in the nose compartment would have been to remove the supply of further fuel to the heater, because of the 'fail-safe' design of the combustion heater control system. It was not possible to determine whether the cessation to the fuel supplied into the fire was because of this 'fail-safe' effect of the fire or because of the removal of electrical power. But, regardless of how the fuel supply was removed, the compartment around this heater was inadequately equipped to allow control of an airborne fire by the pilot. Although compliant with the design requirements of FAR Part 23 at the time of its type certification, the compartment was neither equipped with the means of fire warning nor of fire suppression.

Because of the fragmentation of the nose section, it was not possible to determine either the exact manner in which the fuel escaped from the combustion heater system or the manner in which it was ignited. However, the geometry in this area suggests that the fuel was probably present as a result of a small fuel leak, most probably at a pipe union, and that the ignition was from either the heater exhaust or, possibly, an electrical or heater fault.

In general, however, these problems normally manifest themselves over a period of time and the system of periodic inspection is designed to catch such problems before they become a threat. In this case, the low utilisation of this aircraft meant that, under the FAA maintenance regime applied to this 'N-registered' aircraft, specific inspections of the combustion heater were very rare.

A different approach to continued airworthiness, where compartment design does not meet current certification standards, has been taken by the CAA in the UK. The CAA Airworthiness Notice No 41 (Maintenance of Cockpit and Cabin Combustion Heaters and their associated exhaust systems) applies a further requirement, ensuring that, irrespective of operating hours, a combustion heater will be specifically dismantled and inspected at least every two years. There is clear merit in ensuring this sort of 'calendar backstop' for periodic inspections and, in this instance, there is also a case for requiring repeat inspections using the content of the manufacturer's Service Bulletin MEB95-9. The following Safety Recommendation is therefore made:

Safety Recommendation 2005-066

It is recommended that the FAA introduce inspection and maintenance requirements for combustion heaters in Part 23 aircraft to ensure that adequate detailed inspections are carried out at specified calendar intervals.

Conclusion

It is concluded that a fire in the nose baggage compartment, which started in the vicinity of the cabin heater, caused the smell of smoke in the cockpit. This prompted the pilot to request a return to Leeds Bradford Airport six and a half minutes after he had taken off for Connaught (Knock) in Ireland. The aircraft successfully negotiated a level turn to the left onto a south-easterly heading but then started a rapid descent and a steep turn or series of turns. This may have been the result of controlled flight or uncontrolled manoeuvres. The aircraft was seen to be flying slowly and 'not in trouble' a matter of seconds before it struck the ground. However, the impact marks are consistent with an uncontrolled impact. The positions of some of the controls suggest that the pilot may have been trying to make a forced landing, albeit with a tailwind, into a sloping field which may have appeared level from the air.

The post mortem concluded that there was no evidence of cabin air contamination which could have had an incapacitating effect on the pilot and that he died as the result of multiple injuries sustained at the time of impact.

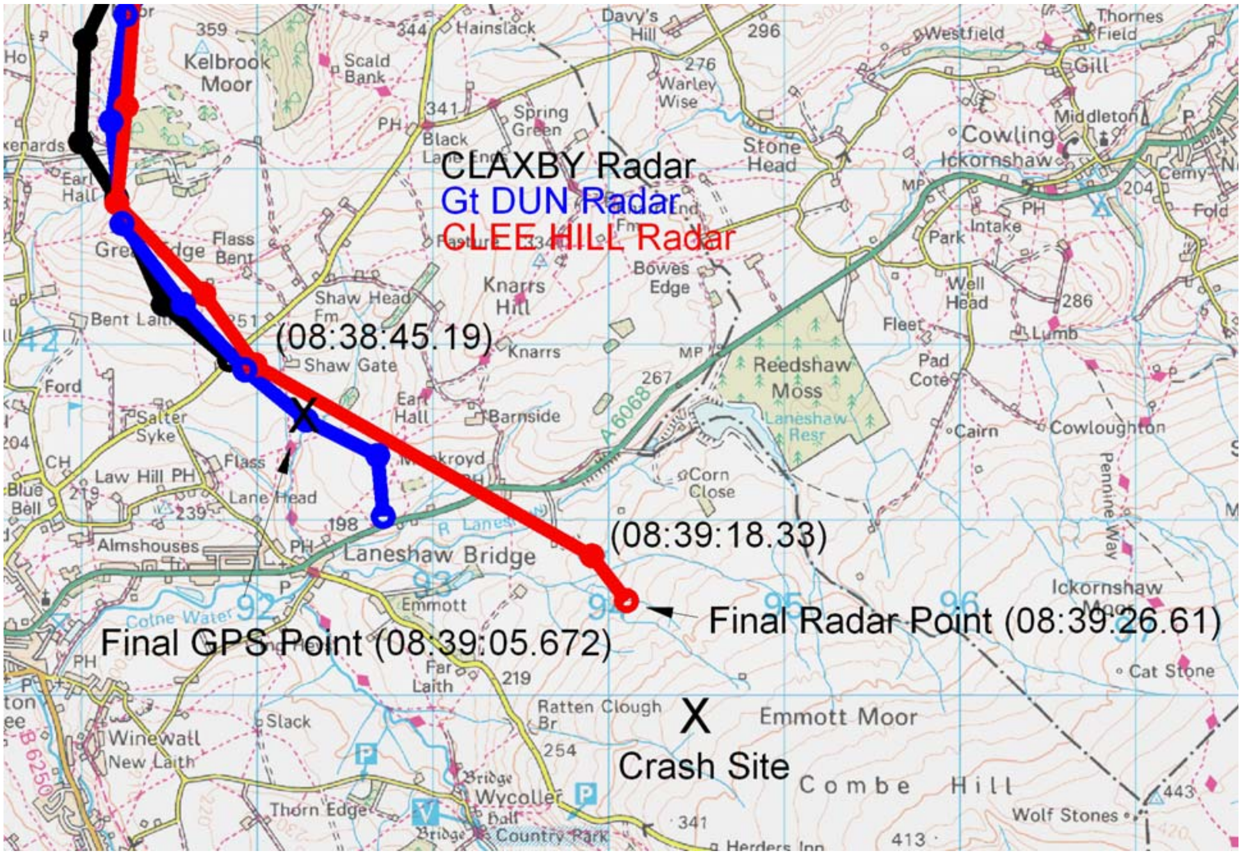

CLAXBY Radar
Gt DUN Radar
CLEE HILL Radar
(08:38:45.19)
(08:39:18.33)
Final Radar Point (08:39:26.61)
Final GPS Point (08:39:05.672)
X
Crash Site

Figure 1

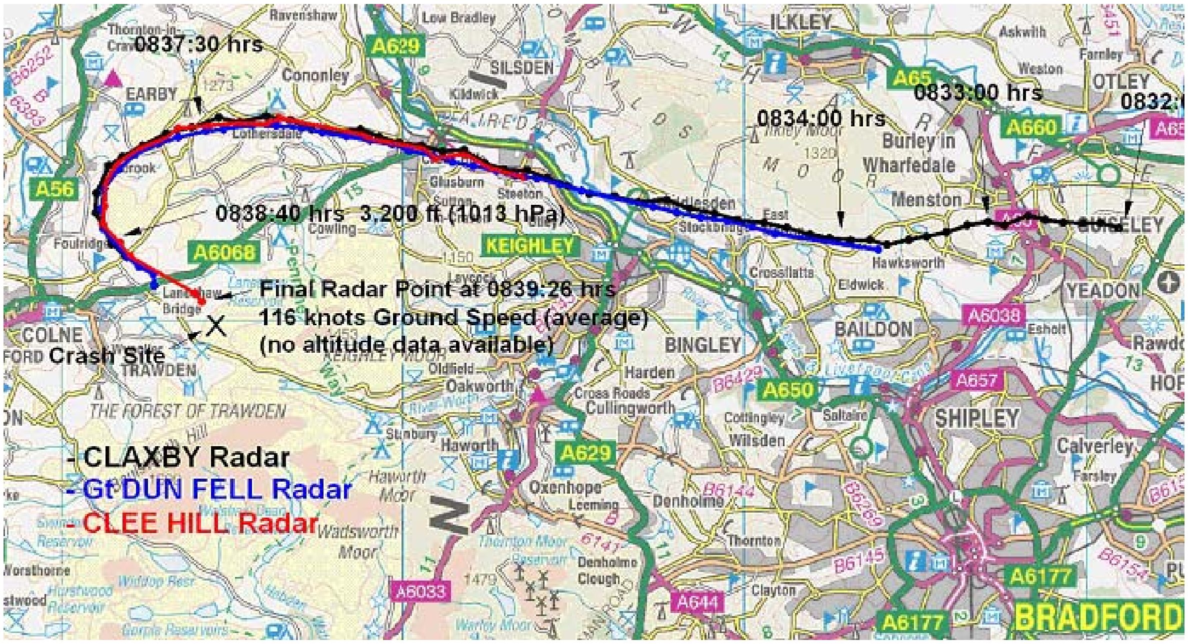


Figure 2 - Radar traces of flight by N6834L

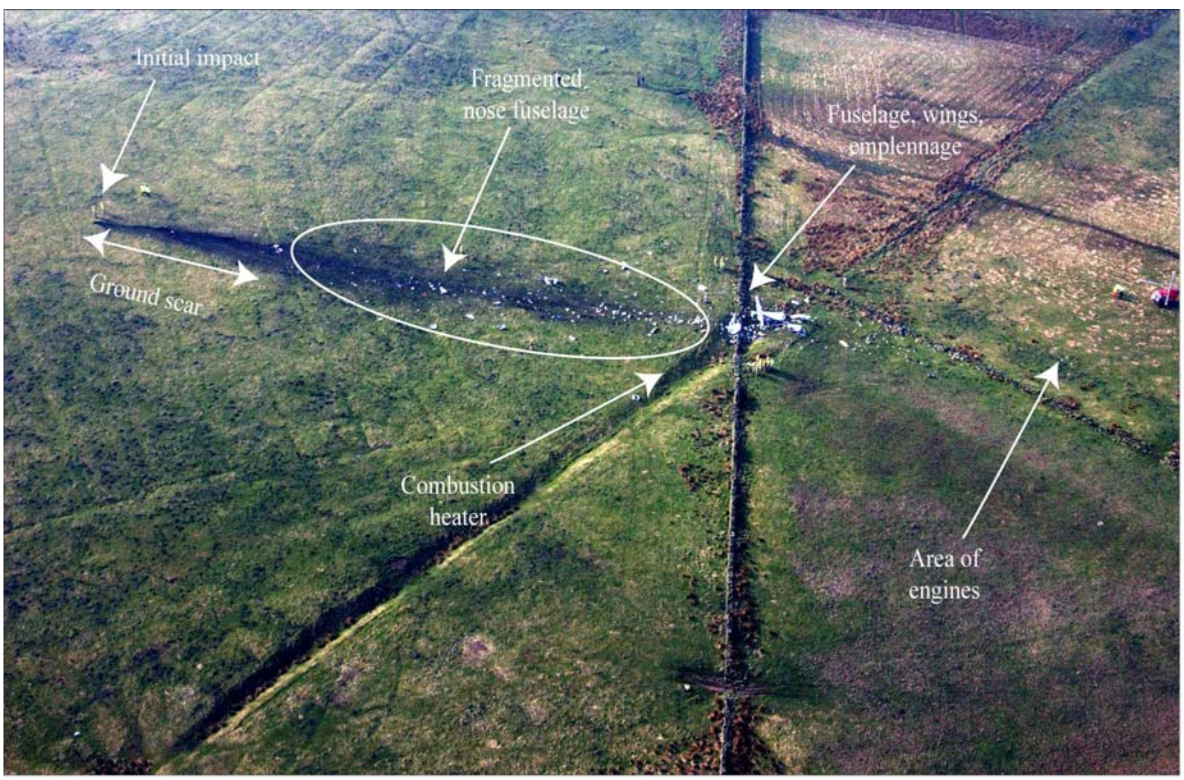


Figure 3 - Accident site - N6834L

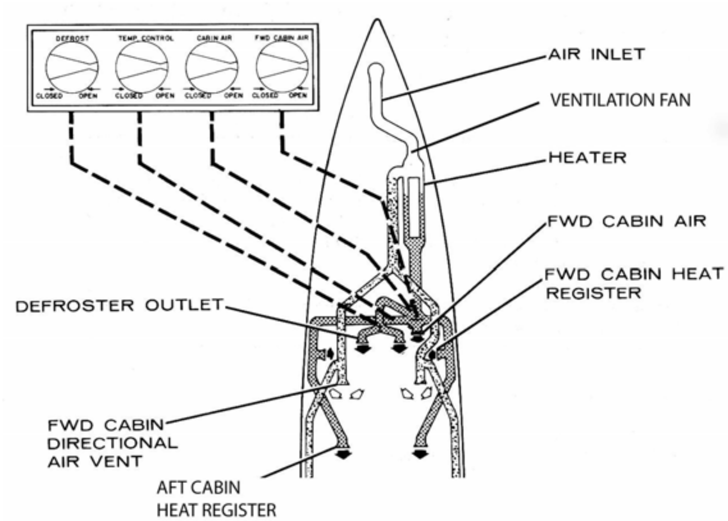


Figure 4 - Heater and ventilation system - T310R

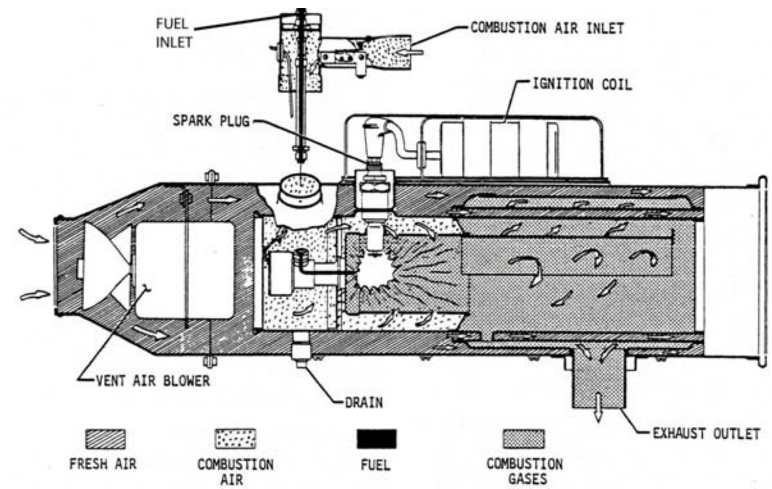


Figure 6 - Combustion heater function

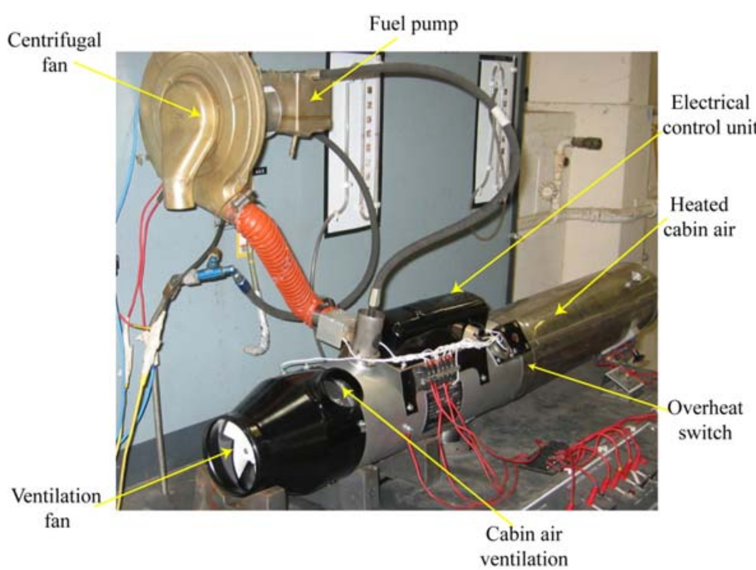


Figure 5 - Typical T310R combustion heater - bench test

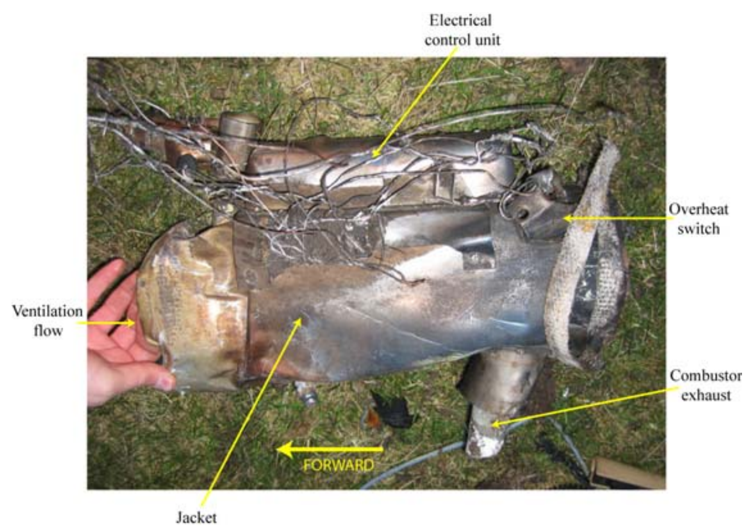


Figure 7 - Combustion heater, N6834L - left side

Aircraft Type and Registration:	Folland Gnat T Mk 1, G-BVPP
No & Type of Engines:	1 Rolls-Royce Orpheus Mk 10101 jet engine
Year of Manufacture:	1963
Date & Time (UTC):	17 September 2004 at approximately 1240 hrs
Location:	Near to the A414 road, 1 nm north-west of North Weald Airfield, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to underside of aircraft
Commander's Licence:	Basic Commercial Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	1,250 hours (of which 40 were on type) Last 90 days - 15 hours Last 28 days - 5 hours
Information Source:	AAIB Field Investigation

Synopsis

Whilst approaching the circuit to land at North Weald Airfield, the engine lost power. As the pilot considered that the aircraft had insufficient energy to complete the turn on to final approach, he elected not to order an ejection and landed the aircraft wheels up in a partially ploughed field, approximately one nautical mile to the north-west of the airfield. With a landing speed of approximately 160 kt and approximately 800 lbs of fuel on board, the aircraft touched town, bounced and then slid to a halt with minimal damage. There was no fire and both occupants made their escape unaided. No definitive technical cause could be established for the loss of power but it was considered likely that a restriction in the fuel supply to the engine had occurred late into the flight.

History of the flight

The aircraft took off from North Weald at 1147 hrs, with 3,063 lbs of Avtur fuel on board (full tanks), bound for the Royal Naval Air Station Yeovilton. The route, to be flown under the Visual

Flight Rules (VFR), was planned to take the aircraft overhead Cranfield Airfield and then direct to Yeovilton, passing to the south of Swindon. The pilot had decided that, in view of the deteriorating weather conditions to the west, he would make a decision abeam Swindon as to whether to continue on to Yeovilton or return to North Weald.

The flight proceeded as planned until the aircraft reached the decision point at Swindon. Here the pilot established that the weather at Yeovilton was unsuitable and he elected to return, routing via Cranfield Airfield's overhead and from there to North Weald. At Cranfield the aircraft descended to an altitude of 1,500 feet amsl, having previously transited at various levels below FL100. At that point the pilot observed the aircraft's fuel gauge was indicating 1,100 lbs, which, on the basis of a consumption rate of approximately 42 lb per min, gave a total endurance of about 26 minutes. The pilot also stated that the throttle was set at about 70% to give a speed of less than 250 kt.

At 1233 hrs the pilot contacted North Weald to advise them that G-BVPP was north of Luton's control zone and "inbound". North Weald radio acknowledged this call and advised the pilot that they were using Runway 20 with right hand circuits. When the aircraft reached the Visual Reference Point at Ware the pilot recalled seeing a fuel state of just below 800 lbs. With an estimated one and a half minutes to go to touchdown, he considered that the aircraft was behaving normally.

About 30 seconds after passing Ware, the amber FUEL caption, located on the secondary warning panel on the pilots instrument panels, illuminated. The passenger also observed the corresponding caption on the rear seat instrument panel and he recalled that the fuel gauge was reading between 800 and 850 lbs at that point. The pilot checked that the fuel booster pump was on, which it was, and about 15 seconds after he had first seen the caption the engine lost power and 'spooled down'. With the airfield in sight, the pilot opened the throttle but was unable to restore the power. Suspecting an engine flame out, he pressed the relight button for approximately 10 seconds but this had no effect either. By now the aircraft was at about 1,000 feet agl and a speed of approximately 240 kt. The pilot shut the high pressure fuel cock (HPC) and carried out the relight drill from memory. He recalled that on opening the throttle the engine remained at very low power and sounded as if it was idling. He could not remember what the engine gauges were indicating.

The aircraft had now reduced speed further to about 190 kt and was descending through 800 feet on the North Weald QFE pressure setting. Despite being close to the north-western side of the airfield, the pilot considered that the aircraft had to negotiate too large a turn to the right to enable it to reach Runway 20 so he elected to land in a large field approximately one nautical mile to the north-east of the airfield. He briefly considered ejecting but decided that a forced landing was the better option. The aircraft landed one third of the way into a partially ploughed field at a speed of about 160 kt, on a southerly heading, with full flap selected and the landing gear retracted. G-BVPP bounced and remained controllable until it landed a second time. During the subsequent ground slide the pilot jettisoned the canopy and after an estimated 200 metres the aircraft slewed to the right and slowed down rapidly over the final 100 metres, remaining upright. The Gnat came to a halt pointing 45º to the right of the direction of the ground slide. The pilot shut the engine down and he and his passenger exited the aircraft. They were uninjured and moved away to a safe distance. Seeing no signs of smoke, fire or leaking fuel, they then returned to the aircraft to make the ejection seats safe.

The pilot had not transmitted a MAYDAY on the radio before landing. Consequently it was about 10 minutes before the emergency services began to arrive at the scene after being alerted by a member of the general public.

Meteorology

The synoptic situation showed a moist south-westerly airflow covering the intended route between North Weald and RNAS Yeovilton, with a cold front lying to the north along a line from the Humber through Gloucester to Penzance. The front was moving slowly south-east.

The conditions at North Weald at the time of the accident were cloudy with the base at 2,500 to 3,000 feet above airfield level (aal). There was 30 km visibility and a surface wind from 210º/15 to 25 kt. The surface air temperature was 18ºC and the dew point was 11ºC.

Procedures

The aircraft's emergency flight reference cards (FRCs), as used when the aircraft was in service with the Royal Air Force (RAF), state that in the event of the FUEL caption illuminating:

> *'If there is a restriction in the fuel supply, max engine RPM may be reduced. There is a slight risk of flame-out, preceded by fluctuating RPM and rough running.'*

The pilot's actions are to:

> *'1. Throttle back.*
>
> *2. If light goes out, maintain power (if possible) at a setting below that at which the light comes on.*
>
> *3. If the light does not go out, keep power to the minimum possible, avoiding negative g.*
>
> *4. In either case, land as soon as possible.*
>
> *Note: If the engine runs normally, treat as booster pump failure and return to base. If the DC caption comes on, momentarily switch on ILS to check for DC failure'.*

There was no report of the DC caption illuminating.

The procedure for a belly landing is given as:

1. *Make a normal approach aiming to land gently on the runway at normal touchdown speed.*
2. *On touchdown stream brake chute and select HP OFF.*

There is no procedure given for an 'off-runway' forced landing. The FRCs also include the following warning and limitations:

> *'If a safe landing is doubtful, both crew must eject before the minimum height/speed for safe ejection, allowing at least 300 feet to regain level flight prior to ejection.'*
>
> *'Minimum height/speed for ejection. Ground level/90 knots (level or climbing)'*

Also, paragraph 5.2 of Chapter 7 of CAP 632, *Operation of 'Permit-to-Fly' ex-military aircraft on the UK Register*, issued by the CAA, states:

> *'Forced landings should only be carried out in jet aircraft as a last resort, unless they can be made onto a suitable airfield. If ejection or abandonment is inevitable, every effort must be made to ensure that the aircraft falls into an unpopulated area. ……..'*

Aircraft description and history

The Gnat is a two seat (tandem) aircraft, powered by a single Bristol Siddeley Orpheus jet engine, and is equipped with a tri-cycle retractable landing gear. It was originally designed by the Folland company, but built by a division of Hawker Siddeley Aviation for the RAF. Production of the type in the UK ceased before 1970 and all examples had been withdrawn from military service in the UK by 1984. The original agreement of sale for the engines incorporated a contract for the engine manufacturer to provide technical support whilst the type remained in service with the original operators. All UK manufactured examples of the engine were withdrawn from service approximately 20 years ago, once the Gnat and the Fiat G91, the other type to use this engine, ceased to be operated by the British and Italian air forces respectively.

The Orpheus engine type was also built under licence in India and installed in a number of aircraft types, including the licenced produced Gnat, and these engines continued in service after the withdrawl of the UK produced engines. Thereafter, Rolls Royce, the inheritor of the Bristol Siddeley company, sold the Orpheus project to India and relinquished any responsibility for further development, production, product-support or flight safety involvement with the engine type. Consequently, some two decades later, little manufacturer's expertise specific to the Orpheus engine remains. BAE Systems, the inheritor of the airframe manufacturer, similarly no longer retains in-house specific knowledge of the aircraft. Thus, the support of such aircraft is difficult to provide and, together with the lack of newly manufactured spares, is likely to become increasingly so in the future.

Engine history

The engine was released to service with zero hours from overhaul in 1975 and returned for repair in 1976, having run for 69 hours. It was returned again in 1978 with a total running time of 269 hours for the replacement of some bevel gears. It was fitted to G-BVPP at 3,550 airframe hours, on 6 February 1987, with a total running time of around 403 hours, and inhibited in May 1993 after which it was not used for some two years. At the time of the accident some 3,670 airframe hours were recorded, indicating that the engine total running time was around 522 hours in the 29 years since it had been overhauled.

Fuel system description

At the time of the accident, G-BVPP was fitted with two under-wing slipper tanks and eight airframe fuel tanks were in use, Figures 1 and 2. (The two rearmost fuselage tanks were reportedly isolated.) Pneumatic pressure, bled from the engine compressor, is supplied to each slipper tank and causes the fuel to be transferred to the associated wing tank, from where it subsequently transfers into two pannier tanks, one located each side of the fuselage. From there, the fuel transfers to the fuselage centre tank group. All fuel tanks on the aircraft eventually feed into the No 1 centre tank in the fuselage, which contains a boost pump, from where the engine is supplied via the low pressure fuel cock (LPC). A flow proportioner ensures that equal volumes of fuel are taken from each tank group (left and right) to prevent any imbalance across the aircraft. A fuel low pressure switch, downstream of the engine low pressure filter, operates the FUEL warning light on both pilots instrument panels should the boost pump pressure be lost or the filter become blocked. Additionally, a fuel low level float switch triggers a warning light when the contents of the No 1 centre tank become depleted to a level that only assures sufficient fuel for a missed approach, a go-around and a landing.

A single fuel gauge in each cockpit indicates the total amount of fuel on the aircraft, and fuel levels (full/empty) in the slipper tanks are indicated by a pair of 'dolls-eyes'. Should pneumatic pressure be lost to the slipper tanks, any remaining fuel would not transfer to the fuselage tanks and would be unavailable for use. Similarly, some of the wing fuel would not transfer. Under such conditions a sensor in the pneumatic line, downstream of a pressure reducing valve between the engine compressor and the slipper tanks, should cause a fuel transfer (FTR) warning light to illuminate in both cockpits, and the fuel gauge would then only indicate the remaining available fuel on board.

The engine fuel control system consists of a low pressure fuel filter, a high pressure fuel pump, a combined control unit (CCU), a pressure ratio limiter (PRL), and an air-fuel ratio controller (AFRC). The CCU, PRL and AFRC are separate units connected to the high pressure fuel pump by a network of pipes, all of which provide fuel pressure signals to control the output of the pump, and hence engine speed.

Aircraft examination

General

Little physical examination of the aircraft could be carried out in the field whilst the aircraft remained on its belly so the aircraft was salvaged by the operator's maintenance organisation and returned to its base at North Weald Airfield. As the circumstances of the accident appeared to indicate a problem with the fuel system, the airframe and engine fuel systems were examined in detail, albeit some time after the accident.

With the aircraft standing on its landing gear, an examination of the underside showed that although most of the fuselage skins had been destroyed in the ground slide, the bottom of the No 1 tank and piping to the engine mounted fuel components remained intact. A small crack in the main fuel gallery between the boost pump and the engine main fuel filter, however, allowed a very slow weep of fuel to occur. With the batteries installed and power selected to ON, the fuel contents gauge indicated in excess of 700 lb of fuel remained on the aircraft.

Fuel system tests

A flow test, carried out with the boost pump running and the fuel gallery disconnected at the outlet to the engine, produced a flow of fuel from the No 1 centre tank well above the minimum figure specified in the available maintenance documentation and, when re-connected, the low fuel pressure warning light extinguished. Inspection of the low pressure fuel filter revealed no major contamination.

The engine was externally examined and found to be free to turn, with no visible damage to the compressor or turbine. Temporary repairs were made to the damaged lower lips of the engine intake ducts using 'speed-tape', and a successful attempt was made to start the engine. It was found to accelerate normally to approximately 50% of full speed, at which point further thrust lever movement had no further effect. The units forming the fuel control system on the engine were then selectively disconnected and, as appropriate, their open ends blanked, prior to conducting a series of engine runs. This revealed that when the AFRC was taken out of the control loop, 100% engine speed could be achieved, but only around 50% when either the CCU or PRL were disconnected. The AFRC was then removed from the engine with the intention of conducting a performance check on a test rig. It was noted that the compressor pressure sensing connection was heavily contaminated with what appeared to be soil, most likely occasioned during the forced landing.

The AFRC was manufactured by Lucas Aerospace, now part of the Goodrich company. Their fuel system specialists were able to access archived data relating to this unit and were able to modify an existing rig to facilitate testing. The results of the test indicated that, although its performance differed from the archived figures, when allowance was made for in-service wear and tear, and possible use of available adjustments on installation, the unit was probably capable of satisfactory operation when fitted to the engine, provided the correct compressor delivery pressure could be sensed.

The operator's maintenance organisation dismantled the airframe fuel system and examined all its components. Their observations on any abnormalities were:

- Contamination of a coarse mesh strainer in the connection between the left wing tank fuel/air air transfer pipe and the left No 1 (pannier) tank, was present in the form of a small strip of white sealant.
- Failure of the No 1 centre tank float switch had occurred due to the float becoming adhered to sealant in the roof of the tank.

Additional information

An accident involving a RAF Gnat during the latter years of its service, occurred after the engine lost thrust/flamed out. The crew ejected and the aircraft crashed into a grass covered field. Evidence of fuel splashing on the ground indicated that an asymmetric fuel state existed at the time of impact. It was established that the aircraft had been refuelled in error from one side only, the refuelling crew not realising that the flow proportioner did not allow significant fuel transfer across the aircraft. Although designed to allow the system to draw equal volumes of fuel from each side of the aircraft, the proportioner apparently drew air from the 'unrefuelled' tanks once their contents were depleted. This allowed the No 1 tank to empty and the engine to run down, the consumption rate of the engine being greater than the supply from only one group of fuel tanks. The investigation into this accident reportedly found that the No 1 tank low level float switch was not functioning. It is not known if slipper tanks were fitted to this aircraft.

A former RAF instructor pilot who had flown the Gnat for a large number of hours, recalled that he had once experienced asymmetric fuel consumption from each side of a Gnat when flying with slipper tanks. On that occasion, the condition became rapidly evident as he needed to apply increasing lateral stick force/deflection to maintain wings level flight. An early landing was carried out. This characteristic is referred to in the RAF Aircrew Manual for the Gnat as a *'possibility'*.

The Defence Air Safety Centre (DASC) was requested to review any data on fuel system, fuel transfer and related engine performance problems that might have been recorded by the RAF Directorate of Flight Safety during the service life of the Gnat. No events were identified that had any bearing on the accident to G-BVPP, although the basis upon which such events might have been recorded was not established.

The Civil Aviation Authority's policy with regard to permitting the operation of ex-military aircraft is contained in both CAP 632 *Operation of 'Permit-to-Fly Ex-Military Aircraft on the UK Register* and *BCAR A – Chapter A8-20.*

Analysis

Examination of the aircraft after its recovery to North Weald Airfield failed to determine the reason for the loss of power reported by the pilot shortly before landing. The engine tests and rig test of the AFRC left little doubt that the reason for the failure of the engine to accelerate during the post-accident engine runs was the contamination by soil of the compressor delivery pressure connection on the AFRC. As the aircraft reportedly carried out most of the flight without problems, it is reasonable to assume that the contamination occurred late in the flight and probably whilst the engine was running during the ground slide.

The post accident examination of the aircraft showed that a reasonable amount of fuel was present in the aircraft at the time of the accident, that sufficient fuel was contained within the No 1 tank for a satisfactory flow rate test to be conducted, and that it was physically possible for the engine to produce full power, albeit with the AFRC disconnected. However, the exact distribution of fuel within the aircraft during and immediately after flight, which is dependant upon the actual rate at which fuel flows from each side of the proportioner, may have differed from that at the time of testing. This is because it is possible that fuel may have transferred into the No 1 centre tank under the influence of gravity during the intervening period. After attempting a relight, the pilot reported that the engine remained at very low power and sounded as if it were idling which, together with the observed FUEL warning, suggests that a restriction or a lack of fuel in the supply line from the No 1 centre tank to the engine (manifested as a low delivery pressure) had occurred. Also, the normal indication that its contents are low is the warning light operated by the low level float switch, but that warning was found to have been inoperative and was unlikely to have provided any such indication during the last flight. If bleed air pressure in the fuel system had failed early in the flight, then it is unlikely that fuel from one or both slipper tanks would have transferred. If such a failure had occurred but affected only one tank, the pilot should have been able to detect this as an imbalance in roll as the slipper tanks are located well outboard on the wing. None was reported. However, should such a failure have occurred later in the flight and affected either one or both sides of the aircraft, most of the fuel would have been in or close to the fuselage and roll imbalance would have been more difficult to detect. Although no evidence of a failure in the fuel transfer air system was discovered during the investigation, the possibility that the No 1 centre tank became depleted due to a failure of fuel to transfer from one or both sides of the aircraft, late in the flight, leading to the loss of power, could not be dismissed.

Until the amber FUEL caption illuminated shortly before arriving back at North Weald, the pilot considered that the aircraft had been behaving normally. At this point it was reported that some 800 lbs of fuel remained on the aircraft, a figure consistent with 700 lbs indicated when the aircraft was powered up after the accident. Thus, complete exhaustion of the fuel on board the aircraft could be dismissed as a cause of the loss of power.

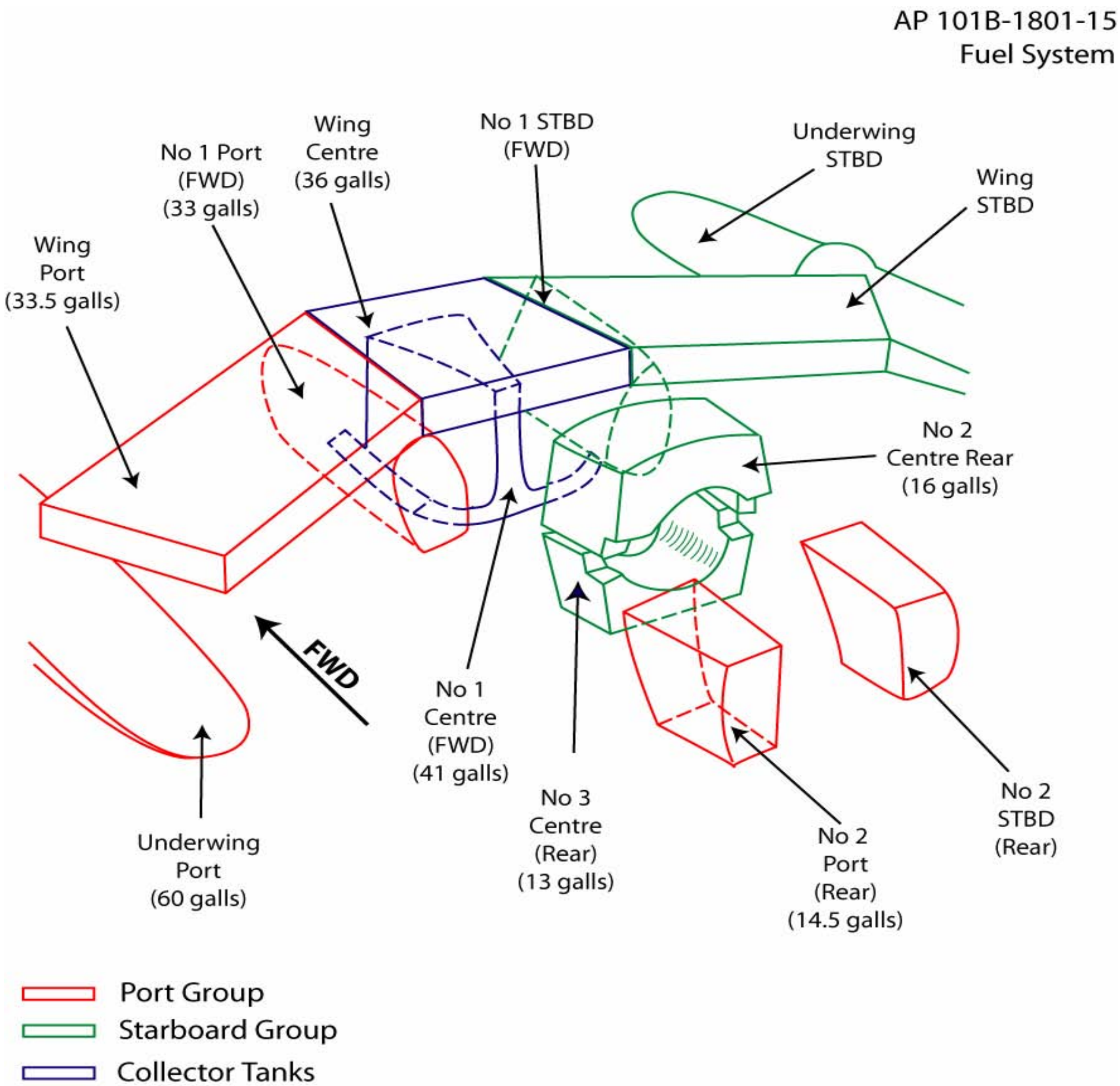
The FRCs relating to the Gnat were those published for use when the aircraft was in service with the RAF and, although information is given on the procedure for a belly landing on a runway, there is no such information for an off-runway landing. Indeed, the FRCs state that if a safe landing is doubtful then both crew members are required to eject. The aircraft was thought be have been above the minimum limits for ejection, ground level/90 kt, level or climbing, at the time the decision to land was made. Also, paragraph 5.2 of Chapter 7 of CAP 632, *Operation of 'Permit-to-Fly ex-military aircraft on the UK Register* stated that:

> *'Forced landings should only be carried out in jet aircraft as a last resort, unless they can be made onto a suitable airfield. If ejection or abandonment is inevitable, every effort must be made to ensure that the aircraft falls into an unpopulated area. ……..'*

Conclusions

In this event, a successful off-airfield forced landing was carried out at relatively high speed into a partially ploughed field, and the crew exited the aircraft uninjured. Welcome as that was, the prevailing advice indicates that ejecting would have been the preferred option and, in the circumstances, the crew were fortunate to avoid a much more serious outcome. However, had the crew ejected, then it is almost certain that the aircraft would have been destroyed, with the attendant risk that it may well have continued a short distance and crashed into an inhabited area. The investigation did not establish any definitive reason for the loss of power as the aircraft approached North Weald Airfield. It was, however, established that the engine and its control system should have been able to provide full power and so it became probable that a lack of, or a restriction in, the fuel supply to the No 1 centre tank occurred.

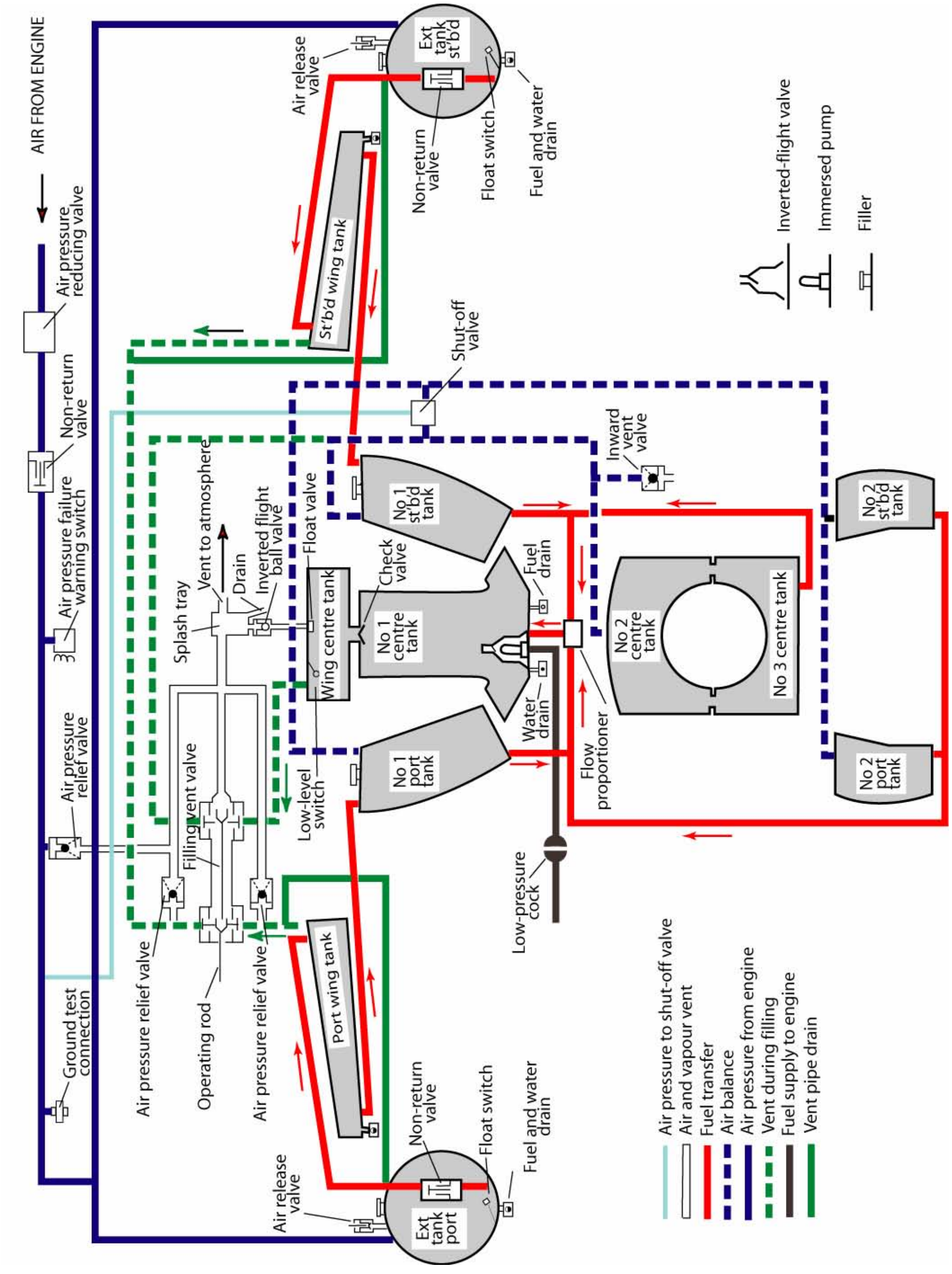
Figure 1



Fuel Tank Layout Diagram

(taken from GNAT T Mk 1 Aircrew Manual)

Figure 2



Fuel System Diagram

(taken from GNAT T Mk 1 Aircrew Manual)

Aircraft Type and Registration:	Cessna 150M, N8174V	
No & Type of Engines:	1 Continental 0-200A piston engine	
Year of Manufacture:	1974	
Date & Time (UTC):	19 May 2005 at 0847 hrs	
Location:	Approximately 20 miles north of Dundee, Scotland	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	ICAO Airline Transport Pilot's Licence and FAA Private Pilot's Licence	
Commander's Age:	43 years	
Commander's Flying Experience:	2,400 hours (of which 1,500 were on type) Last 90 days - 50 hours Last 28 days - 30 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries by the AAIB	

The pilot was on a ferry flight from USA to Europe and had landed at Inverness Airport for an overnight stop. His next planned sector was to Newcastle Airport. The forecast weather for this leg of his trip indicated a wind of 220º/20 to 25 kt, visibility between 10 and 20 km and light rain with cloud overcast at 3,000 feet amsl. The pilot's original plan was to follow the coast line but, due to time constraints resulting from a need to get to Zurich that day, he decided to take a direct routing towards Newcastle.

After an uneventful takeoff at 0730 hrs, the pilot set course to the south under VFR and climbed to approximately 3,000 feet amsl. He decided not to use an ATC service. However, in the early part of the flight the weather deteriorated with heavier rain and reduced visibility. The pilot climbed, but levelled the aircraft at 3,300 feet amsl, which was the freezing level but which was below Minimum Safe Altitude (MSA). N8174V was now in cloud and the pilot continued his flight using a GPS which had basic terrain information. Some time later, he suddenly became aware that the aircraft Vertical Speed Indicator (VSI) was indicating full scale down deflection and that the altimeter was also indicating a descent. The pilot immediately applied full power but was unable to arrest the descent. Looking ahead, he saw a mountain about 50 metres away and was unable to alter course before striking the ground at an estimated ground speed of 65 to 70 kt. The pilot was able to get out of the aircraft and used his mobile telephone to call his family in Austria, who then alerted their national Rescue Co-ordination Centre.

Once the UK Aeronautical Rescue Co-ordination Centre (ARCC) at Kinloss had been alerted, the duty controller contacted the pilot by telephone at 0947 hrs. The pilot confirmed that he only had minor injuries and that he was well equipped with a GPS receiver, survival suit, life jacket and dinghy. Thereafter, ARCC maintained regular contact with the pilot and alerted a SAR helicopter from RAF Lossiemouth. Low cloud prevented the helicopter from visually locating the pilot and a Mountain Rescue Team (MRT) was flown to the area for a ground search. Under instructions from the ARCC, the pilot used a whistle to enable the MRT to locate him at about 1500 hrs. The altitude at the crash site was approximately 2,600 feet amsl. The highest obstacle indicated on the 1:500,000 CAA VFR topographical chart for the region some 20 nm north of Dundee was 4,100 feet amsl.

The pilot confirmed that N8174V was serviceable prior to ground impact. On reflection, he considered that he had relaxed after reaching Inverness Airport on his ferry flight and did not properly plan the subsequent legs. With his experience of flying in the Alps, he did not consider that the Scottish mountains would cause him any problems.

Aircraft Type and Registration:	Cessna 182Q, G-WMLT	
No & Type of Engines:	1 Continental Motors Corp O-520-F-TS piston engine	
Year of Manufacture:	1979	
Date & Time (UTC):	23 June 2005 at 0900 hrs	
Location:	Yew Tree Lodge, White Horse Lane, Barton, Lancashire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Nose wheel bent under and propeller damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	49 years	
Commander's Flying Experience:	910 hours (of which 770 were on type) Last 90 days - 19 hours Last 28 days - 5 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The aircraft had departed from Blackpool to fly to a grass strip at Barton, adjacent to the pilot's home. The strip was about 320 metres in length, oriented 200/020º. At the time of the accident the grass had been recently mown and was short and dry. The wind was reported as being 230º/11 kt, and in the into-wind direction there was a 2º up-slope. The strip had been inspected by the pilot on the evening before the accident; but he had not noticed a deep rut close to the (unmarked) threshold, possibly because the grass was even after being mown.

During the landing the aircraft touched down normally but then entered the rut and became airborne again. The pilot applied power before re-landing, and the second touchdown was normal. Although the nose wheel was held off initially and no braking used, the nose landing gear collapsed during the rollout and the aircraft came to rest after about 16 metres.

The pilot has advised that the threshold will be marked at the start of the rolled and inspected strip.

Aircraft Type and Registration:	Jabiru UL-450, G-DJAY	
No & Type of Engines:	1 Jabiru Aircraft Pty 2200A piston engine	
Year of Manufacture:	2001	
Date & Time (UTC):	8 June 2005 at 1305 hrs	
Location:	Wycombe Air Park, Buckinghamshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Propeller tips and nose wheel	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	76 years	
Commander's Flying Experience:	609 hours (of which 78 were on type) Last 90 days - 4 hours Last 28 days - 2 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Following a private flight from Popham to Wycombe Air Park, the pilot prepared the aircraft for a landing on Runway 24 Right. The weather at the time was good with the wind from 180º/2 kt. On landing, the aircraft bounced which resulted in damage to the nose wheel rubber shock absorber, collapse of the nose wheel and damage to the tips of the propeller. The pilot, who was wearing a lap strap and diagonal harness, was uninjured and exited the aircraft normally.

Aircraft Type and Registration:	Jodel D112, G-BIVB	
No & Type of Engines:	1 Continental Motors Corp A65-8F piston engine	
Year of Manufacture:	1960	
Date & Time (UTC):	1 May 2005 at 1606 hrs	
Location:	Private strip at Twineham, West Sussex	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Minor)	Passengers - N/A
Nature of Damage:	Substantial	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	50 years	
Commander's Flying Experience:	253 hours (of which 4 were on type) Last 90 days - 4 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot was a member of a flying group. The group had recently acquired the aircraft and during the previous week the group members, including this pilot, had spent some time at Goodwood Airfield on familiarisation flights. The flights were conducted informally with another pilot, who was experienced on the type, flying with each group member until they felt that they were proficient.

The group planned to operate the aircraft from a private grass strip which was measured by them at 330 metres (1,082 feet) in length and orientated 02/20. The pilot flew the aircraft from Goodwood to the strip and landed successfully on Runway 02 in calm wind conditions. Later in the afternoon the pilot decided to fly some circuits; the surface wind now slightly favoured Runway 20.

The pilot was familiar with the strip and followed his usual circuit pattern. On final approach he made some corrections to his approach path and at about half a mile he was satisfied with the position of the aircraft. When he was some 50 to 75 metres short of the boundary hedge he realised that he was a little low and made a power correction. The aircraft has a throttle lever mounted on a quadrant on the left side wall of the fuselage but in making the adjustment he inadvertently moved the lever backwards thereby reducing power, instead of forwards as he had intended. By the time he recognised his mistake the aircraft was sinking and he was unable to clear the hedge.

The wheels hit a low bank and the main body of the aircraft then passed through the hedge and stopped rapidly, having slewed around to the left, but remained upright. The pilot was wearing a four point harness and was able to exit the aircraft unassisted having suffered only minor injuries.

The pilot later stated that the aircraft had less forward field of view when on approach than the previous type he had been flying. The group decided, subsequent to the accident, that in future type familiarisation training should be carried out in a more formal manner, probably with a flight instructor.

Aircraft Type and Registration:	Pierre Robin DR400/180R, G-BPZP
No & Type of Engines:	1 Lycoming O-360-A4A piston engine
Year of Manufacture:	1980
Date & Time (UTC):	7 May 2005 at 1300 hrs
Location:	Lasham Airfield, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Substantial damage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	75 years
Commander's Flying Experience:	469 hours (of which 120 were on type) Last 90 days - 8 hours Last 28 days - 8 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by AAIB

History of the flight

The aircraft was one of a number being used to provide aero-tows to club gliders at Lasham. The pilot, himself an experienced glider pilot and instructor, was just completing his second flight of the day in the aircraft and was approaching to land when the accident happened. Gliders were assembled near to the threshold of Runway 27, and the aero-tow aircraft were landing on a grass area adjacent to the gliders and immediately to the south of the main runway. A number of witnesses in the vicinity of the gliders observed the aircraft as it completed its turn onto final approach, at a height estimated to be between 150 and 250 feet. The aircraft was seen to roll to the right, in what initially appeared to be a controlled manner. However, the roll to the right continued and the aircraft departed from controlled flight, impacting the ground in a steeply banked attitude, having turned through about 120º from the direction of landing. Initial contact with the ground was made by the right wing tip. The aircraft then cart-wheeled, during which the engine separated and further substantial damage occurred to the left wing and empennage, though the cabin area remained largely intact. The fuel tank, situated behind the passenger compartment, remained intact and there was no fire.

Gliding club members were quickly on the seen and attended to the pilot. With no immediate risk of fire, the pilot was advised to remain in the aircraft until he could be examined and treated by the emergency services, which attended directly. The pilot was wearing a four point harness and suffered only minor injuries in the accident.

The aircraft was recovered to the gliding club's own maintenance facility where it was examined; no sign of a pre-impact failure was found. The aircraft had recently been the subject of an extensive rebuild at a facility in France and had flown some 75 hours since its last check. It had flown thirteen times on aero-tows during the day with no reported faults, and had been re-fuelled when the pilot had assumed his tug-pilot duties on the flight before the accident.

Pilot experience

The pilot was an experienced glider pilot and instructor, with about 4,000 gliding hours, and was well regarded within the gliding community. His powered flying experience was mainly gained in club aero-tow aircraft and motor gliders. The gliding club monitored tug pilots' currency and competency, and the pilot was considered fit for aero-tow duties. The pilot sometimes had difficulty in maintaining adequate currency on the Robin, but was in the practise of asking for a check flight if he felt it necessary. In this case, as the pilot had not flown the Robin for a period, he had undergone a check flight a week before the accident with a Class Rating Instructor (CRI). This flight included stall manoeuvres and practise engine failures and was followed by a dual sortie conducting aero-tows. There were no issues arising from the two flights, and the instructor assessed the pilot's handling skills as very good.

Possible causes

The pilot's initial thought was that the tow cable must have snagged in trees during the approach and imparted a yaw to the aircraft which caused the roll. In flight at 60 kt the end of the cable is about 50 feet below the tug aircraft, and the pilot was conscious of this during the approach. As he completed the turn onto final, he became aware of a sink rate developing and applied power to correct, though not as much as full power. He then thought he sensed a 'tugging' from the tow cable and initiated a dive which he hoped would break the weak link in the cable. However, almost as soon as he moved the control stick forward, the aircraft started to roll to the right, and the pilot was unable to stop the roll with full 'opposite controls'. He did not further alter the power setting prior to impact with the ground.

The tow cable was subsequently inspected. Weak links at either end of the cable were set at 900 lbs and 1100 lbs and were designed to indicate if a force approaching the limit had been experienced. Both weak links were in good condition and showed no signs of distress: the cable itself bore no evidence of contact with trees. Additionally, eye witnesses believed that the aircraft was too far from the trees for this to be a causal or contributory factor in the accident.

Although it was a fine day there was a brisk surface wind from the north-west at an estimated 20 to 25 kt. From this direction the wind was blowing over a line of substantial trees, thereby creating turbulence on the approach down to about 50 feet. The pilot reported that his airspeed on the approach was 65 kt with half flap selected. This approach speed was appropriate for calm conditions but the club recommendation was to add half the wind strength to the approach speed; it was therefore less than recommended in the given conditions.

From the pilot's account, eye-witness information and known conditions, it is likely that the pilot encountered negative wind shear during the approach which caused the aircraft's right wing to stall. Once the wing was stalled, the roll and the pilot's application of full left aileron would have served to exacerbate the situation, causing the aircraft to enter an autorotative manoeuvre from which there was insufficient height to recover. The pilot subsequently flew a sortie with the CRI which included a number of stall manoeuvres, including aggravated stalls with an induced wing drop. The pilot was subsequently of the opinion that a stall on finals in the gusty conditions was a likely cause of the accident.

Aircraft Type and Registration:	Piper PA-23-250 Aztec, N54211	
No & Type of Engines:	2 Lycoming TIO-540 piston engines	
Year of Manufacture:	1974	
Date & Time (UTC):	5 February 2005 at 1310 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 nose cone, nose underside and nose gear doors	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	41 years	
Commander's Flying Experience:	999 hours (of which 13 were on type) Last 90 days - 10 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB	

Synopsis

The nose landing gear would not lock down in flight due to an unidentified technical defect involving a loss of hydraulic fluid from the nose landing gear system. Upon landing the nose gear collapsed resulting in damage to the aircraft's nose. During the recovery operation the main landing gear collapsed resulting in further damage to the aircraft. At the time of compiling this report (May 2005) the aircraft had not been raised on jacks to identify the source of the hydraulic leak or to carry out repairs.

History of the flight

The purpose of the flight was to test the engines following the aircraft's annual maintenance check. The pilot, who was also the maintenance engineer, carried out his normal pre-flight checks. The aircraft's hydraulic system was function checked on the ground by cycling the flaps and checking that the landing gear selector returned to neutral following a gear DOWN selection. The pilot carried out a normal takeoff and then selected the gear and flaps UP. The flaps retracted normally and the amber light illuminated indicating that all three landing gear legs were up and locked. The pilot then carried out a large visual circuit, verified the engine operation, and then lined up for a long final approach to Elstree. On final he selected one stage of flap and selected the gear DOWN. Both main gear legs locked down as evidenced by two green indicator lights, but the nose gear's green light did not illuminate. There was also slower traffic ahead so, from a two mile final, the pilot initiated a go-around, retracted the flap and selected gear UP. The flap retracted and he felt the main gear retract but not the nose gear. A visual check via the mirror on the left engine nacelle revealed that the nose gear was in a semi-retracted state.

The pilot left the circuit and flew to a nearby area to troubleshoot the problem. He selected the gear DOWN and obtained two 'greens' on the main gear but the nose gear did not lock down. He then used the emergency hand pump to try and extend the gear but he felt no resistance while pumping and noticed a strong smell of hydraulic fluid in the cabin. Next, he slowed the aircraft and activated the emergency gas blow-down bottle. He heard the bottle discharge but still the nose gear did not lock down. As a final resort he manoeuvred the aircraft around to try and lock the nose gear down but to no effect. He then informed Elstree Information by radio of his predicament. The emergency services were activated and then the pilot circled for approximately 30 minutes to permit some local aircraft to recover to the airfield. The pilot carried out a flapless approach and then once over the runway threshold, he shut down both engines and feathered both propellers. After a normal touchdown on the main gear the aircraft rolled for a short distance before the nose sank to the runway. The nose gear retracted and the nose of the aircraft scraped along the runway surface until the aircraft came to a rest. Both the pilot and his passenger were able to vacate the aircraft via the normal exit door.

Recovery of the aircraft

The recovery plan for the aircraft was to lower the tail so that the nose gear could be manually pulled forwards until it locked into position. A truck was connected to the tie-down ring on the tail of the aircraft using a rope. Then, whilst the pilot was holding the foot brakes, four people sat on the horizontal tail of the aircraft and the truck pulled on the rope to lower the tail. With the tail lowered the pilot got out of the aircraft and then started to pull the nose gear into the locked position. As he did this, the main gear retracted, the aircraft hit the ground, and the truck pulled the tie-down ring and surrounding skin off the aircraft.

Description of the landing gear system

The aircraft has a hydraulically actuated retractable tricycle landing gear system. The nose gear leg retracts aft while both main gear legs retract forwards. Each landing gear leg is individually actuated by a hydraulic actuator. When the landing gear is selected DOWN, hydraulic pressure causes each actuator to extend a drag link on the respective gear leg until the link reaches an over-centre position. The final movement of the actuator causes a mechanical lock to lock the drag link in the over-centre position. Once the landing gear has locked down, microswitches for each gear leg trigger a respective green light in the cockpit and the gear selector returns to the neutral position. When the gear is selected UP, the actuators retract causing the downlocks to unlock and the drag links to collapse. Once the gear is locked up, microswitches cause an amber light in the cockpit to illuminate and the gear selector returns to the neutral position. When no lights are illuminated the landing gear is in an intermediate position. If the engine driven hydraulic pump fails, an emergency hand pump can be used in its place. In the event of a hydraulic system failure caused by a line rupturing, an emergency CO_2 bottle can be activated to blow the landing gear down.

The hydraulic lines of all three landing gear actuators are connected such that when the system is depressurised, manually moving one actuator will cause hydraulic fluid displacement that will result in the other two actuators moving in the opposite direction.

Maintenance history

The most recent maintenance on the aircraft was an annual inspection completed on 1 February 2005. The accident flight was the first flight since this maintenance. During this maintenance input the aircraft was jacked up and the landing gear was cycled several times and operated satisfactorily. A check of the hydraulic lines and actuating cylinders for 'leaking and security' was also documented in the maintenance worksheets.

Between August 2002 and the accident flight, the aircraft had only flown on one other occasion - a 45 minute flight on 10 May 2004. The accident flight was the aircraft's first flight in nine months. The aircraft's total airframe hours at the time of the accident were 2,341 hours.

Landing gear examination

An inspector from the AAIB examined the aircraft and did not find any evidence of a mechanical fault with the main landing gear or the nose gear. Hydraulic fluid was found congealed around the nose gear door and on the belly of the aircraft aft of the nose gear bay. The nose landing gear actuator and hydraulic lines were not accessible for inspection with the aircraft on the ground. The aircraft needed to be jacked up to determine the source of the hydraulic fluid but this was not possible at the time of inspection.

Analysis and conclusions

The nose landing gear retracted on landing because it was not locked down. No mechanical fault of the nose gear was found that would have prevented it from locking down and therefore it was a loss of actuating power that prevented the nose gear from locking down in flight. The nose gear extends forwards in flight, against the slipstream, and therefore more actuating force is required to extend the nose gear than to extend the main gear which extend aft. The evidence of congealed hydraulic fluid on the belly of the aircraft aft of the nose gear bay indicated that it was a loss of hydraulic fluid in flight that resulted in the loss of actuating force. The source of the hydraulic fluid leak could not be determined at the time of inspection. It is possible that the aircraft's low usage over the past two years may have contributed to the deterioration of a component within the hydraulic system.

The main gear collapsed during recovery of the aircraft because, as the nose gear actuator was being manually extended, the displaced hydraulic fluid caused the main gear actuators to move in the retract direction which caused the downlocks on the main gear drag links to unlock. Fortunately no one was injured but more damage resulted to the aircraft from the recovery operation than from the landing itself. This incident demonstrated how important it is to fully understand an aircraft's landing gear system before attempting a recovery.

Aircraft Type and Registration:	Piper PA-28-140 Cherokee, G-BCGT	
No & Type of Engines:	1 Lycoming O-320-E3D piston engine	
Year of Manufacture:	1968	
Date & Time (UTC):	17 April 2005 at 1115 hrs	
Location:	Compton Abbas, Wiltshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Nose landing gear collapsed, propeller bent, engine shock loaded, right wing tip buckled	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	57 years	
Commander's Flying Experience:	225 hours (of which 136 were on type) Last 90 days - 6 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft touched down heavily and bounced following an approach to Runway 26 at Compton Abbas, where the surface wind at the time of the accident was reported as 15 kt from the south-southwest. The nose landing gear collapsed during the subsequent touchdown and second bounce. The propeller, engine and right wingtip were also damaged. The pilot considered that the use of full flap during the final approach reduced his ability to control the aircraft in a strong crosswind, and that he should have executed a missed approach immediately after the first touchdown.

History of the flight

The aircraft was on a private flight from Shoreham to Compton Abbas, which the pilot had visited on several occasions. He was accompanied by two passengers, who had flown with him previously. On initial contact with Compton Abbas Radio, the pilot was advised to join downwind for a right hand circuit to Runway 26 and to report on final approach.

As he turned onto the final approach at approximately 500 feet agl, the pilot noticed a significant southerly wind component and, after reporting on final, was advised that the surface wind was "SOUTH-SOUTHWEST AT 15 KT". In his statement to the AAIB the pilot commented that he felt comfortable about landing in these conditions, which he had done frequently. Judging that the aircraft was slightly high, he selected full flap and continued the approach at 70 kt, using a "crabbing" technique to allow for the crosswind. The approach proceeded normally until, at approximately 100 feet agl, the aircraft encountered turbulence and began to sink more rapidly than expected. The aircraft landed heavily, bounced and touched down again. The pilot was unable to prevent a second bounce and subsequent heavy touchdown, during which the nose landing gear collapsed. The aircraft continued along the ground in a nose down attitude for a distance of approximately 50 metres before coming to rest, upright, with damage to the propeller and right wingtip, which had come into contact with the runway during the final touchdown. The pilot switched off the fuel and electrical systems and all of the occupants vacated the aircraft without injury.

Airfield

Compton Abbas is a grass airfield, situated on a ridge that runs east to west at an elevation of 811 feet above mean sea level. The single, well maintained grass Runway 08/26 is 803 metres long. The UK Aeronautical Information Publication notes that a line of trees along its southern boundary will cause turbulence on the approach to either runway when the wind has a southerly component. This advice is repeated in commercially available airfield guides.

Aircraft handling

The Cherokee 140 has flaps actuated manually using a handbrake-type lever mounted on the floor between the front seats. The lever has detents in four positions, corresponding to UP, 10º, 25º and 40º. Instructors familiar with the type commented that the aircraft is more controllable in a crosswind with 25º of flap selected. The 40º flap setting is intended to create extra drag and to reduce landing speed, but its use is also likely to degrade the go-around performance of a heavily loaded Cherokee 140. The operating handbook published by the manufacturer does not give any specific guidance on these issues, but states that the maximum crosswind component in which a landing was demonstrated during certification was 17 kt.

Aircraft Type and Registration:	Piper PA-28-140 Cherokee, G-ZEBY	
No & Type of Engines:	1 Lycoming O-320-E2A piston engine	
Year of Manufacture:	1973	
Date & Time (UTC):	23 June 2005 at 1500 hrs	
Location:	Full Sutton Airfield, Yorkshire	
Type of Flight:	Training	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Nose leg collapsed and propeller damaged	
Commander's Licence:	Student pilot	
Commander's Age:	52 years	
Commander's Flying Experience:	24 hours (all on type) Last 90 days - 9 hours Last 28 days - 4 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The accident flight was the pilot's second solo flight as part of his training for a Private Pilot's Licence. The wind was from 260ºM at 4 kt and the visibility was greater than 10 km. The pilot had already completed five successful circuits when he lined up to land on grass Runway 22. The aircraft touched down on the runway and then bounced back into the air. It then descended and bounced again heavily. The pilot applied full throttle to attempt a go-around but at this point the aircraft's pitch attitude was below the horizon and the aircraft touched down heavily on its nose landing gear causing its collapse. The pilot shut down the aircraft and was able to exit the aircraft via the cabin door.

The pilot candidly admitted in his report that he had misjudged his height during the flare and this resulted in the initial bounce. The severity of the bounce took him by surprise and he applied power at the wrong time to initiate a successful go-around.

Aircraft Type and Registration:	Piper PA-28-161 Cherokee Warrior II, G-BHIL
No & Type of Engines:	1 Lycoming O-320-D3G piston engine
Year of Manufacture:	1979
Date & Time (UTC):	8 February 2005 at 1100 hrs
Location:	Near Horsmonden, Kent
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	225 hours (of which 142 were on type) Last 90 days - 5.5 hours Last 28 days - 5.5 hours
Information Source:	AAIB Field Investigation

Synopsis

G-BHIL was returning to the UK on a VFR flight from Zwartberg Airfield, near Genk in Belgium. Although the final destination was Shoreham, it was likely that the pilot intended to land at Old Hay Farmstrip in Kent, before continuing to Shoreham. The weather in Belgium was good but large areas of patchy fog covered the southeast of England. The pilot was using a combination of GPS and visual navigation but, towards the end of the flight, was following the line of the railway between Ashford and Tonbridge. When 2.7 miles to the east of his destination, he appeared to have been unable to continue and commenced a series of climbing and descending manoeuvres in and out of the fog. Whilst in a descending right turn, the aircraft crashed into a grass field, fatally injuring the pilot.

History of the flight

The pilot had visited the flying club at Shoreham, which operated G-BHIL, and discussed joining the club with the intention of making flights to the continent in connection with his business. On 31 January 2005, he flew with a club instructor on a VFR flight for one hour, as part of the requirements for hiring aircraft from the club. The instructor considered that he demonstrated a good level of ability, especially as the pilot's last flight prior to the check flight had been on 3 June 2004, nearly eight months earlier.

On 7 February 2005, the pilot arrived at the flying club at about 1100 hrs for a planned 1400 hrs departure. He carried out his flight planning in one of the club briefing rooms and sought the assistance of an instructor to help him file his VFR flight plan. His intended route was from Shoreham to Zwartberg Airfield in Belgium, via the St Inglevert NDB and Bruno VOR. The pilot had recently purchased a handheld GPS navigation unit and, with some assistance, his outbound route was entered.

The pilot was not seen to leave the flying club but he started up the aircraft and taxied to the fuelling point where he instructed the person refuelling his aircraft to fill both tanks, uplifting a total of 51.8 litres. The aircraft departed Shoreham at 1410 hrs and arrived at Zwartberg at 1631 hrs. A member of the Zwartberg flying club saw the aircraft arrive with only the pilot on board and assisted him with closing his flight plan. He also helped the pilot with filing his return VFR flight plan, the declared route being via the Bruno VOR, Calais, Dover, Mayfield VOR, and then direct to Shoreham. The pilot then refuelled his aircraft with 29.93 litres and returned it to the parking area before taking a taxi to his hotel. Although requested by the club member, he did not enter his details in the 'booking in/out' ledger. That evening, in a telephone call to the UK, he expressed at length his satisfaction with his GPS unit, especially the confidence he had in it and the accuracy of the equipment. He also telephoned one of the owners of Old Hay Farmstrip, located to the east of Paddock Wood and just to the south of the Ashford/Tonbridge railway line, and informed him that he might be landing there the next day. He was told to check before he did so, and was given a mobile telephone number to call.

Zwartberg Airfield is closed on Tuesdays. On the morning of Tuesday 8 February 2005, the manager of a maintenance organisation arrived at the airfield at about 0730 hrs and saw G-BHIL parked on the apron covered in frost. From his office, which does not overlook that part of the apron where the aircraft was located, he did not see the pilot arrive but, at about 0830 hrs, he saw G-BHIL backtrack Runway 21 and takeoff. The pilot, however, had not activated the flight plan that was filed the previous evening.

Before the aircraft departed, the pilot telephoned the mobile telephone number for Old Hay and left a message to say that he was coming. Some time after 0800 hrs, the airfield owner received the message and called the pilot's mobile number. When the call was answered, the airfield owner could hear the noise of the aircraft's engine in the background, suggesting that the aircraft was in flight. The airfield owner had just returned from driving his children to school and recalled that it was foggy, with a visibility of 100 to 200 metres. Accordingly, he told the pilot that the weather was too misty if he was thinking of coming to Old Hay. The pilot replied that he couldn't hear the message, which was then repeated. However, the pilot said that he could still not hear the message, and the call was terminated. The airfield owner called back several times and left messages for the pilot to call him, the last at about 1100 hrs, but by then the aircraft had crashed. The airfield owner was unaware of this fact.

The pilot's GPS unit survived the accident and was downloaded by the AAIB. This gave good track, route and altitude data which, together with information from witnesses, enabled details of the flight to be established. The active route for the aircraft was actually Zwartberg to the Bruno VOR, EGKH (Lashenden-Headcorn) and then via Old Hay Farmstrip to Shoreham.

The pilot made contact with Brussels Information and transited Belgium VFR at about 1,500 feet. At 1009 hrs, the pilot contacted London Flight Information Service and transmitted "GOLF INDIA LIMA PA-28 FROM ZWARTBERG TO SHOREHAM ROUTING VIA CALAIS AND DOVER AND MAYFIELD, CURRENTLY 1,500 FEET WITH ABOUT 10 MILES TO RUN TO DOVER".

At 1015 hrs, the aircraft had crossed the English Channel and coasted in to the south-west of Dover, just before which the pilot requested, and was passed, the Chatham QNH of 1022 hpa. After flying inland for a short distance, he carried out a figure of eight manoeuvre before following the coastline north-east towards Dover. At 1017 hrs, London Information advised the pilot that they had been contacted by Shoreham with the information that his flight plan had been cancelled[1]. The pilot offered no explanation for this and was passed details of the Shoreham weather, which gave the surface wind as calm, visibility of 2,500 metres, cloud FEW at 1,200 feet and a QNH of 1025 hpa. At Dover, the pilot turned to fly north-west until he regained his planned route towards Old Hay. At 1026 hrs, the pilot transmitted to London "IS IT POSSIBLE FOR YOU TO GET ME THE CLOUDBASE AND VISIBILITY FOR HEADCORN?" At 1028 hrs, when G-BHIL was in the area just to the north of Ashford, London Information passed the requested weather to the pilot: "HEADCORN SAY THAT THE SKY IS OBSCURED AND VISIBILITY IS ABOUT ONE KILOMETRE, WIND CALM". The pilot responded "ROGER TO THAT. YOU DON'T KNOW THE HEIGHT OF THE CLOUD ABOVE THE GROUND, DO YOU?" London Information replied "NEGATIVE SIR, ITS OBSCURED SO THEY CAN'T TAKE A PROPER READING. ITS OBVIOUSLY PRETTY LOW".

As the aircraft transited west from Ashford along the line of the railway, it descended several times as low as 200 feet agl. London Information offered the pilot the Lydd weather, to which he responded "NEGATIVE, I'M ACTUALLY BELOW CLOUD NOW SO I CAN SEE WHERE I'M GOING".

[1] A flight plan which has been filed, but not activated, and for which no cancellation or arrival message has been received is automatically cancelled three hours after the designated time of departure plus the estimated elapsed time for the flight. Archived copies are kept for both activated and inactivated flights.

London Information responded "FAIR ENOUGH SIR, THE WEATHER SEEMS TO BE A LITTLE BIT BETTER TOWARDS THE COAST. IT'S A LOT BETTER THAN HEADCORN". The pilot replied "BEAR THAT IN MIND". At 1032 hrs, the pilot gave his position to London Information as six miles east of Headcorn, but there were no radio transmissions between Headcorn and the pilot of G-BHIL. At about this time an aircraft maintenance engineer at Headcorn heard, but did not see, an aircraft pass by at low level to the north with a high power setting as if it were making a fly-past. At about 1038 hrs, a witness at Staplehurst, who was the Flight Operation Manager at Lashenden Airfield at Headcorn, initially heard and then saw from her rear garden a low winged aircraft emerge from fog, pass overhead, make a left turn and then become lost from sight whilst in the turn.

At about 1040 hrs, the aircraft was approximately three nautical miles to the east of Old Hay when the aircraft climbed to some 1,200 feet over a period of approximately 1.5 minutes. Initially, the climb was very steep, and the aircraft then flew between 1,000 and 1,200 feet. After climbing to the right in the turn through 150º, it turned to the left through 60º at the top of the climb. The aircraft settled on a south-westerly track and maintained a height of between 1,100 and 1,300 feet. At 1043 hrs, the aircraft then entered a right orbit over the eastern edge of the village of Horsmonden. Half way around this orbit the aircraft made a rapid descent, passing over the village at about 400 feet. A witness saw the aircraft coming from the east at low level with the engine sounding at high power. As it departed to the west of the village it was seen to disappear into fog. Then, after a sharp left turn, the aircraft described an orbit to the right at about 500 feet, before adopting a north-easterly track whilst reducing height. At 1048 hrs, London Information requested the aircraft's position, to which the pilot replied "JUST LEFT HEADCORN (break) STILL HEADING TOWARDS MAYFIELD". At the same time, the aircraft commenced a gentle right descending turn, close to some farm buildings. The turn appeared to tighten before the aircraft crashed into a grass field. Approximately one kilometre ahead of the aircraft was a line of electricity pylons but, considering the visibility, it was unlikely that he was turning to avoid them. A witness, who was surrounded by dense fog some 700 metres south-west of the accident site, heard the aircraft at low power, the sound of the engine either continuing up to the sound of the impact or possibly ceasing one or two seconds before. This witness located the wreckage in the fog and contacted the emergency services, who attended the scene. There was no post-crash fire and the sole occupant, the pilot, was fatally injured. Found amongst the contents of the aircraft were large quantities of Class C drugs and tobacco.

Impact parameters

The aircraft made initial contact with the ground at relatively high speed with its right wingtip, on a heading of 200ºM and whilst in a nose low attitude and with right bank in excess of 45º. The aircraft continued forward for approximately seven metres when its nose impacted the ground beside a stout hedge. The inboard section of the left wing then made contact with a low tree within the hedge, rupturing the fuel tank and causing fuel to be spilled, and this brought the aircraft to an abrupt halt (within 10 metres), uprooting the hedge in the process.

Weather

The synoptic situation at 1200 hrs on 8 February 2005 showed low pressure over Iceland and high pressure over the former Soviet satellite states, which was feeding a light south-westerly flow over Belgium and south-east England. At 1100 hrs, the conditions over Kent, around the Tonbridge Wells and Headcorn areas, were widespread mist with some lingering fog patches. Surface visibility was generally 1,500 to 2,500 metres in mist, but locally as low as 800 metres in fog. There were also areas of BKN/OVC stratus cloud, with a base of 800 feet and tops of between 1,500 and 2,000 feet, and SCT/BKN thin strato-cumulus cloud with a base of 5,000 feet. The surface wind was 180º/05 kt and the 2,000 feet wind 210º/12 kt. The surface temperature and dew point were 5ºC/4ºC and at 2,000 feet 4.2ºC/-0.3ºC.

The Shoreham Terminal Area Forecast (TAF) covering the period of the flight was:

EGKA 080847Z 080816 VRB03KT 2000 BR SCT050 TEMPO 0810 0800 FG BKN010 BECMG1113 7000 NSW

The Meteorological Actual Reports (METARS) for the time at which the aircraft was in the following areas, or passing the reporting airfield, were:

Ostend:	*EBOS 080920Z 13005KT 2000 BR SKC 01/M02 Q1027 BECMG 3000=*
Manston:	*EGMH 081020Z 15005KT 120V210 1800 BR BKN 070 06/05 :*
Biggin Hill:	*EGKB 081050Z 21010KT 180V240 1800 BR BKN002 06/05 Q1025*

The unofficial observations at Old Hay and Headcorn Airfield both reported fog.

Pilot history

The pilot commenced flying in February 1981 and flew 37 hours over the following 12 months. He did not fly again until June 1987 and, having completed a total of 70 hours, was issued with a Private Pilot's Licence on 20 April 1988. He gained an IMC rating, issued on 23 June 1989, which remained valid until 22 July 1991 but this was not renewed after that period. He continued to fly VMC cross country flights within the UK and to Western Europe by day and his most recent Certificate of Revalidation was completed, and his log book signed, on 9 July 2003. This was valid until 31 July 2005. He held a current JAA Class two medical certificate valid until 29 April 2005.

Medical aspects

Post mortem examination of the pilot revealed that he died as a result of multiple injuries consistent with being sustained in the accident. Toxicological examination revealed no evidence of alcohol or drugs of any kind being present. However, the pilot had clear evidence of severe pre-existing coronary artery atheroma but there was no gross evidence of an acute cardiac episode. The pilot underwent an ECG in April 2004, which was reported as being normal, but the pathologist stated that:

> "it is certainly not unheard of for severe coronary artery disease to be both clinically silent and to produce no ECG changes".

He went on to state that:

> "it is difficult to interpret the possible significance of the coronary artery atheroma in the context of this accident. The circumstances of the flight were such that the pilot was under extreme pressure to complete his flight, even though the weather was clearly bad and the visibility was very poor. It appears that there is every reason for the aircraft to have crashed due to procedural factors, and the possibility of medical incapacitation does not necessarily need to be invoked. However, the stress which the pilot would undoubtedly have been experiencing combined with his coronary artery disease could well have produced a spectrum of cardiac-related symptoms, potentially ranging from mild discomfort or palpitations through to the possibility of collapse or indeed death. It is thus entirely possible that his heart condition may have contributed to the accident, although there is no way of being sure of this".

Recorded data

The only source of recorded data relating to this flight was contained within the pilot's handheld Garmin GPS96 receiver found at the accident site. Radar data from London Heathrow, London Gatwick and the Debden radar heads was checked by NATS at the request of the AAIB, but no track of the aircraft was found. The radar head with potentially the best visibility of the southeast was at Pease Pottage, but this was not in service at the time of the accident. However, given the GPS derived altitudes, it is doubtful that this would have had visibility of the final part of the flight.

GPS receiver physical condition

Apart from a cracked screen cover (the screen itself was intact) and slight damage to the surrounding plastic, the receiver was intact. On inspection, the two AA batteries were in place and maintained a good voltage of 2.9v. The unit was switched on whilst shielded from reception of signals from the

GPS satellites and track logs were downloaded using a PC. The pertinent route and waypoint data were recorded by manual interrogation of the unit.

GPS data

Two manually entered waypoints were found stored in the receiver, one relating to the home of the pilot and the other HAY, correlating to Old Hay Farmstrip some 1.5 nm to the northwest the accident site. Various routes were also stored, all starting and ending with either Zwartberg or Shoreham, including the active route at the time of the accident. Apart from spurious short tracks on the ground, there were two flights recorded as log 32 and log 33.

Log 32 started at 1411:15 hrs on 7 February 2005 with a track of 119ºM and a groundspeed of 74 kt. This was 2 minutes 9 seconds after the end of log 31, which related to a position on the ground at Shoreham Airfield. Log 32 ended at 1631:39 hrs with an altitude of 278 feet, a track of 217ºM and a groundspeed of 7.2 kt. This related to a position at Zwartberg Airfield.

Log 33 started at 0821:37 hrs on 8 February 2005, with the aircraft stationary on the ground at Zwartberg. It took off at 0835:19 hrs, on a track of 214ºM and a groundspeed of 68 kt. The log ended at 1048:32 hrs whilst the aircraft was on a track of 187ºM, at an altitude of 321 feet and a groundspeed of 105 kt.

Figure 1 shows the track of the aircraft when over the UK together with plots of groundspeed, terrain elevation and GPS altitude, as well as the position of Old Hay Airfield.[1] Figure 2 focuses on the final part of the flight between Staplehurst and the accident location, where the aircraft's ground speed varied between 66 kt and 101 kt. If the aircraft was being flown with the flaps retracted then there were two data points at which the aircraft was being flown within 5 to 10 kt of its stall speed. If it was being flown with the flaps fully extended then there were six points in this portion of the flight at which the maximum permissible speed with flaps extended was exceeded. One of the data points at which the aircraft is near to the stall speed is less than 10 seconds from one of the points at which the maximum flap extension speed is exceeded.

Aircraft description and history

G-BHIL was a Piper Cherokee Warrior II fitted with a Lycoming four cylinder, air-cooled piston engine driving a fixed pitch propeller. The aircraft was constructed in 1980 and had accumulated some 9,465 hours at the time of the accident. The engine was fitted in July 2002 and had run for

[1] GPS altitude data is not as accurate as GPS lateral data. Analysis of GPS data recorded whilst on the ground indicated that the altitude datums used by the GPS track log, the Ordinance Survey maps and the terrain elevation database (used during analysis for generating terrain profiles beneath the aircraft) correlate.

some 895 hours since new. A 150 hour inspection had been completed on 30 November 2004 and the last maintenance activity occurred on 5 January 2005 when a replacement artificial horizon had been fitted. There were no recorded outstanding maintenance issues.

Wreckage examination

Examination of the wreckage at the site revealed that the aircraft had been complete and structurally intact prior to the accident and that there had been no airborne or ground fire. The pilot was found seated in the front left pilot's seat with his lapstrap secured but with the lateral upper body restraint (diagonal strap) possibly not secured.

Approximately seven litres of liquid, with the visual appearance and odour of Avgas, were recovered from the right wing fuel tank, which had also been ruptured. Fuel staining on the grass over a wide area forward of the left wing was observed the following day indicating that a significant amount of fuel was on board the aircraft at the time of the accident. The propeller and engine cowling had both detached from the engine during the impact and were found approximately 1.5 and 15 metres respectively from the main wreckage. There was evidence of some bending and chordwise scoring on the two propeller blades, suggesting that the engine had been turning and producing some power at the time of impact with the ground.

The fuselage had been severely disrupted in the impact but it was possible to determine that the cabin door had been closed and latched at the time. Continuity of the flying control systems was established and there was no evidence that any control jams had occurred. The horizontal stabiliser trim system was determined as being set close to neutral, a reasonable setting for cruising flight. The flap operating lever in the cockpit was found in the UP position but the linkage to the flap surfaces had been severely disrupted. It was not possible to confirm this selection by means of flap surface position.

The engine could still be turned by hand after the accident and a strip examination later revealed that it had been mechanically sound. The engine tachometer was damaged and found indicating 2,500 RPM, a high power reading for normal cruise conditions, although it could represent a lower power if the aircraft was descending at high speed. The engine fuel and oil pressure gauges had frozen on impact and all indications were in the normal range. The vacuum pump, which powers the attitude and heading indicators, was intact and free to turn. Both magnetos were tested and found to be in satisfactory working order and the spark plugs had a normal appearance. The carburettor hot/cold air selection box had been crushed in the impact but it was possible to determine that the air supply was selected to cold at the time of impact.

In summary, no technical pre-accident defects were identified with the aircraft as a result of the examination of the wreckage.

Analysis

In the absence of any technical reason for the accident being established, this analysis concentrates on the operational aspects of the flight.

Before being allowed to hire an aircraft from the flying club and make his trip to Belgium, the pilot had demonstrated a good level of flying ability during a flight in VFR conditions with a club examiner. However, whilst he had previously held an IMC rating, there was no record in recent years of the pilot having undertaken any IMC flying or training. As his most recent recorded flight as pilot-in-command in a light aircraft was some eight months prior to the accident flight, it is likely that he was not as proficient in using instruments as the sole attitude reference as when his IMC rating was valid. It was not established if he had obtained any detailed weather information prior to the return flight; this would normally have been available at Zwartberg but the airfield was closed on the day of his departure and so was not available from that source.

For his trip, the pilot had carried out thorough flight and route planning both for the outward and return journeys. Whilst his waypoints and route had been loaded into his GPS receiver with some assistance for the outbound flight, he had satisfactorily entered those for the return journey himself. Despite being requested to do so, the pilot had not 'booked' in when he arrived and had not 'booked' out prior to his departure from Zwartberg. Also, although he had filed a flight plan for the return journey to the UK the evening before, it was not activated by telephone or by radio after takeoff. This may well have been an oversight on his part as he may have believed that when he made contact with Brussels Information, activation would be automatic. Crossing an international boundary without a flight plan later attracted the attention of London Information, who specifically asked him where the aircraft had come from and why the flight plan had been cancelled. He failed to give them a reason for this and also omitted to state that he intended to land at Old Hay Farmstrip. All of these actions could be associated with the apparent purpose of his flight, ie, his intention to make an undeclared landing at Old Hay before continuing on to his declared destination of Shoreham.

The flight appears to have been manageable in weather conditions acceptable to the pilot, even when he made landfall to the south-west of Dover. His figure of eight manoeuvre and two rapid descents followed by climbs, both of which were promptly abandoned at 800 feet, appear to have been attempts to get below cloud. From 1020 hrs to 1028 hrs, it is probable that the aircraft was above the fog, with the pilot navigating using his GPS receiver and possibly being able to maintain intermittent visual contact with the surface. The report from London Information at 1028 hrs of the poor weather at Headcorn clearly concerned the pilot, although apparently not enough for him to divert to Lydd or go direct to Shoreham. Until the aircraft reached Staplehurst, its track closely matched that required to reach Old Hay. From 1021 hrs to 1028 hrs, the GPS receiver recorded a continuous descent from

1,600 feet to 1,100 feet, and then a more rapid descent to 600 feet (GPS altitude, not height above terrain). Then, at 1031 hrs, the pilot's comment to London Information that "I'M BELOW CLOUD NOW SO I CAN ACTUALLY SEE WHERE I'M GOING" suggests that he had achieved VMC below stratus cloud to the north-east of Ashford.

From that point until the aircraft was in the Staplehurst area, the aircraft's track paralleled the line of the railway from Ashford to Tonbridge, a well known and distinct line feature. It was apparent from the GPS data that the pilot had flown with the railway on the left side of the aircraft, the side on which he was seated. Visibility was poor in this area with the aircraft flying ever lower, presumably in an attempt to maintain visual contact with the surface. Around this time, the witness at Headcorn heard the aircraft fly past but did not see it due to the poor visibility. From 1038 hrs to 1040 hrs, the aircraft described an erratic series of climbing and descending manoeuvres, generally following the line of the railway, and it would appear that the pilot was experiencing increasing difficulty in following the railway due to the fog. During this period, the Flight Operations Manager from Lashenden Airfield at Headcorn, saw the aircraft emerge from fog as it approached the north side of Staplehurst. Just after 1040 hrs it is likely that, after a rapid climb to 1,200 feet, the aircraft became VMC on top of the fog as it then headed directly towards Old Hay. It seems probable that the pilot intended to fly over the farmstrip at Old Hay to assess the possibility of letting down there but, before reaching the airfield, the aircraft turned to the south-west where the fog was more patchy. The right orbit to the east of Horsmondon at 1043 hrs was over a break in the fog into which the pilot made a rapid descent, levelling off a few hundred feet above the village. The witness here clearly saw the aircraft approaching the village at low level in a gentle right turn, before entering fog.

At this point, the pilot was a few miles from Old Hay, flying in very poor visibility, almost certainly with an insufficient view of the ground to map read and over an area with numerous similar roads and ground features. His low orbits at 1045 hrs probably afforded him some visual contact with the surface which, given his apparent desire to land at Old Hay, he would have been desperate to retain.

The pilot's position report at 1048 hrs, just before he crashed, that he had "JUST LEFT HEADCORN" and was "STILL HEADING TOWARDS MAYFIELD" was incorrect as, at the time of talking to London Information, he was heading in the opposite direction to Mayfield. This meant that either the pilot was lost and disorientated, was passing false information in the hope that London Information would not realise his intention to land at Old Hay, or that he had abandoned his intention to land at Old Hay Farmstrip and intended to route via the Mayfield VOR to Shoreham. He may also have been attempting to navigate to a known point where the weather conditions were better using the VOR and/or his GPS unit. It seems unlikely that he knew his exact position but his GPS was capable of providing him, at the very least, with information on his general location. In the dense fog, he would not have seen the line of pylons crossing his track one kilometre ahead and so it was unlikely that he was taking avoiding action. Given that the carburettor air heat control flap was found in the COLD position, and the fact that the aircraft was flying in and out of fog, the possibility that carburettor icing may have formed and reduced the engine power could not be completely dismissed as a reason for the final descent to the ground. However, the indications from the engine instruments suggested that a reasonable level of power was being produced at the time. Also, the right turn initiated just before the impact may have been the start of a turn towards Mayfield, or an attempt to avoid flying low over a farm. It could also have been a result of a medical distraction or incapacitation.

Whatever the reason for the final right turn, the pilot appeared to have lost situational awareness, resulting in his loss of terrain separation which, until that point, he had managed to maintain over a relatively long period of demanding and stressful flying.

Conclusions

The pilot had undertaken a long international flight to an undeclared destination in an area of weather conditions well below VFR minima. His apparent desperate need to land at Old Hay contributed to poor decision making processes in the later stages of this flight. In attempting to maintain or regain visual contact with the surface, possibly whilst distracted by activity in the cockpit related to navigation, loss of engine power due to carburettor icing, loss of situational awareness due to inadvertent entry into fog or due to a medical distraction or incapacitation, the aircraft descended into the ground. No technical causal factors for the accident were identified.

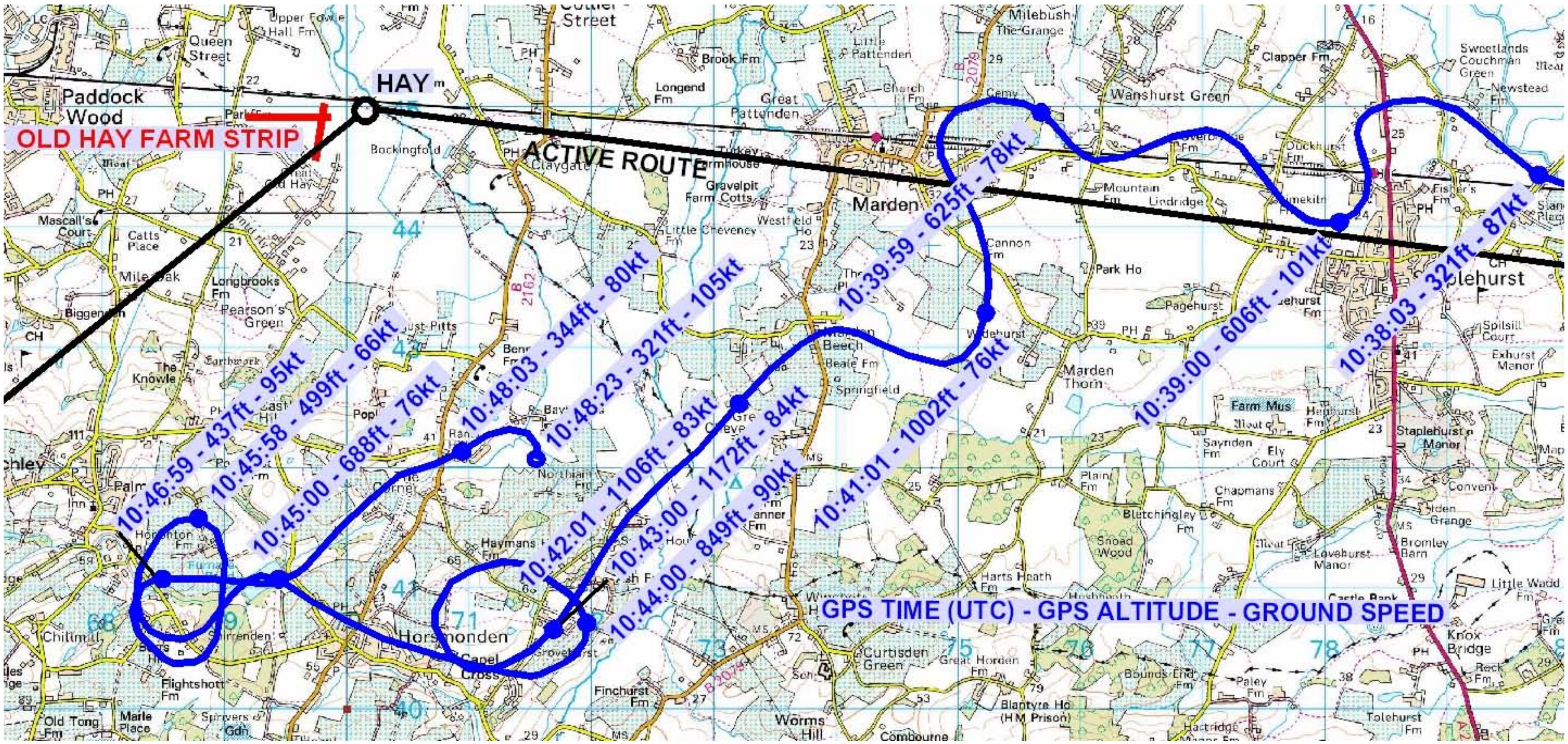
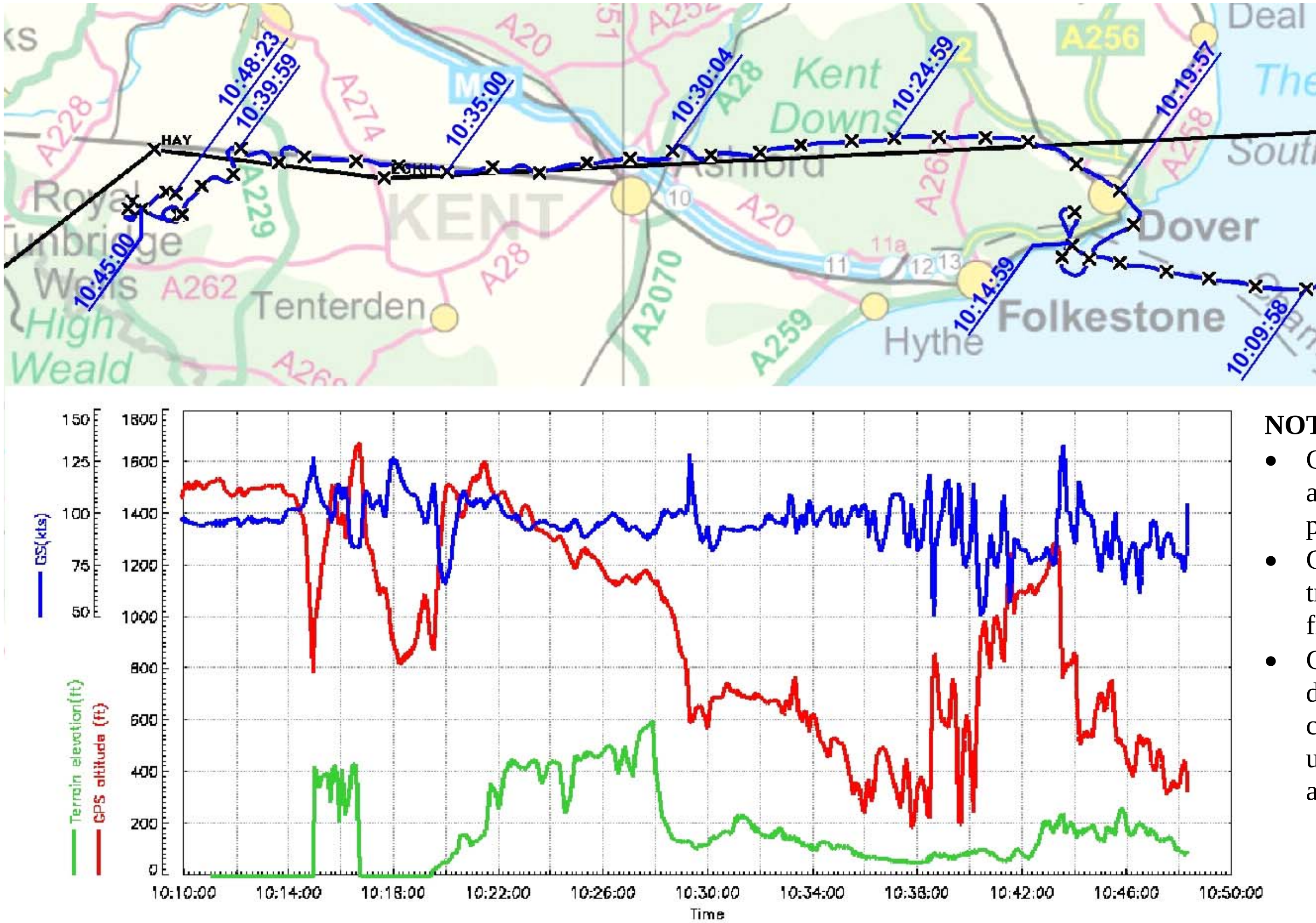


Figure 1

G-BHIL - GPS Aircraft track and height for the last 10minutes of flight



NOTES

- GPS altitude is not as accurate as GPS position.
- Ground speed and track are derived from GPS position.
- Given the sources of data, terrain clearance should be used as an approximation only.

Figure 2

Basic flight parameters and plan view of the accident flight from 10:10 UTC. (Accident G-BHIL on 8 February at near Horsmonden, Kent)

Aircraft Type and Registration:	Piper PA-28-161 Warrior II, G-BOXC	
No & Type of Engines:	1 Lycoming O-320-D3G piston engine	
Year of Manufacture:	1988	
Date & Time (UTC):	26 April 2005 at 1300 hrs	
Location:	Jersey Airport, Channel Islands	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to noseleg fork, nosewheel and engine bearers	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	43 years	
Commander's Flying Experience:	63 hours (all on type) Last 90 days - 0.4 hours Last 28 days - 0 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot was cleared for takeoff from Runway 27 at Jersey Airport. The wind was given as 180º/13 kt, so there was a direct crosswind of 13 kt. The pilot prepared to practice a 'short field' takeoff and set two stages of flap.

As the airspeed reached about 45 kt, the pilot found that he could no longer keep the aircraft tracking straight down the runway and that it wanted to turn to the left, into the wind. The pilot felt that he was losing control of the situation. He did not want to build any more airspeed, and risk a more serious event, so he abandoned the takeoff and shut down the engine. The aircraft ran onto the grass to the left of the runway, suffering damage to the nose landing gear.

The pilot commented that the causes of the accident were that he had not had sufficient practice in crosswind conditions and that he had not applied sufficient into-wind aileron during the take-off run. Beyond this, he did not have a ready explanation as to the causes of the accident. An instructor from the local aero club, with a good knowledge of this pilot's flying abilities, commented that a major factor appeared to be that the pilot had applied insufficient right rudder pedal to compensate for the crosswind from the left coupled with the application of take-off power.

Aircraft Type and Registration:	Piper PA-28R-200-2, G-BCGS	
No & Type of Engines:	1 Lycoming IO-360-C1C piston engine	
Year of Manufacture:	1972	
Date & Time (UTC):	2 May 2005 at 0850 hrs	
Location:	Little Gransden Airfield, Bedfordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Propeller destroyed, engine shock loaded, damage to the under-side of fuselage	
Commander's Licence:	Commercial Pilot's Licence with Instructor Rating	
Commander's Age:	35 years	
Commander's Flying Experience:	3,173 hours (of which 15 were on type) Last 90 days - 100 hours Last 28 days - 42 hours	
Information Source:	Aircraft Accident Report Forms submitted by the pilots and telephone enquiries by AAIB	

History of flight

The aircraft owner's Private Pilot's Licence (PPL) had lapsed, and he had not flown for some time. Consequently, he contacted an experienced flying instructor, who was familiar with the aircraft type, for some tuition in preparation for a renewal Skill Test. The instructor briefed the owner on the Skill Test exercises, and the two prepared for a flight consisting of upper air exercises, circuits, and Practice Forced Landings (PFLs).

The aircraft's landing gear automatic extension system (intended to extend the landing gear automatically to prevent a wheels-up landing) had been removed in accordance with Piper Service Bulletin SB866A and replaced with a landing gear warning system, in the week before the accident flight, and both instructor and owner briefed themselves on the functioning of the newly installed warning system. The warning system sounds a horn and illuminates a light if either the throttle is closed or the flaps are extended beyond the first position without the landing gear being locked down.

The aircraft departed Little Gransden Airfield and the flight began with upper air exercises, including steep turns, slow flight, stalls in various configurations, and PFLs. During these exercises, the landing gear warning horn sounded several times and for long periods.

The aircraft returned to Little Gransden for some circuits and PFLs on Runway 10. During the final PFL, it became apparent that the wind was favouring the opposite Runway 28, and the owner flew a go-around, raising the landing gear and flaps as he did so. The owner began a manoeuvre to reposition the aircraft directly onto a base leg for Runway 28, but during the climb, the instructor noticed some horses in the field below, and took control to avoid over-flying them.

The instructor handed control back to the owner, and instructed him to make a flapless approach and landing. The owner flew the aircraft onto the approach, regained the extended centreline of the runway lower and closer in than normal, and used a small amount of power to maintain a correct speed and approach angle.

The owner closed the throttle in the flare, and the aircraft settled *"fairly gently"* onto the runway, sliding to a stop on the underside of the fuselage in a short distance. Both occupants, who were wearing lap and diagonal harnesses, vacated the aircraft without injury through the normal door. There was no fire.

The owner commented that he believed that he did not select the landing gear DOWN, because the final approach was flown without a downwind leg, and that distraction and high workload caused him to omit his customary 'Red, Blue, Green'[1] check on final approach. He did not recall hearing the landing gear warning horn prior to touchdown, but he added that the long periods of activation of the landing gear warning horn during the flight had conditioned him to be *'immune'* to the operation of the horn, and that the system provides little protection in the case of a flapless approach and landing.

The flying instructor reported that although there was no specific time pressure on the day, the flight had been *'intense'* and that the accident occurred at a *'period of high workload'*. He added that the owner had performed well throughout the flight and that he may have relaxed somewhat as a consequence of this. He recalled hearing the landing gear warning system horn just prior to touchdown, when power was reduced, and commented that it is not possible to see the landing gear indications in the cockpit from the right seat, without deliberate movement of the head.

[1] The 'Red, Blue, Green' check is often used in 'complex' light aircraft as a final check just prior to landing. 'Red' relates to a check of the position of the mixture control (coloured red in the cockpit), 'Blue' to that of the propeller control (coloured blue), and 'Green' to a check of the landing gear indications (green lights indicate that the landing gear is down).

Aircraft Type and Registration:	Piper PA-28RT-201T, G-JANG
No & Type of Engines:	1 Continental Motors Corp TSIO-360-FB piston engine
Year of Manufacture:	1985
Date & Time (UTC):	13 June 2005 at 0850 hrs
Location:	Swansea Bay, 51 33.716N 00359.391W, Wales
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	62 years
Commander's Flying Experience:	945 hours (of which 340 were on type) Last 90 days - 25 hours Last 28 days - 17 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB enquiries

The aircraft had been flown from Swansea to Kerry on the preceding Friday, three days before the accident. For this flight it had been filled to capacity, a total of 280 litres of Avgas. It was flown back to Swansea the day before the accident, without incident. The return flight time was 3 hours 20 minutes, and a total of 160 litres of fuel had been consumed. On the day of the accident, the pilot intended to fly from Swansea to Exeter, where and annual inspection was to be performed on the aircraft, after which the pilot planned to fly on to Guernsey. He arrived at Swansea Airport at 0815 hrs, added a further 40 litres of fuel to give a total fuel on board of 160 litres, and carried out a pre-flight inspection during which he noted that the fuel from all three water drains was clear and that there were no defects.

The aircraft took off from Runway 28 at 0846 hrs and turned left to fly along the coast towards Mumbles Head, from where the pilot intended to track direct to Exeter. Several minutes after takeoff, and while heading east at 1500 feet the engine lost all power. The pilot lowered the nose and transmitted a MAYDAY call. He then attempted to restart the engine but was not successful.

When the aircraft had descended to below 1,000 feet agl, the pilot observed that to his left were populated areas and he judged that any fields were beyond safe gliding range. The pilot realised that the nearby beaches had people on them, so he prepared to ditch the aircraft. With the landing gear retracted, a successful downwind landing was made on the water, about half a mile from a Coast Guard station. The pilot was able to climb out of the aircraft and inflated his life jacket which he had been wearing, as was his habit. He also inflated a spare lifejacket to assist with flotation. He was immediately assisted by a fishing vessel, and taken to a nearby hospital, however he had sustained no injury. The aircraft sank in about 6.5 metres of water.

Fuel samples from the supply at Swansea had been retained, but these were visually satisfactory and no other aircraft reported any difficulty with the fuel. In discussion with AAIB, the pilot believed that a fuel system problem had caused the engine failure.

As the Coast Guard had advised that there were strong currents in the area, which would probably move and break up the aircraft, it was decided not to attempt to recover the aircraft for further investigation.

Aircraft Type and Registration:	Rans S6-ES, G-CBTO	
No & Type of Engines:	1 Rotax 912-UL piston engine	
Year of Manufacture:	2002	
Date & Time (UTC):	3 June 2005 at 1050 hrs	
Location:	Near Sellafield, Cumbria	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Propeller, right wing and engine damaged	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	41 years	
Commander's Flying Experience:	454 hours (of which 41 were on type) Last 90 days - 28 hours Last 28 days - 10 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The aircraft was being flown along the coastline of the Lake District, northwards towards St Bees Head at approximately 1,300 feet amsl. In order to avoid the Sellafield restricted zone, the pilot turned inland and commenced a climb to avoid the high ground ahead. There were multiple cloud layers covering the high ground which the pilot realised was rising at a steeper angle than the aircraft was able to climb. He attempted to manoeuvre the aircraft away from the high ground and, whilst concentrating on avoiding the restricted area, inadvertently entered cloud. On exiting the cloud, he found himself close to the ground with no obvious escape route away from further areas of cloud. He decided to land the aircraft in the grass field beneath him and, with his speed already close to the stall, accomplished this successfully. During the short landing roll on the rough terrain, the right wing tip struck the ground and the nosewheel became detached. Both occupants were able to vacate the aircraft through the normal exit doors.

Aircraft Type and Registration:	Rockwell Commander 112, G-DASH	
No & Type of Engines:	1 Lycoming IO-360-C1D6 piston engine	
Year of Manufacture:	1975	
Date & Time (UTC):	11 April 2005 at 1815 hrs	
Location:	Bourn Airfield, Cambridge	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to propeller, engine nacelle and nose landing gear leg	
Commander's Licence:	UK Private Pilot's Licence	
Commander's Age:	69 years	
Commander's Flying Experience:	490 hours (of which 70 were on type) Last 90 days - 10 hours Last 28 days - 10 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB inquiries	

Synopsis

At the end of the ground roll, following a normal landing, the nose landing gear retracted and the propeller hit the ground.

History of flight

On returning from an uneventful flight to St Mawgan for a landing on Runway 24 at Bourn, the pilot lowered the landing gear and confirmed that the three green landing gear indication lights were illuminated. The pilot stated that the landing and initial ground run was normal; however, as he applied the wheel brakes lightly, with a ground speed of approximately 10 kt, the nose landing gear partially collapsed and the propeller struck the ground causing the engine to stop. The pilot considered that there were a number of rough patches on the surface of the runway.

Significant features of the landing gear system

The aircraft is equipped with a hydraulically operated, retractable tricycle landing gear that is controlled by a two position, detented, switch mounted on the instrument panel. This switch is approximately six inches to the left of the flap selector switch. Three green lights in the cockpit are illuminated when the landing gear is locked down and a red unsafe light is illuminated when the landing gear is in transit. The nose landing gear system consists of an oleo-pneumatic shock strut, drag brace assembly, emergency extension springs, hydraulic actuator incorporating a mechanical lock, pressure and position switches. A squat switch is located on the right main landing gear leg to prevent the landing gear retracting whilst the aircraft is on the ground.

When the landing gear selector switch is selected to DOWN, the hydraulic pump is activated and hydraulic fluid is directed to the down port of the landing gear actuator. As the nose leg actuator operates, the leg extends, assisted by the emergency extension springs, and the drag brace moves into the over-centre position where a geometric lock prevents the nose landing gear leg from retracting. When all three landing leg actuators are in the fully down position, hydraulic pressure switches de-energise the hydraulic pump and the mechanical locks, under spring pressure, move to physically lock the actuators in the down position. These mechanical locks will only disengage when hydraulic pressure is applied to the 'up' side of the actuators. On selecting landing gear UP, providing the squat switch on the right main landing gear leg has closed (ie no weight on the wheel), the hydraulic pump is activated and hydraulic fluid is directed to the 'up' port of the landing gear hydraulic actuators. The mechanical locks in the actuators disengage, the drag brace is pulled through its geometric lock and the gear retracts. Once all three gears are retracted, the position switches de-energise the hydraulic pump and the landing gear is retained in this position by hydraulic pressure within the system. Loss of hydraulic pressure and partial extension of the landing gear is detected by the position switches, which re-energise the hydraulic pump causing the landing gear to move back into the retracted position.

Maintenance

During the investigation, an intermittent earth connection was discovered in the electrical circuit for the nose leg down-lock position switch, which had not been apparent during normal operation of the aircraft. However, this fault was in the gear-down circuit and could not cause the gear to retract. Apart from this intermittent earth connection, the maintenance organisation could find no other fault in the landing gear system. Moreover, retraction tests, undertaken with the accident and replacement nose landing gear legs fitted to the aircraft, also revealed no other faults in the system.

Analysis

Whilst the intermittent earth connection in the nose down-lock position switch could prevent the landing gear from extending normally; the pilot stated that he had three green landing gear indication lights prior to landing, indicating that the landing gear was down and locked at the time. However, if the landing gear selector had inadvertently been moved to the UP position after landing, and the squat switch had closed as the aircraft ran over a rough surface of the runway, then the landing gear might have started to retract. Normally the order in which the landing gear legs retract is dependent on the force that each hydraulic actuator must act against and, therefore, it is probable that the nose landing gear would start to retract before the main landing gear legs. If the landing gear selector switch was subsequently moved back to the DOWN position, and the earth circuit on the nose-down lock switch was broken, then the hydraulic pump would not operate and the weight of the aircraft would cause the nose leg to collapse whilst the main landing gear legs remained locked. The pilot does not recall selecting landing gear UP after landing.

Aircraft Type and Registration:	Tri Kis, G-TKIS
No & Type of Engines:	1 Lycoming O-290-D2 piston engine
Year of Manufacture:	1995
Date & Time (UTC):	15 May 2005 at 1410 hrs
Location:	Hexden Private Airstrip, near Rye, East Sussex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller and fractured wing spars
Commander's Licence:	Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	598 hours (of which 488 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot landed on the runway with insufficient distance remaining in which to stop. Consequently, the aircraft hit a fence damaging the propeller and wing spars.

History of the flight

The pilot planned to fly to Andrewsfield and Old Hay before returning to his departure airfield at Biggin Hill. The wind at Andrewsfield and Old Hay was light and variable, and both landings were uneventful. The pilot was particularly pleased with the short landing at Old Hay, which was achieved without the use of brakes, following a well controlled shallow approach. Whilst at Old Hay the pilot decided to visit Hexdon, a private airstrip he had visited once several years previously and, for a reason he could not remember, had felt was unsuitable for his aircraft. The aircraft departed Old Hay with a full fuel load and some baggage.

The pilot stated that the runway at Hexdon is approximately 450 metres long and is orientated on a magnetic heading of approximately 290/110º. Low voltage electrical cables, approximately five metres high, cross the approach of Runway 29 and an isolated tree is adjacent to the approach to Runway 11. The wind at the time was light and variable and the pilot elected to land on Runway 11. A steep approach was made in order to remain clear of the tree and, during the later stage of the approach, the pilot applied power to reduce the rate of descent; however, the aircraft bounced on the runway and the pilot executed a successful go-around. The pilot then decided to land on Runway 29. On the approach the pilot concentrated on clearing the electrical cables with a good margin of safety and, once clear, he realised that he was high and slightly off the runway centreline. Nevertheless, he continued the approach, reducing the excessive height and regaining the centre line; during this period the pilot stated that he concentrated on the runway and did not monitor his airspeed. The aircraft touched down well beyond the threshold, ran off the end of the runway and hit a fence. Both the main and rear wing spars were damaged in the impact.

Remarks

The pilot had some considerable experience on this type of aircraft and has stated that he can land it, from a flat approach, within a distance of around 200 metres. However, the accident occurred at an unfamiliar airstrip, early in the flying season when the pilot was building up his currency. The steep and fast approach meant that the aircraft landed on the runway with insufficient distance remaining in which to stop.

Aircraft Type and Registration:	Vans RV-9A, G-CCZT
No & Type of Engines:	1 Lycoming O-320-E2A piston engine
Year of Manufacture:	2004
Date & Time (UTC):	14 April 2005 at 1630 hrs
Location:	Bicester Airfield, Oxfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose landing gear damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	107 hours (of which 12 were on type) Last 90 days - 12 hours Last 28 days - 12 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft was landing on Runway 13, the grass surface of which was damp, in a two to three knot easterly wind. The pilot reported that, while rolling out after a 'very acceptable landing', he applied a small amount of back pressure to the control column to keep the weight off the nose wheel. As the speed decreased through about 30 kt the aircraft encountered some surface undulations and the first of these pitched the aircraft into the face of the second. The pilot stated that the ground in that area was soft and it appeared that the nut at the bottom of the nose landing gear, in front of the wheel, had dug in to the surface causing the nose leg to bend.

The pilot considered that the accident was partly due to his landing technique, in that he did not apply sufficient back pressure to ensure that weight was kept off the nose landing gear as long as possible. He commented that he was very new to the aircraft and needed further practice on this aspect of his flying. He also concluded that he should have ensured that the landing surface was acceptable. He stated that the airfield is known for being a little bumpy in places and that, being a new operator there, he was not familiar with the areas to avoid.

The grass runways at this airfield are unlicensed and, in practice, identify the landing direction only. The runway lengths are defined but there are no runway edge markings and the pilot stated that all the grass is mown to a uniform length. The airfield is primarily used as a gliding site. Light aircraft are welcomed but pilots are advised that it is at their own risk. General Aviation Safety Sense Leaflet 12C, entitled *Strip Sense*, provides advice on unlicensed aerodromes and private strips. It includes a section on 'Assessing the Strip' and the factors to consider. The pilot stated that in this accident he encountered the undulations half way along and towards the left of the landing area.

INCIDENT

Aircraft Type and Registration:	Piper PA-18-150, G-SUPA	
No & Type of Engines:	1 Lycoming O-320-A2B piston engine	
Year of Manufacture:	1957	
Date & Time (UTC):	23 June 2005 at 1500 hrs	
Location:	Headcorn, Kent	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Main landing gear support frame failure	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	52 years	
Commander's Flying Experience:	1283 hours (of which 479 were on type) Last 90 days - 11 hours Last 28 days - 6 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

As a result of a missing bush from the left side of the main landing gear V section support frame, the end of the frame failed at its attachment to the airframe, which resulted in the wing dropping gently to the ground.

History of flight

Whilst taxiing to the hanger, following an uneventful landing, the right wing slowly dropped until it rested on the ground. The engine was shut down and the propeller remained clear of the ground. An examination of the aircraft revealed that the left side of the V section support frame, which supports the main undercarriage suspension units, had failed across the hole where it is bolted to the airframe mounting lug, see Figure 1.

Discussion

The landing gear support frame is manufactured from two steel tubes welded together to form a V section. The airframe attachment at the end of each tube consists of a bush mounted on the end of the tube, which is held in place by a shaped plate welded around the end of the tube. A comparison of the left and right attachment fittings, which were sectioned to facilitate inspection, revealed that the bush on the left fitting was missing, see Figure 2. The repair agency for the aircraft confirmed that the bush was not attached to the securing bolt that remained fitted to the aircraft. Witness marks inside the tube indicate that a bush had originally been fitted to the leg, which suggested that the bush might have come out when the frame had been removed from the aircraft. Reassembly of the V section frame without a bush installed would have left the securing bolt in contact with the welded plate, which then appears to have failed in overload during normal operations. The frame was last inspected during the annual maintenance undertaken six months and eight flying hours prior to the accident. Whilst there was no requirement during this inspection, to remove the fitting from the aircraft and inspect the bolt holes, the maintenance organisation have stated that the assembly felt secure with no sign of excess movement at that time.

Figure 1 Undercarriage V Section Frame Failure

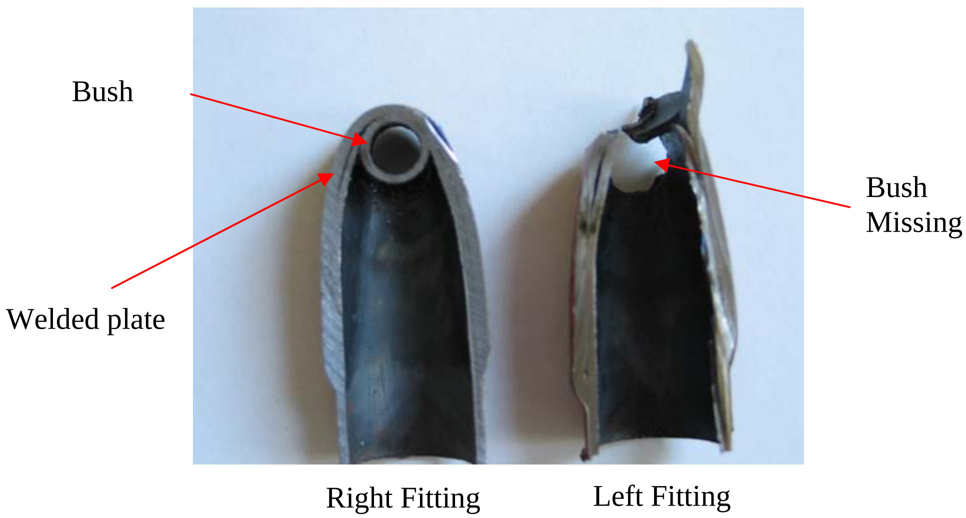


Figure 2 Sectioned V section frame end fittings

INCIDENT

Aircraft Type and Registration:	Piper PA-38-112, G-BJUR	
No & Type of Engines:	1 Lycoming O-235-L2C piston engine	
Year of Manufacture:	1979	
Date & Time (UTC):	13 May 2005 at 1300 hrs	
Location:	Nottingham Airfield, Tollerton, Nottinghamshire	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damaged windscreen	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	37 years	
Commander's Flying Experience:	2,294 hours (of which 1,613 were on type) Last 90 days - 140 hours Last 28 days - 51 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Whilst preparing for a training flight the instructor asked his student to check the fuel and engine oil levels. The student reported that the oil level appeared a little low and was instructed to direct the ground crew to put a quart of oil into the engine. This was accomplished and when the instructor subsequently approached the aircraft, the student had boarded it and was in the process of putting on his harness. The instructor checked the fuel levels in both wing tanks before checking the engine oil level by means of the dipstick, closing the cowling and boarding the aircraft.

After conducting the necessary checks the instructor carried out a normal takeoff. However, at a height of approximately 500 feet, whilst the aircraft was turning and banking to the left, there was a bang and the left side engine cowling was seen to rise up, partially blocking the view forward. It was apparent that the cowling had struck the lower part of the right hand side of the windscreen, producing a hole several inches across. The instructor levelled the aircraft, transmitted a 'PAN' call, on the radio and subsequently landed back at the airfield without further event.

This type of aircraft is equipped with left and right side engine cowlings, each mounted on a longitudinally orientated hinge either side of the aircraft centre line and secured by two 'butterfly clip' latches on the lower edges. Both butterfly clips were noted to be missing from the left side cowling on G-BJUR after landing.

The instructor reported that he had on occasions, whilst conducting daily inspections on other aircraft in the fleet, noted that butterfly clips were missing from the cowlings. He therefore concluded that at least one clip had been lost from the subject aircraft on a previous flight. However, it is possible in this instance that the student, when asked to check the oil, had initially looked in the left side of the engine (the dipstick and oil filler are in fact located on the right). This raised the possibility that the left cowling may not have been properly secured before the flight.

Aircraft Type and Registration:	Hiller 12 OH-23B, N33514	
No & Type of Engines:	1 Franklin 6V335B piston engine	
Year of Manufacture:	1954	
Date & Time (UTC):	18 November 2004 at 1258 hrs	
Location:	Northampton (Sywell) Aerodrome, Northamptonshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Tail boom severed, damage to main rotor blades, one skid bent and engine crankcase fractured	
Commander's Licence:	FAA Private Pilot's Licence	
Commander's Age:	58 years	
Commander's Flying Experience:	7,152 hours (of which 16 were on type) Last 90 days - 28 hours Last 28 days - 19 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft ran out of fuel transitioning to the hover during an approach to land. The fuel gauge was reading approximately 25% full at the time. Investigations revealed that the fuel gauge fitted was not approved for use on aircraft.

History of the flight

The pilot had agreed to take two associates of the owner for short flights, and the aircraft owner's representative was present to assist in the activities. The pilot arrived at Sywell at about 0900 hrs and carried out a full daily pre-flight check of the helicopter whilst it was still in the hangar. The weather was poor with a cloudbase of approximately 600 feet, light and variable winds and a visibility around 3,000 metres in light drizzle. The pilot assessed that the weather would be suitable for hovering manoeuvres on the aerodrome and low level circuits.

At midday, the two passengers arrived and, having been joined by the pilot, all three boarded the helicopter. The engine start and warm-up proceeded normally and the helicopter lifted off into the hover. However, when the pilot attempted to transition into forward flight he found that, even with full throttle, the helicopter did not perform adequately so he therefore set it down again. One passenger disembarked and the aircraft subsequently lifted off and performed acceptably. The pilot recalls that the time of this lift-off was about 1215 hrs. The aerodrome movement record, kept by the Aerodrome Flight Information Service Officer (AFISO), showed the aircraft's departure time as 1204 hrs, although it is not clear whether this relates to the first attempt at takeoff or the subsequent successful departure. The sortie then consisted of a hover-taxi to an area of the aerodrome set aside for helicopter manoeuvres, a few spot turns, takeoffs and landings, and a brief circuit. The pilot then hover-taxied the helicopter to the dispersal and, with the engine running, the passengers swapped over. The pilot then flew another similar sortie.

Returning to the dispersal following the second flight, the pilot indicated to the owner's representative that he intended to shut down. However, the owner's representative indicated that another passenger wished to fly. Again, the passengers swapped over, and the aircraft departed for a third detail similar to the previous two.

On approach to land from this third detail, at approximately 60 feet agl, with the speed close to 40 kt, the pilot began a gentle transition into the hover. The engine then, very suddenly, lost power. The pilot described the loss of power as being "instant" and "as though the magnetos had been turned off".

The pilot lowered the collective lever immediately, assessed that there was insufficient speed and height for full auto-rotation and therefore concentrated his efforts on maintaining a level attitude before attempting to cushion the touchdown with an upward application of collective control. He is of the opinion that the rotor RPM had only decayed slightly by the time the collective was lowered in response to the engine failure.

The helicopter touched down without significant yaw and with some forward speed. The touchdown was firm enough to cause the helicopter to bounce several feet into the air. The pilot reported that he lost tail rotor authority at this stage and the helicopter touched down a second time slightly right skid low. Ground marks left by the helicopter's skids were consistent with this recollection. The pilot reported that the rotor disc then toppled causing the main rotor blades to strike and sever the tail boom. The accident occurred at approximately 1258 hrs; between 43 and 54 minutes after the first lift-off.

Both the pilot and passenger, who had been wearing four point harnesses, vacated the aircraft without injury. The helicopter sustained considerable damage to the main rotor blades, the tail boom was severed, the lower part of the engine case fractured and the right hand skid was slightly deformed. There was no fire.

The avoid curve

The Hiller Flight Manual includes a depiction of the *'Height-Velocity Chart for Safe Autorotation Landings'*. Examination of the chart showed that at 60 feet and 40 kt, the helicopter is just outside the cross-hatched ('avoid') area.

The pilot

The pilot was a self-employed helicopter instructor with UK CAA instructor qualifications and an FAA Private Pilot's Licence. He had received type conversion training on the Hiller UH-12 from an FAA examiner.

The helicopter

The Hiller UH-12B, first flown in the late 1940s, is a conventional three-seat light helicopter, designed for military training and utility use. It has a two-blade main rotor and a conventional tail rotor. It is powered by a vertically-mounted, six cylinder, horizontally-opposed, Franklin piston engine (another engine option may be fitted). Fuel is stored in a bladder tank, housed in an enclosed space under the engine mounting structure. The tank is fitted with a float type fuel quantity sensor/sender, which is connected to a fuel gauge mounted on the right hand side of the instrument panel.

The Hiller Flight Manual states that total fuel capacity is 28 USG, of which 1.5 USG is unusable. It does not give fuel consumption information, although early editions of the manual state that fuel endurance is 1 hour 20 minutes at V_{NE} and 1 hour 50 minutes at 70 mph.

The aircraft had been placed into storage in the USA following a heavy landing in 1984, and then 're-manufactured' by a corporation whose main business was the re-manufacture of Hiller helicopters. It had flown approximately 12 hours since being 'zero-timed' in the summer of 2004. The Helicopter Log showed that parts from several other helicopters had been used in its construction. The Engine Log Book showed that the engine had been disassembled, repaired, and overhauled prior to installation in the helicopter on 16 June 2004. The Engine Log Book stated that the engine had *'zero time since overhaul'* but gave no detail of the total engine hours. The Helicopter Log Book included an unsigned entry detailing work carried out in the re-manufacture of the helicopter, dated 18 June 2004 and, in different hand-writing, sequentially after this entry, certification of an annual inspection dated 10 June 2004.

The aircraft owner, who had no previous experience of trading in aircraft and was not a qualified pilot or engineer, had established a business with the intention of marketing Hiller helicopters in the UK. He had made arrangements for the importation of the helicopter, which was to be offered for sale and used to demonstrate the type to potential buyers.

When inspected after the accident, the helicopter was found to be fitted with a 'Datcon' fuel gauge. No record of approval of fitment of this type of gauge to the helicopter could be found in the Log Book. Investigation revealed that the fuel gauge was of a type not approved for use in aircraft.

Enquiries revealed, that according to FAA Unapproved Parts Notification No 2003-00043, the FAA had withdrawn the Mechanic Certificate held by the President of the corporation concerned. He had also been found to have '*approved aircraft and engines for return to service, contrary to Federal Aviation Regulations'*. The Notification advised that '*all products approved for return to service by* (this individual) *should be considered suspect'*. The owner stated that, prior to the accident, he was not aware of FAA Unapproved Parts Notification No 2003-00043. Further investigation revealed other action taken by the FAA in respect of the individual.

Fuel management

The owner had developed a policy of always filling the helicopter with the maximum fuel load prior to flight and it appears that this policy had been adhered to by those concerned with the operation, until the day of the accident.

The owner did not keep a Technical Log for the aircraft, and thus reference to fuel loaded and consumed was not possible.

Prior to the series of flights, the pilot made an assessment of the quantity of fuel on board. Although on previous occasions he had used a calibrated dipstick to measure the level of fuel in the tank, on this occasion he was not able to locate the dipstick. Instead, he made a visual assessment, looking down the fuel filler neck into the tank and using a small torch. He had not received training in assessing fuel quantity in this manner. He estimated the tank contents to be between half and three-quarters full and equated this to roughly 16 USG. The fuel gauge in the cockpit showed just over half a tank remaining, which the pilot believed equated to roughly 15 USG.

The pilot stated that during his type conversion training he was told that the helicopter consumes between 12 USG to 14 USG per hour. During cross-country flying in the USA, in a similar helicopter, the pilot had assessed the fuel consumption as being about 13 USG or 14 USG per hour. Another experienced Hiller pilot stated that he believed fuel consumption to be 14 USG per hour in typical cruise, and about 16 USG per hour during hovering flight, although he added that these figures were not conservative.

The pilot anticipated flying only two flights, lasting about 15 minutes each, and calculated that, using a fuel burn of 14 USG per hour with 20 minutes reserve, he required a total fuel quantity of 11 or 12 USG. Therefore, he assessed the fuel quantity to be adequate for the planned flying.

The pilot reported that the fuel gauge was reading slightly over ¼ full prior to the last circuit and that it was his usual practice to consult the fuel gauge as part of his 'FREDA' checks when downwind in a circuit, although he does not recall clearly whether he did this on the final circuit. The pilot had not previously flown the helicopter with a fuel quantity below ½ full and stated that he had no specific reason to disbelieve the gauge, although he shared the commonly-held opinion that fuel gauges in light aircraft and helicopters tend to be unreliable.

FREDA checks

FREDA checks are very widely taught in both fixed and rotary wing flying, as routine checks to be carried out in flight. The mnemonic represents Fuel, Radios, Engine(s), Direction, and Altimeter. The 'Fuel' element is commonly taught to involve a check of the fuel remaining in the tanks, that the correct tank is selected (if more than one is fitted), and that the fuel indicated is sufficient for the continuation of the flight. It is also usual for other in-flight checklists, such as those carried out prior to descent, approach, or landing, to include an action relating to fuel quantity assessment by reference to the fuel gauge(s).

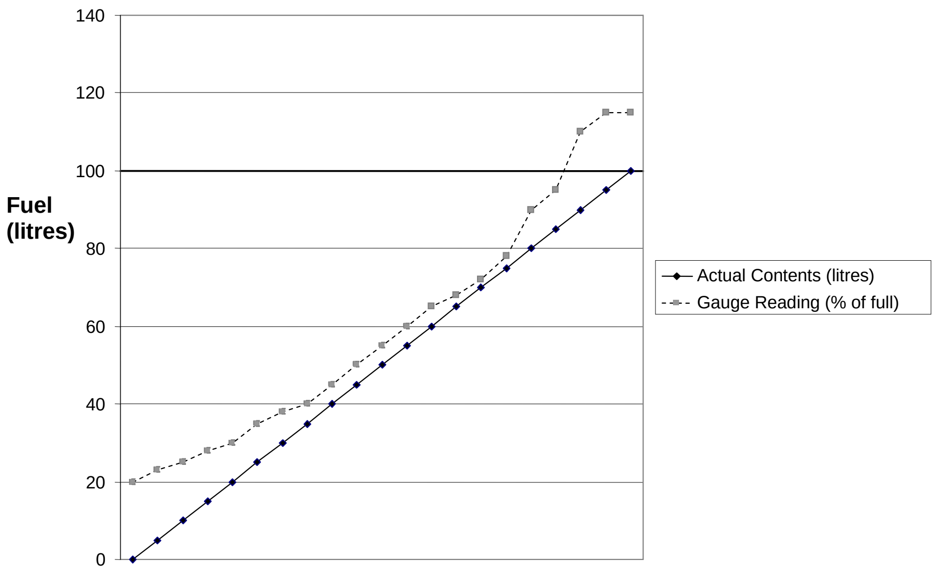
Flight records

There is no requirement, under Federal Aviation Requirements, for aircraft not used for commercial flight operations for an accurate record of flying hours to be kept contemporaneously. The Aerodrome Flight Information Service recorded flying operations, but ground running and brief hovering flight at the owner's hangar were not recorded in this manner. The owner kept approximate records of flight time. Federal Aviation Requirements do, however, require owners to make accurate entries of aggregate flight times in the Helicopter and Engine Logs.

Fuel remaining after the accident

The AAIB investigation began with an assessment of the fuel remaining in the helicopter. The helicopter had been moved from the accident site to the owner's hangar and was standing on its skids in a normal level attitude. The fuel feed to the carburettor was disconnected at the carburettor end and a suitable container was positioned to collect fuel. The electric fuel pump was switched on.

Fuel flowed readily from the tank and no cavitation of the electric fuel pump was apparent. The helicopter's tail was then weighted down, to simulate a nose-high attitude, as might be encountered when transitioning into the hover. In this attitude, the pump was again selected on, and fuel began to flow. Very soon, the flow became less steady and the pump was heard cavitating. Some 700 mls of fuel were collected before flow ceased. The helicopter was again returned to the level attitude and the test re-commenced, with a further one litre being collected before flow stopped. The tank was then drained into a measured container. The total fuel taken from the tank was determined to be 4.8 litres, or 1.3 USG.



The fuel tank was gradually re-filled with measured quantities of Avgas, the gauge readings being taken at various fuel states. The chart above compares fuel in the tank with fuel contents indicated on the gauge.

Airworthiness requirements

The aircraft type was certificated in October 1948, according to US Civil Air Regulations (CARs), the precursors of the current Federal Aviation Regulations (FARs). These regulations made provision for civil certification of aircraft by proof of conformity with the CARs and also made provision for certification of aircraft which had been certificated to a US Army or Navy standard, without proof of conformity with the CARs, on the grounds that these standards provided similar levels of safety to the CARs then extant.

Those Regulations in force in 1956, included CAR6.613, which states: *'Fuel quantity indicators shall be calibrated to read zero during level flight when the quantity of fuel remaining in the tank is equal to the unusuable fuel supply…'*. The current (2004) FARs, and others, include similar requirements regarding fuel gauge accuracy. The passing of time made it very difficult to establish that CAR6.613 was in place when the Hiller UH-12B was first certificated and whether the aircraft was certificated on the basis of military certification (the fact that the aircraft was built in substantial numbers for the armed forces makes this likely). The investigation did not attempt to establish what requirements were in place within the US Army and Navy standards.

Analysis

In the absence of the dipstick, the pilot was able to assess the fuel quantity before flight only by visual inspection of the tank contents and from the reading on the fuel gauge. He was not familiar with assessing fuel quantity at low levels in this fashion and training on the type had not covered this. Indeed, given the arrangement of the filler neck and fuel tank, an accurate visual assessment would certainly have been difficult.

However, it appears that the pilot's initial assessment of fuel quantity was reasonably accurate, as evidenced by the subsequent calibration tests of the gauge system. His initial assessment of the fuel requirement for the proposed operation also appears reasonable, given the absence of meaningful consumption data in the aircraft Flight Manual. However, his knowledge of expected fuel consumption related more to cruise flight than operations such as continuous hovering and hover-taxiing, which by their nature, are times at which high power is required, with consequently high fuel consumption.

The difficulty that the pilot experienced in transitioning into forward flight with three persons on board, on his first attempt, may indicate that the engine was not delivering full power. Given this, its fuel consumption may have been higher than usual in the ensuing manoeuvres. The engine suffered significant damage in the accident, to the degree that post-flight tests to assess performance and fuel consumption were not feasible.

However, the first two flights proceeded without incident, and it is apparent that the pilot was assessing fuel consumption during these flights, by reference to the fuel gauge. This was in accordance with his training and the training that pilots normally receive. During this time the gauge indicated a gradually decreasing fuel quantity and this over time would have given a strong indication as to the rate of fuel consumption. When requested to fly the additional flight, the pilot understood the fuel contents to be around ¼ (equivalent to some 7 USG). This quantity of fuel would have been sufficient to carry out a brief circuit, albeit with little more than a minimal reserve.

Tests after the accident showed that at fuel quantities close to the minimum usable, the fuel flow ceased when the aircraft nose was pitched up, as would be the case when transitioning into the hover, and this accounts for the sudden power loss.

The power loss occurred at a speed and height very close to the 'avoid curve', a time when a very high degree of pilot skill and familiarity with the type would be required to ensure a 'normal' touchdown. Although the pilot was very experienced in helicopter flying, he lacked substantial experience on the Hiller helicopter. His decision to maintain a level attitude and cushion the touchdown as much as possible was a good one, and ensured the safety of the helicopter's occupants.

The practise of advising pilots to distrust fuel gauges is necessarily contradictory to that of instilling reference to the fuel gauge readings, such as during a FREDA check, in flight. The availability of 'real-time' information about fuel states may cause a pilot to re-assess his fuel plan, where he is not certain of the fuel consumption of the aircraft (for example, because he has little knowledge of predicted fuel burn or because the manoeuvres being executed may result in fuel burn which is erratic or unpredictable). A pilot, once airborne, may be expected to place some reliance upon the fuel gauge unless he has specific reason to doubt its accuracy and this is reflected in regulatory requirements. Reason to doubt a gauge might be that it appears not to move, or shows a clearly erroneous reading. However, a gauge which, at first inspection appears to indicate the tank contents (as assessed by other means) accurately, and then continues to show sensible changes (a decreasing fuel quantity over time, at a reasonable rate), will not give the pilot cause for doubt. It is probable that the pilot believed the gauge reading was accurate for this reason and there was nothing about the gauge's performance which would have given him reason to distrust it.

The possibility that the fuel gauge sender unit was disrupted during the impact sequence was considered. If this had occurred, the subsequent evaluation of the gauging system would have been invalid. However, the minor damage to the helicopter's skids indicates that the impact was not extreme. The float is of low mass and would have been cushioned by the fuel beneath it in the tank in any downward deflection. Other significant damage to the helicopter appears to have resulted from the toppling of the rotor disc, destruction of the blades and subsequent extreme vibration of the rotor, rotor head, engine and mountings. The fuel gauging system, as tested after the accident, performed in a manner which reflected the pilot's recollection of gauge indications. For these reasons, it is considered unlikely that the sender unit was disrupted in the accident sequence.

The owner's policy of refuelling prior to every flight appears, at first, to have considerable merit. However, this policy, together with the duration of flights conducted, meant that the aircraft had never previously been operated at a low fuel level. Had the aircraft been refuelled from a low level to full, the disparity between the gauge reading and the actual contents might have been discovered, through comparison of fuel quantity uplifted and tank capacity. However, as technical records were not kept, this discovery would have relied upon the expertise and insight of those conducting the refuelling.

With regard to the absence of a Technical Log, it is apparent that in order for aggregate flight times to be entered correctly in the aircraft log books, there must be a source of accurate data on individual flights. The absence of this requirement may cast doubt on the accuracy of log book records on aircraft not used for Public Transport or Aerial Work. If an accurate record of flight times and of fuel uplifted and consumed had been kept, the owner could have determined fuel consumption accurately and have kept track of fuel on board. The fuel gauge error could therefore have been identified.

The FAA had previously investigated the activities of the President of the Corporation re-manufacturing the helicopter, with particular regard to the use of unapproved parts on aircraft and had deprived him of his professional qualifications. It appears that, despite this, his corporation was still involved in re-manufacturing helicopters with unapproved parts.

The accident helicopter was one which the owner had acquired from the US with a view to establishing a business marketing similar 're-manufactured' helicopters of the same type. However, the fact that the helicopter was certificated under an airworthiness code (possibly a military one), which was derived more than fifty years ago, calls into question the issue of 're-manufacture' of old aircraft, as a helicopter offered 'as new' for sale today, may in fact meet very different standards of airworthiness to those currently in force. In particular, an aircraft certificated to a very old Standard, may not incorporate safety features which have been developed through the ongoing process of safety improvement in the intervening time.

Conclusions

The accident occurred as a result of sudden loss of power caused by fuel starvation and at a time when the height and speed of the helicopter made a successful auto-rotation to a normal power-off landing difficult. The power loss was sudden, as the pitch attitude of the aircraft is critical to the fuel supply from the tank when the tank is very nearly empty. The pilot's handling of the helicopter minimised the damage and ensured a safe outcome for its occupants. Furthermore, the inherently strong design of the helicopter and its wide skids contributed to their safety.

The pilot relied upon the quantity indications displayed on the fuel gauge and had no specific cause to doubt the readings. The fuel gauge fitted to the helicopter was inaccurate, indicating significantly more fuel on board than was present in the tank. The fuel gauge was not approved for use on the helicopter. The pilot or owner however, could have established a better knowledge of the helicopter's fuel consumption, had records of flying times and fuel consumed been kept.

Safety action

The FAA has been notified of this accident and is undertaking an investigation into the installation of the unapproved fuel gauge.

Aircraft Type and Registration:	Robinson R22 Beta, G-SUMT
No & Type of Engines:	1 Lycoming O-320-B2C piston engine
Year of Manufacture:	1992
Date & Time (UTC):	27 May 2005 at 1950 hrs
Location:	Sherburn in Elmet Aerodrome, Leeds
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - 2 (Minor) Passengers - N/A
Nature of Damage:	Extensive
Commander's Licence:	Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	63 hours (all on type) Last 90 days - 3 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries by the AAIB

After a short local flight lasting about 30 minutes, the pilot in the right cockpit seat made his approach to Sherburn in Elmet Aerodrome. On departure the wind had been about 11 kt from 030º and the pilot made his approach to the right and parallel with Runway 06. The weather was good although the visibility was becoming hazy. The pilot descended to about 15 feet agl over the aerodrome and hover taxied to his intended landing area where the helicopter crashed. He subsequently recalled that there were no other aircraft in the area and that the wind sock appeared to be "Full". However, from that time he could not recall anything else until he regained consciousness in the wreckage of the helicopter.

There was a R22 rated pilot seated in the left seat. Although the dual controls were fitted, he confirmed that his hands and feet were clear of the controls at the time of the accident. His recollection was that the pilot flew a normal approach and was coming to a halt nearly into wind at about five feet agl when the helicopter started to turn to the left. He was then aware of a rapidly increasing turn rate but could not be certain about the direction. The helicopter struck the ground hard moving backwards.

The aerodrome was closed at the time so there was no Air/ Ground Operator on duty. However, one of the resident fixed wing flying instructors was walking in the area and saw part of the accident. He had watched the helicopter make an approach on a heading of about 060º to a hover height of about six feet agl and then hover taxi in the same direction. He then looked away but when he looked back, the helicopter had pitched nose up and was yawed to the right. It then appeared to slide back to contact the ground tail first. The witness estimated the surface wind at the time as 030º/12 to 15 kt. This wind direction would not normally result in turbulence on the aerodrome.

Enquiries with a type training organisation confirmed that the anti-torque pedals on the R22 are very effective and that left pedal would be used to counter any yaw caused by the application of collective lever as the helicopter came to a hover. Additionally, there would have been a wind induced left yaw as the helicopter came to the hover on a heading of about 060º The pilot subsequently confirmed that there had been no unserviceabilities with the helicopter on the flight prior to the final hover.

Aircraft Type and Registration:	Schweizer 269C, G-HFLA	
No & Type of Engines:	1 Lycoming HIO-360-D1A piston engine	
Year of Manufacture:	1989	
Date & Time (UTC):	28 May 2005 at 1117 hrs	
Location:	Norwich Airport, Norfolk	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - 1 minor	Passengers - N/A
Nature of Damage:	Substantial	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	65 years	
Commander's Flying Experience:	13,986 hours (of which 108 were on type) Last 90 days - 45 hours Last 28 days - 21 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

After a short training flight in the local area the helicopter returned to Norwich Airport. Weather conditions were clear; wind conditions were gusty with a reported surface wind from 230º/23 kt. The instructor crosschecked the wind against the windsock and decided to demonstrate an engine off landing on Runway 22 grass. Autorotation was commenced at 1,300 feet agl and at 500 feet agl, when certain that the landing area would be reached, the instructor fully closed the throttle. At around 200 feet agl he checked the airspeed was at his target of 55 kt and the rotor was at 490 RPM.

At a low height the instructor commenced a flare, not too steep because of the wind velocity, then levelled the aircraft and cushioned the touchdown with the collective. As he did so the aircraft hit the ground hard and came to a stop some 10 to 15 metres further ahead having sustained substantial damage. Both occupants had been wearing four point harnesses and were able to vacate the aircraft unassisted, the student having sustained minor injuries.

The instructor, in his report, was uncertain as to the exact cause of the accident but did suggest that windshear, in the strong and gusty wind conditions, was a likely factor. The ground slide following the hard landing was relatively short which could indicate a low forward speed at touchdown.

INCIDENT

Aircraft Type and Registration:	Gazelle HT Mk 2, G-GAZL
No & Type of Engines:	1 Turbomeca Astazou IIIN2 turboshaft engine
Year of Manufacture:	1974
Date & Time (UTC):	4 November 2004 at 0948 hrs
Location:	On approach to Sheffield City Airport, Sheffield
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Separation and destruction of right-hand engine cowling plus superficial damage to main rotor blades
Commander's Licence:	Private Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	2,657 hours (of which 384 were on type) Last 90 days - 46 hours Last 28 days - 6 hours
Information Sources:	Aircraft Accident Report Form submitted by the pilot, plus aircraft examination by the AAIB and a metallurgy report

Synopsis

Following a loud bang and a jolt during his approach, the pilot determined that the engine and rotor systems were operating within limits and so he landed normally. After landing the right engine cowling was missing and there were small marks on the main rotor blades. Two fractured portions of the missing cowling were later found. Each cowling panel has two hinges at the top, a lower latch and part of a single latch which secures the forward edge of both panels. It appears that at least one of the top spigot fittings had failed through cracking from previous overloads and the aft lower latch had probably not been fully secure. Tests showed that this aft lower latch can appear latched when it is not actually engaged. Two Safety Recommendations were made concerning detailed visual inspections of these fittings.

History of the flight

The pilot planned to fly from a private landing site near Derby to another private site near York, refuelling at Sheffield City Airport on the way. He states that he checked that all the cowlings and latches were secure before leaving Derby.

The flight proceeded normally until, about two miles south of Sheffield City Airport on a left-hand base leg for Runway 28, there was a loud bang and a jolt to the helicopter. The pilot thought he might have had a birdstrike and so he immediately lowered the collective lever as a precaution for a possible autorotation. However, the engine temperature, RPM and pressure indications remained normal so he continued on final approach to a landing.

After shutdown the pilot noted a small mark on one of the main rotor blades and then, upon leaving the helicopter, he realised that the right-hand engine cowling was missing. He reported the facts to ATC and looked for further damage. This was limited to small marks on the other two rotor blades. Later, an engineer arrived from the maintenance organisation with a spare pair of cowlings and the helicopter was returned to service the following day. Two items of wreckage, fractured portions of the missing cowling, were later forwarded to the maintenance organisation by ATC at Sheffield.

Engine cowling description

The engine cowling assembly on the Gazelle is formed of two large symmetrical cowling panels of complex curvature and composite construction. Together these cowling panels surround the engine and cover the engine connections and the portion of the tail rotor drive shaft located directly below the engine. Both the left-hand and right-hand cowlings are hinged at the top of the engine, with two spigots engaging hinge fittings close to the aircraft centreline. On this version of the Gazelle, the SA341 with the Astazou III engine, there is one latch on each cowling side with a further single, common, front latch attachment formed of two halves, with one half on the forward edge of each cowling. This simple over-centre latch below the centreline of the engine secures the two cowlings together and the other latches, farther aft, secure the cowlings to short roller fittings mounted on the engine.

This aft latch on each cowling is designed to engage automatically when the cowling is closed (see Figure 1). The latch is a very simple mechanism, with a latching lever marked OPEN and LOCKED. In addition, there is an 'anti-chatter' device; a length of spring steel formed into a curved W-shape (see Figure 2).

The lever is normally retained in the LOCKED position by a spring. To open the cowling, the operator holds the lever in the OPEN position, while lifting the cowling. To close the cowling, the lever will move momentarily towards the OPEN position as the latch engages the roller fitting on the engine and then to its sprung LOCKED position. There is no additional visual indication to confirm that the roller is engaged in the latch.

Examination - G-GAZL

Only three items of the right-hand cowling were available for examination. These were the fractured spigot from the forward hinge at the top of the engine, the portion (approximately 300 mm by 180 mm) of the cowling which would normally be attached to this spigot and another portion (approximately 350 mm by 330 mm) of the cowling, including the aft latch. The forward spigot had been retained in the hinge by a safety pin.

G-GAZL was examined by the AAIB with the replacement cowlings in place. In operating the latches and opening and closing the cowlings, it was clear that if the forward latch joining the cowlings was left undone, it was visually obvious and untidy. With the aft latches, however, it was possible to close the cowlings so that these latches did not engage and the cowling appeared very similar to the same cowling with the latch fully engaged. In each case, the lever was in its sprung LOCKED position.

As a trial, the fractured item of cowling panel containing the aft latch was engaged with the roller on the engine. It engaged correctly and the application of forces in a variety of directions failed to disengage the latch indicating that it had very probably not been engaged at the time the cowling opened in flight.

Examination - fractured fitting

The fracture surfaces of the spigot fitting were examined by a metallurgist, who used both visual and fractographic (Scanning Electron Microscope [SEM]) methods. The metallurgist identified the material as low alloy steel and reported that the fracture surface was generally darkened and discoloured, consistent with cracking in the material, with two narrow bright regions, consistent with a final overload failure.

The SEM examination showed the fracture generally to be 'terraced' in appearance, ductile and primarily tensile in nature, with the path of the fracture being heavily influenced by the directionality of the microstructure. The discolouration showed that most of the fracture had been present for an extended period and it had probably developed as a result of a number of overload cycles. The small size of the final fracture surfaces indicated that the door was, when in position and properly secured, well-supported and that only small loads would pass through the hinge points.

In summary, the metallurgist reported that the pattern and orientation of the fracture was consistent with the door being rapidly opened a number of times beyond its normal position, such as when opening in strong winds and that this would have taken place over a long period of time, probably years. He also commented that a detailed visual inspection of the spigot fittings would, in most instances, reveal whether cracks were present.

Military and civil experience

With the assistance of the Defence Aviation Safety Centre (DASC), the occurrence records of the UK military services were examined for similar instances on Gazelle helicopters.

One incident in particular was very similar to the occurrence to G-GAZL. In this case, in late 2003, a Gazelle AH1 of the British Army had lost a right-hand engine cowling while descending to land and there was damage to the main rotor blades very similar to that to G-GAZL. The items of cowling could not be recovered so the state of the securing latches could not be determined. In common with G-GAZL, previous cracking was noted around the hinge spigots and the conclusion of the technical report was that the loss of the cowling had been a result of a combination of the cracking and the failure, or non-securing, of one or more of the lower latches.

In addition, there have been at least two cases in the UK of engine cowling separation from civil-registered Gazelle helicopters previously reported by the AAIB.

Maintenance requirements

The Gazelle helicopters currently registered in the UK are both from civil production, with Certificates of Airworthiness, and ex-military helicopters on CAA Permits to Fly, such as G-GAZL. Both ex-military and civil, however, are of the original SA341 design, with similar engine cowlings.

The maintenance schedule for the ex-military helicopters is based on the UK military schedule. For examination of the fittings on the engine cowlings, amongst other items, the main inspection is the 'T1', scheduled for every 500 operating hours (or a maximum of 24 months calendar time).

Discussion

The presence of the cracking around the hinges in G-GAZL was clearly significant. However, the indications from the metallurgist's report were that these hinges finally failed when an overload was applied and the design is such that normal flight applies only low loads to the hinges when the cowlings are correctly latched.

The absence of certain hardware items from G-GAZL, such as the right-hand portion of the forward latch, prevents a definite finding as to the cause of the separation of the right-hand cowling. However, the fact that the aft latch was found complete and undamaged, separate from the roller with which it would engage, makes it highly probable that the aft latch was not correctly engaged before flight. This accident, like the Gazelle AH1 in late 2003, occurred during descending flight, when the airflow around the fuselage would have a strong upward component and would draw the unlatched cowling outwards and upwards, applying further loads to the hinges. The AAIB could not determine whether the forward latch was insecure at the start of the flight or if it was released by distortion of the cowling under air loads. In either case, the likelihood in both accidents is that there was a combination of cracked hinge brackets and at least one unsecured latch.

This accident is a reminder to operators of Gazelle helicopters to exercise particular care in the positive latching of engine cowlings. However, the problem of cracking in the spigot fittings appears to be a common feature in these occurrences and a more detailed visual inspection should identify those engine cowlings at risk. Therefore, the AAIB issued the following Safety Recommendations:

Safety Recommendation 2005-049

The UK Civil Aviation Authority should review the periodic inspection of the spigot fittings on the engine cowlings of SA341-type Gazelle helicopters operated on CAA Permits-to-Fly, to reduce the number of cracked fittings in service.

Safety Recommendation 2005-050

The European Aviation Safety Agency should review the periodic inspection of the spigot fittings on the engine cowlings of SA341-type Gazelle helicopters operated on Certificates of Airworthiness, to reduce the number of cracked fittings in service.

Figure 1 - Engine cowling - Aft latch (outside) and latch lever

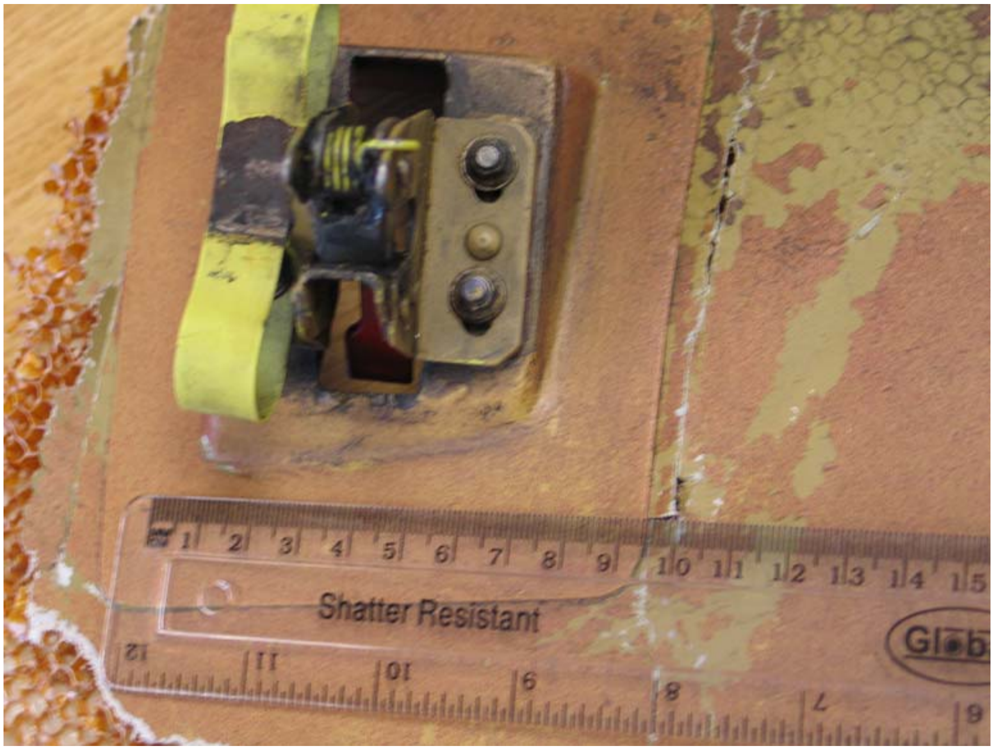


Figure 2 - Engine cowling - Aft latch (inside) and 'anti-chatter' device

INCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-DERB
No & Type of Engines:	1 Lycoming O-320-B2C piston engine
Year of Manufacture:	1989
Date & Time (UTC):	15 November 2004 at 1400 hrs
Location:	Biggin Hill, Kent
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Main rotor blade cracked
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	2,950 hours (of which 2,080 were on type) Last 90 days - 252 hours Last 28 days - 71 hours
Information Source:	AAIB Field Investigation

Synopsis

Following a flight during which an unusual vibration developed, the helicopter landed safely but then experienced intense vibration whilst subsequently hover taxiing to a maintenance organisation. Inspection showed that one of the main rotor blades had cracked from the trailing edge, through approximately 75% of its chord, as far as the spar at about the ⅓ span position. The teeter hinge was found to be extremely stiff, and this had been assembled about 20 hours beforehand without the necessary shims. The cracking was attributed to higher than normal stresses caused by the stiff teeter hinge.

History of the flight

The commander had completed a daily inspection in preparation for a flight from Manston to Biggin Hill. The two crew consisted of the commander and a student preparing for his qualifying cross country for his PPL(H). Shortly before arrival at Biggin Hill the commander noted an unusual vibration. After landing she discussed this with another company pilot and it was eventually decided to hover taxi to a nearby maintenance organisation with experience of the R22. With the commander and student on board, another 0.4 hrs was logged, of which about 0.1 hrs was airborne time.

During the hover taxi, the vibration became intense and the commander landed and shut down. Subsequent examination of the helicopter showed that one of the rotor blades was cracked through about 75% of the chord, from the trailing edge, at about the ⅓ span position. During examination of the rotor system it was found that the teeter hinge, which should be free to pivot, was extremely stiff.

Aircraft details

G-DERB was built in 1989 and had a recorded total of 2,989.9 hours. The main rotor blades carried the part number A016-2, and serial numbers 11646C (the cracked blade) and 11674C. They were fitted on 6 October 1999 and had a total recorded airborne time (as opposed to running time) of 1,205.6 hours. This standard of blade was being phased out of service because of a history of cracking in service, frequently resulting from corrosion damage. On 25 March 2004 the manufacturer issued Service Letter SL-54 in support of FAA AD 2004-06-52 (superseded later that year by FAA AD 2004-19-09). This SL required replacement of A016-2 blades before 10 years calendar life and suggested that, in corrosive environments, these blades should be removed as soon as possible and, in any case, within five years calendar life. For all A016-2 blades with more than 1,000 hours or five years calendar life, additional track and balance of the rotor system was required. On 14 December 2004 the manufacturer issued Service Bulletin SB-94, which required that all A016-2 blades be withdrawn from service by 1 December 2005.

Description of teeter head coning hinges

The Robinson R22 is fitted with a teeter head and coning hinges, Figure 1. In this design, the teeter head allows the rotor disk to take up an attitude appropriate to the flight condition, with the coning hinges allowing the blades to achieve the optimum coning angle appropriate for the flight and loading conditions. In doing so, they remove any bending moment from the blade roots, permitting a lighter blade structure than would otherwise be required. A correctly functioning R22 rotor system in steady state forward flight will therefore experience little or no relative motion between the blade and the head at the coning hinge. The use of a teeter head eliminates the need for flap hinges, and also therefore the need for conventional lead-lag hinges and associated dampers.

Maintenance history

Maintenance records showed that on 24 March 2004, at 2,968.1 airframe hours, various rod ends were renewed in the swashplate/main rotor area. On 31 March 2004, the aircraft was flown to another maintenance organisation to carry out the accomplishment of FAA AD 2004-06-52, which required a main rotor track and balance check, but this could not be completed satisfactorily due to worn bearings in the main rotor head. It was agreed that the blade spindles and main rotor head would be reworked by the agent but, due to delays, the helicopter was transported by road back to its base for the work to be completed there. This included refitting the main rotor head and blades. At this point the helicopter had a total of 2,969.9 hours[1].

On 2 and 3 June 2004, the main rotor head, blades and spindles were reassembled. New spindle bearings had been fitted, the spindles themselves had been inspected and the main rotor head had been re-bushed before being refitted. The mechanic who assembled the main rotor head was studying to obtain a CAA licence and was working as an apprentice under the supervision of the Chief Engineer. He had encountered some difficulties with the assembly and stated that no shims had been returned with the reworked head components. The mechanic also stated that he was told to assemble the head without the shims, as there were none in stock, and therefore did so.

The Maintenance Manual requires that after assembly, the teeter bolt be pre-loaded and the pull-off load[2] be recorded. It remains unclear whether the various parties to this work thought the shims were necessary or not but, when assembled, the mechanic found that the pull-off load was unacceptably high and disassembled the head to investigate. After re-assembly, using the same components, the Chief Engineer witnessed the pull-off load check which, at 15 to 22 lbf, was still high but now within limits, and recorded the values. The main rotor system was then satisfactorily checked with a strobe light, and the work was 'signed off'. The helicopter also received a 50 hour inspection at this time.

The incident occurred 20 flying hours later.

Engineering investigation

Rotor head examination

The rotor system was disassembled and examined, Figure 2. It was found that the cadmium plated surface of the teeter bolt was damaged, that the thrust washers at the teeter hinge and the associated bushes in the main rotor head were deformed. The teeter hinge assembly should be assembled with shim washers, the thickness of which are determined on assembly, but no such washers were found in the assembly from G-DERB when examined by the AAIB. During assembly, the teeter bolt is pre-loaded by torque loading its nut until the extension of the bolt, due to elastic strain[3], achieves a

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[1] The recorded hours must be regarded as suspect because the mechanic confirmed in writing to AAIB that the helicopter had been fitted with an isolation switch, mounted beneath the pilot's seat, which was wired into the Datcon (hours meter). He had been asked to remove this switch, which had apparently been fitted before the aircraft came into the possession of the operator, his employer. Therefore, the hours recorded in the log books before this time may or may not be accurate. In the UK, the Air Navigation Order Article 17 defines the requirement for the keeping of aircraft hours, in that the aircraft log book is to be kept up to date.

[2] A torque value to move the teeter hinge, measured by a spring balance from a special tool.

[3] When the bolt is torque tightened, a tensile load is induced in the bolt, and the bolt stretches elastically. This strain, or extension over its original length, is measured using a dedicated tool. This is a more accurate means of setting the pre-load in a bolt, rather than relying upon a torque value applied to the nut, where variable friction effects may apply.

set value. On disassembly, the residual strain in the bolt was measured and this was found to be sufficiently close to the required value to suggest that the teeter bolt had been correctly pre-loaded. As a consequence of its assembly without the required shims, the bushes on the teeter bolt were not properly clamped, resulting in the thrust washers applying an excessive load directly to the teeter head itself. This caused the teeter motion to occur between the teeter bolt and its bushes rather than, as intended, between the bushes and the head itself. Using information from the Maintenance Manual and the finished dimensions of the detail parts, the required thickness of shims for correct assembly was calculated. It was found that a total of 0.059 inches of shim material was required.

Examination of blade crack

The cracked blade was examined by a specialist laboratory, Figures 3 and 4. Their report concluded that the crack had initiated in the trailing edge of one skin of the blade by a fatigue mechanism, which had then progressed, relatively slowly, forward and into the other skin. It then advanced rapidly through the top and bottom skins forward as far as the blade spar. The spar itself showed no evidence of cracks. The origin of the fatigue crack was not associated with damage, corrosion or material defect, but appeared to be due to higher than normal stresses and was in the area of a local stress concentration at the end of an internal doubler.

Analysis

General

When the head was initially assembled it was rejected by the mechanic, because the teeter hinge was very stiff to move. On inspection of the parts after the incident, it was found that the thrust washers were plastically deformed (bowed) and the mating bushes in the head were distorted to a concave shape. This most probably occurred as the teeter bolt was tightened when first assembled. These plastic deformations would have resulted in changed clearances on re-assembly, even without any shims, and there may also have been some surface grease on the parts which are normally assembled dry. The assembly may have been less stiff after re-assembly for these reasons, resulting in the recorded pull-off values remaining higher than normal due to the absence of the shims, but this time within limits. There was no clear reason established why, over the last 20 flying hours, the teeter hinge had progressively stiffened. It would appear that during this period, it was sufficiently free for the blade tips to be moved down to be inspected from the ground during the daily inspection, although the teeter hinge might have been stiffer than normal. Immediately after the incident, it was found to be extremely stiff. Upon disassembly, damage was observed to the cadmium plated surface of the teeter bolt, about which the teeter motion had been occurring in preference to the bushes and it was found that the bolt did not move freely in the bushes. Cadmium is a soft metal and will 'flow' under heat and pressure. It is likely, therefore, that the soft cadmium was displaced and flowed into the available clearance, causing high friction between the teeter bolt and the bushes.

Fracture mechanism

As described above, there is normally little or no movement of the blades relative to the teeter head at the coning hinges in normal steady forward flight. If, however, the teeter head is stiff or jammed, then the attitude that the rotor disc must adopt relative to the mast, is accommodated by blade flap occurring at the coning hinges. While this may not result in any obvious control difficulties, it will cause the centre of gravity of each blade to move up and down once per revolution, relative to the head. Since the motion occurs about the coning hinge, the centre of gravity of each blade also moves slightly inboard and outboard. Conservation of momentum (the Coriolis effect) thus causes the blade to attempt to change its angular velocity continuously around the rotor disc. Without any lead/lag hinges it is constrained from doing so, and this induces high stresses in the blade itself. This effect is described in many standard text books, for example Newman (1994)[1] states:

> *'The Coriolis forcing will then drive the blades in an in-plane manner. If no allowance for this is made, the loading in the blade will cause damage to the root of the blade or hub…'*

In response to AAIB questions, the helicopter manufacturer responded:

> *'The 'stiff' teeter hinge condition caused by the assembly of the hub to the rotor without proper shims is believed by RHC to have been a major factor in the cracking of the blade…' and.'…The absence of corrosion or other stress riser at the fatigue origin is an indicator of higher than normal loading'.*

Maintenance issues

The pull-off load check, after the rotor head had been assembled for the second time, was within limits and regarded by the mechanic and his Chief Engineer as evidence that the teeter hinge assembly had been assembled satisfactorily. With hindsight, it is apparent that this was not the case and, for this reason, the Chief Engineer has subsequently introduced a stage inspection during assembly to prevent re-occurrence. There are many situations in aircraft maintenance where work cannot be inspected after it is assembled. Where such work is carried out by personnel 'under supervision', it is vital that the responsible licensed signatories assure themselves that all such work has been correctly completed.

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[1] Newman S., (1994) 'The Foundations of Helicopter Flight' p81, pub. Edward Arnold, London, UK, ISBN 0-340-587024

Robinson R22 Main Rotor

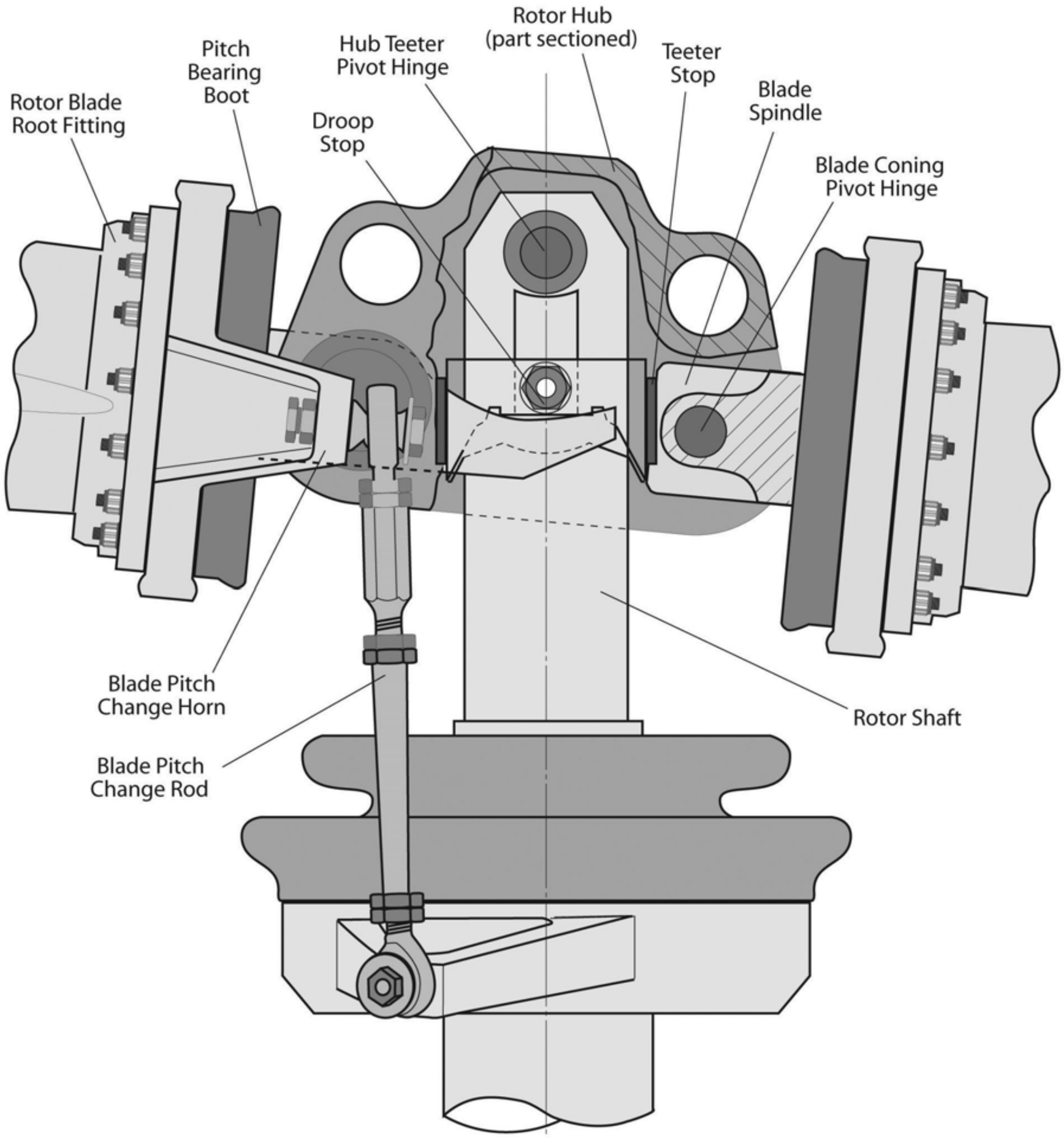
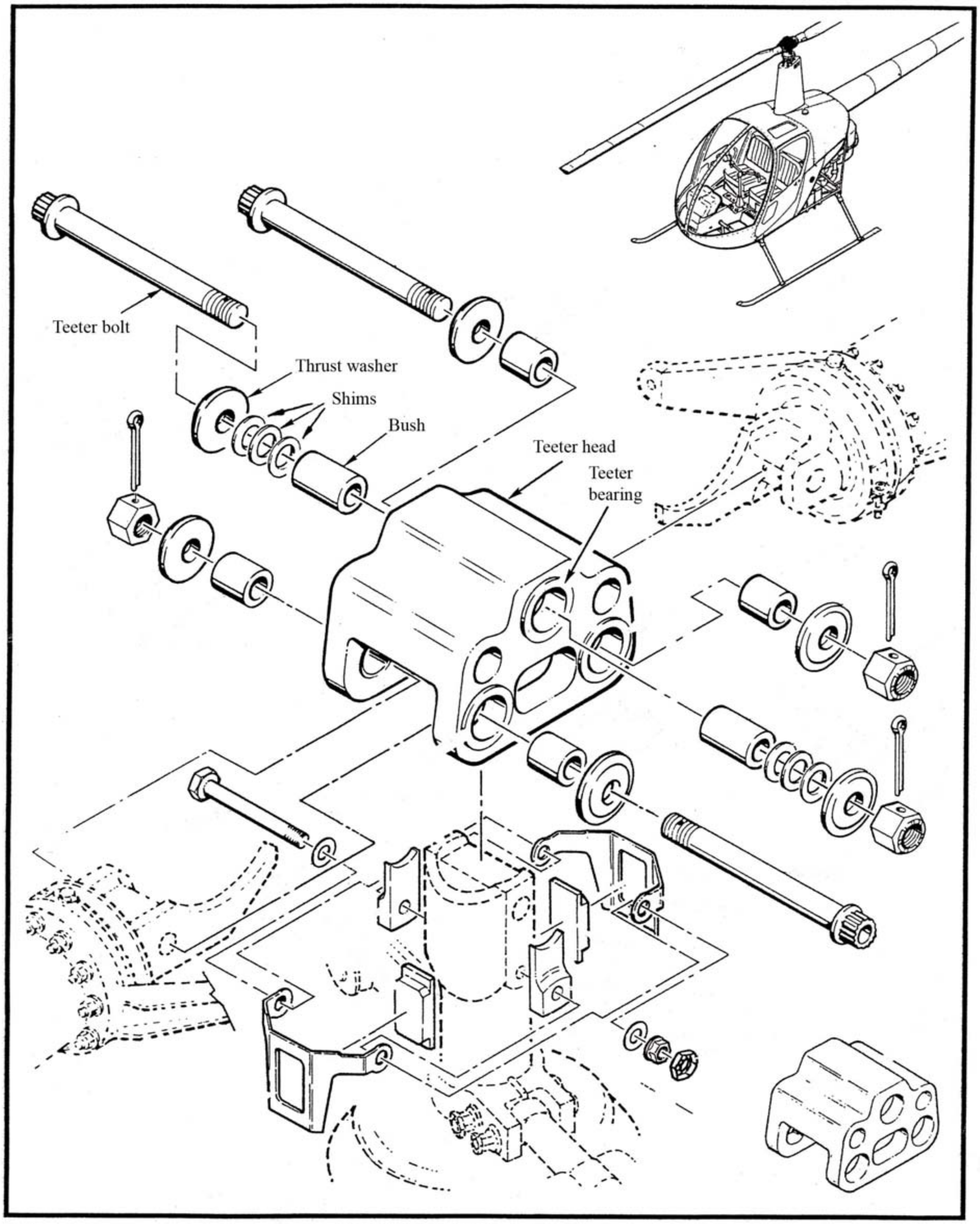


Figure 1

MODEL R22 ROBINSON ILLUSTRATED PARTS CATALOG



6-2 FIGURE 6-3 MAIN ROTOR HUB REV MAR 2004

Figure 2

Figure 3
Photograph showing the crack observed on the upper surface of the rotor blade, as received, trailing edge on the left hand side of the photograph

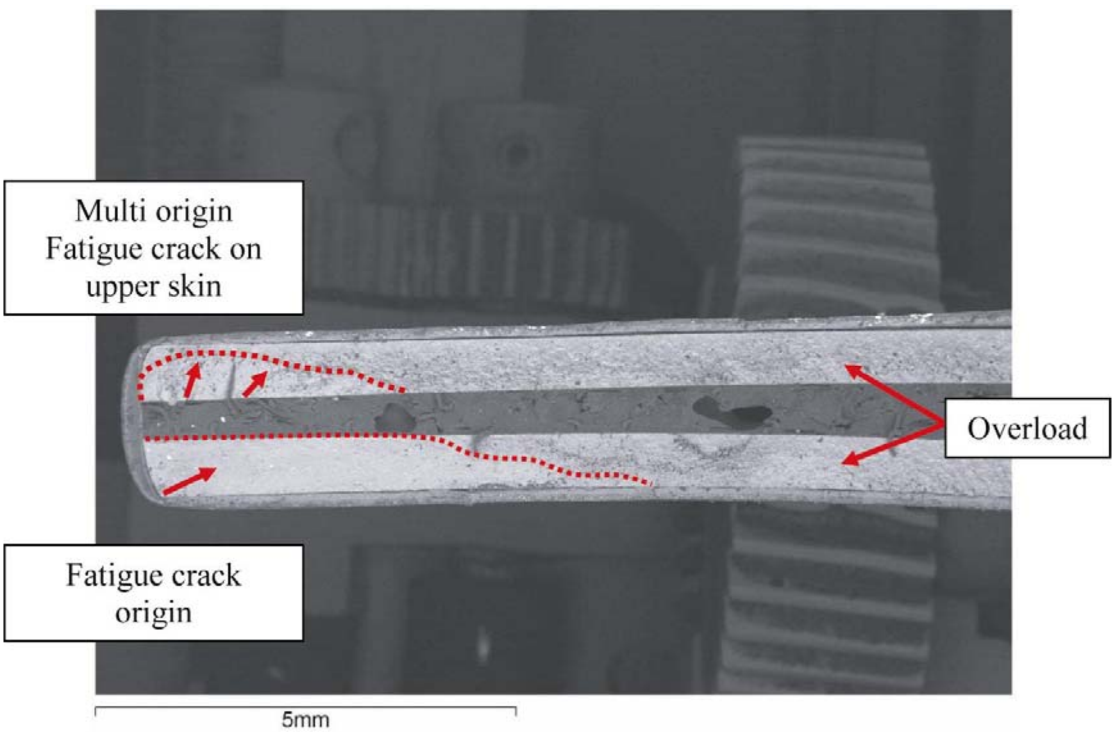


Figure 4
Backscattered electron micrograph of the fracture at the trailing edge location, showing the extent of the fatigue cracks

Aircraft Type and Registration:	ASK13 Glider, FWN
No & Type of Engines:	N/A
Year of Manufacture:	1969
Date & Time (UTC):	6 August 2004 at 1645 hrs
Location:	Booker, Wycombe Air Park, Buckinghamshire
Type of Flight:	Trial lesson
Persons on Board:	Instructor - 1 Student - 1
Injuries:	Instructor - 1 (Minor) Student - 1 (Serious)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	British Gliding Association Pilot's Certificate with Instructor Rating
Commander's Age:	58 years
Commander's Flying Experience:	577 hours (of which 85 were on type) Last 90 days - 74 hours Last 28 days - 25 hours
Information Source:	AAIB Field Investigation

History of the flight

The student and two other members of his party had been given trial gliding lessons as a gift. The party had arrived at the airfield at approximately 1400 hrs. The weather was fine, with a light south-westerly wind and a few clouds. While waiting for their trial lessons the party had a picnic and agreed the order in which the participants would undertake their flights. The first and third students in the agreed sequence had each started to drink a small glass of champagne but they changed these to non alcoholic drinks when an instructor at the gliding club advised the party that those who were having a trial lesson could not consume alcohol before flying. The instructor stated that he was told that those who were due to fly had not had any alcohol and that their drinks were non-alcoholic. He also stated that he had reiterated that this must be the case.

All three students were given temporary Club membership forms to complete, specifically designed for Trial Gliding Lessons, and after about an hour's wait the first student was briefed for and given his flight, which lasted 20 minutes. This was followed by a trial lesson for the second student with the same instructor in the same glider. The first student had taken a camera with him but did not recall being briefed specifically on what to do with it. The design of his glider's cockpit probably encouraged him to hold the camera in his hands (see Figure 1). There was then a pause of about three quarters of an hour before the third student was paired up with another instructor who had just completed a solo 3½ hour cross country flight. This instructor had not been nominated as an instructor for the day's instructional programme but was asked to assist because the instructor who was due to carry out the flight was feeling tired. Apparently it was not unusual for an instructor who had not been rostered to be asked to step in at short notice. However, this instructor could not remember conducting many instructional flights at short notice after a lengthy solo cross country flight. He subsequently commented that he had conducted at least 174 trial lessons.

The instructor briefed his student on FWN, a tandem seat aircraft, which was of an older design than the K21 in which the first two students had flown. He explained the instruments and the flying controls, which are mechanically linked between the front and rear cockpits, and also covered the procedure for handing over control of the glider between the rear seat pilot (the instructor) and the front seat pilot (the student) when they were flying. The instructor advised the student that he would be invited to take control of the glider at some stage during the flight, after they had released themselves from the tug aircraft. He emphasised the need for the student to remain well clear of the controls when he was not flying the aircraft and instructed him that only he, the instructor, would operate the cable release handle, trim lever and airbrake lever. (The airbrakes are used to degrade the efficiency of the wings and increase drag when required, as on the approach to land. After landing the airbrakes are normally deployed fully.) The instructor briefed the student on the parachute that he would be wearing and helped him to strap it on. He also explained the procedure for exiting the glider should they need to abandon it in flight, and how to land after parachuting. The student stated that he had been holding a camera in his hand and, before strapping his parachute on, he placed the camera on the front seat of the glider.

The student then climbed into the front seat, giving the camera to one of the others in his party, and the instructor assisted him with his harness, also explaining how to release it. The student stated that while this was being done the camera, which had been returned to him, was on the cockpit floor in front of him, between his feet, where he had placed it. The instructor did not remember noticing the camera but had a vague recollection of something being passed to the student after he was strapped in. The instructor stated that he did not brief the student on the use of a camera but gave his standard brief covering the items already described. He later stated that he was not aware of any definite protocols or procedures relating to cameras or loose articles, other than when carrying out aerobatic manoeuvres. He recalled that on previous occasions when students had asked what they should do with a camera he had ensured that it was appropriately secured. Aerobatics were not included in the trial lesson.

The instructor strapped himself into the rear seat and completed the pre-takeoff checks out loud. During the full and free check of the aileron and elevator controls he noticed a restriction when moving the control column to the right as the front seat control contacted the student's right leg. The student was asked to keep his leg clear and the instructor satisfied himself that he had the normal full range of control movement. The student's rudder pedals had been adjusted well forward so that he could not reach them, since there would be no requirement for him to use them during the flight.

The canopy was closed, the tow rope was connected between the tug aircraft and the glider and, after the appropriate hand signals had been given by the wing man, the tug aircraft began the takeoff. The instructor followed the usual procedure for an aero-tow in this type of glider. At the beginning of the take-off roll he held the control column against its back stop until the nose of the glider had lifted off the ground and the aircraft was balancing on its wheel. The control column should then be moved forward progressively as the glider takes off and remains just above and behind the tug aircraft.

The take-off roll proceeded normally and the student recalled it being bumpy as the glider accelerated over the grass runway surface. Once the glider was airborne the motion was smooth and the instructor stated that, as FWN started to climb above its normal position behind the tug aircraft, he found that he was unable to move the control column forward when he tried to correct this. The instructor asked the student to take his hand off the controls and the student responded that he was not touching them. The instructor continued to apply forward pressure on the control column while the glider climbed at an increasingly steep angle as the tug continued to accelerate along the runway.

The tug pilot stated that he felt the glider become airborne at the normal point and that, just as his aircraft was leaving the ground, he noticed a progressive 'heave' on the tug, as if the airbrakes on the glider had opened. The force intensified and he needed to apply an increasing back pressure on his control column to maintain the tug aircraft's climb attitude. With the end of the airfield approaching and the tail of the tug aircraft beginning to rise the tug pilot released the tow rope and turned sharply to the right to give the glider the maximum number of options for landing.

At about the same time the instructor seems to have released the tow rope at the glider's end although he has no recollection of doing so. Nor, at this stage, did he recall what control inputs he made, although he did regain some control movement and the student observed his control column moving. However, the instructor had concluded that there was something seriously wrong with the elevator and that a crash was inevitable. The glider was seen to climb steeply to a height of about 100 feet, whereupon it stalled, dropped its left wing and entered a descending turn to the left. As the glider picked up speed the wings levelled and it pitched back up. The glider then struck the ground on its wheel in a level attitude and bounced back into the air. Again it climbed steeply, reaching a height of about 40 feet. FWN stalled a second time, the left wing dropped once more and the glider pitched nose down. The glider struck the ground in an almost vertical attitude left wing first, then on to its nose and finally settled back on the ground the right way up. The instructor later stated that at no stage had he deployed the airbrakes.

The nose of the glider had been crushed and the student suffered severe injuries to both his legs, while the instructor sustained chest and back injuries. Many onlookers went to the glider to render assistance and the local emergency services were called. The airfield's control tower staff and fire and rescue service had stood down at 1630 hrs, as normal, when the airfield had closed and ceased to operate as a licensed airfield. The emergency services arrived at 1655, 10 minutes after the accident, and the student was airlifted to hospital.

Glider Examination

An examination of the glider revealed that, in the accident, the student's camera had been damaged. Initial indications suggested that the camera might have become lodged in the aperture for the front seat control column, between the column and its forward control stop; this is located at the aft end of the cockpit floor. This was possible because the space behind the floor around the control column, which allowed the control to be moved through its full range, was unguarded (see example in Figure 2). Further examination revealed that there was a small piece of black material in the edge of the floor in front of the control column, which looked similar to the material on the camera case (see Figure 3). Also the dents in the camera and witness marks on the camera case appeared to be consistent with the camera being jammed between the floor edge and control column at this point. Consequently, the material that was wedged in the edge of the floor and the camera case were sent for analysis.

The results of that analysis indicated that there were no discernable visual or chemical differences between the two materials and it was concluded that it was likely that the fragment extracted from the edge of the floor came from the camera case.

No evidence was found of any pre-existing deficiencies in the airframe and flying controls.

Procedures

The British Gliding Association (BGA) state in their publication entitled Laws and Rules that *all flying instruction shall be given in accordance with the BGA regulations and syllabus*. This is further amplified by a Code of Practice for Gliding Lessons, also included in the BGA Laws and Rules, which includes the statement that *the flight shall be conducted in accordance with the instructional procedures laid down within the British Gliding Association Instructors Manual.* In the chapter on Airmanship in the Instructors' Manual there is a section entitled *Pre-flight*. This lists a series of checks amongst which is the question, *are all loose articles stowed correctly?*

In advance of the trial lessons for this party, the Gliding Club had sent them some reading material when issuing their tickets. This material included some marketing literature which emphasised the high quality of the instruction given at the club, cautionary *NOTES FOR VISITORS*, which dealt with safety procedures on the airfield, and a more detailed pamphlet, published by the BGA, entitled SOARING. IT'S THE ONLY WAY TO FLY. *Gliding simply explained.* This pamphlet, of which there was one sent for each student, gave a comprehensive explanation of what to expect during a flight, particularly a student's first, and some of the procedures used. Included under the heading *Inside the cockpit* was an explanation of the importance of avoiding loose articles. It stated:

> *As a first time passenger/pupil you should ensure that you have no loose objects that could pose a problem in flight; if you have a camera, put its strap around your neck and hold it tightly to your chest so that it cannot foul the joystick.*
>
> *Drop nothing in the cockpit during flight. Should you inadvertently do so, immediately tell your instructor. Loose objects such as chocolate are best left on the ground but should you have any, they should be stowed securely in the pocket on the cockpit wall.*

Fire and Rescue Services

An agreement existed between the airfield owners and the gliding club that after the airfield closed the gliding club could continue to operate but the airfield was effectively an unlicensed facility. This meant that there were no Fire and Rescue Services available on the airfield and that, in the event of an accident, the Gliding Club would turn to the local emergency services for assistance, as detailed in their Club Accident and Incident Procedures Manual. Many gliding operations take place at unlicensed airfields, so this would be the normal situation at many gliding sites.

Analysis

The results of the investigation indicate that the student's camera, which he had placed on the floor in front of his control column, moved rearwards and became lodged in the gap between the aft edge of the cockpit floor and the front seat control column as the glider accelerated and bounced over the runway surface during the take-off run. This gap had been widened when the instructor had moved the control column to its fully aft position, as usual for this type of glider, at the beginning of the takeoff. Thus, when the instructor attempted to move the control column forward, as the glider started to pitch up, he was prevented from doing so by the presence of the camera. The increase in the glider's nose-up pitch angle and movement of the controls to try and overcome the restriction may have resulted in the camera becoming even more firmly wedged.

After stalling and dropping its left wing, the glider then seemed to regain sufficient airspeed for the flying control surfaces to return the glider to a straight and level attitude at the same time as it struck the ground, before bouncing into the air again.

Briefing material, produced by the Gliding Club and the BGA, was provided for each of the students in the party to advise them of the need to avoid loose articles in the cockpit and what they should do if they wished to take a camera on the flight. The potential hazard presented by a camera is spelled out in the pamphlet entitled 'Soaring', issued by the BGA, which is specifically aimed at the first time student and those on a trial lesson. However, there was no requirement to read this information, comprehensive though it was, before the trial lesson.

The instructor stated that he was not aware that the student had a loose article – a camera - and did not brief him accordingly, nor was he aware of any protocols or procedures for doing so. It seems that a tendency to overlook the BGA guidance relating to loose articles may not have been unique to this instructor. However, on previous occasions when students had asked him what they should do with a camera he had ensured that it was appropriately secured. In this case the student had placed the camera on the floor, in front of the control column, between his feet and it may well have been out of the instructor's field of vision. The instructor did not recall seeing the camera being passed to the student.

The requirement for a check for loose articles is covered in the Instructor's Manual, which is the standard for all instructional flights, and trial lessons are deemed to be instructional flights in which the student is part of the crew. By its nature, the flight may be the student's first in a small aircraft and little knowledge can be assumed. Also, as a possible one-off experience the student is more likely to take a camera aloft then than if it was one of a series of instructional flights with a view to a longer term future in gliding. The BGA seem to recognise the implications of this difference.

The small amount of alcohol that the student had consumed was not considered to be a factor in this accident. However, the Gliding Club has introduced a new form which students sign to confirm that they have not consumed alcohol recently. The form explains what levels of abstinence, in terms of quantities of alcohol and timescales, are considered appropriate.

Information on the need to avoid loose articles when flying in a glider is included in publications published by the BGA and available to instructors and trial lesson students. Despite that, all the indications are that a loose article caused this accident.

Safety Recommendation 2005-077

It is recommended that the British Gliding Association reinforce the message that there must be no loose articles in aircraft when they are being flown.

Figure 1

Figure 2

Figure 3

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