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ACCIDENT

Aircraft Type and Registration:	Cessna Citation 500, VP-BGE	
No & Type of Engines:	2 x Pratt & Whitney (Canada) JT15D-1A turbofans	
Year of Manufacture:	1975	
Date & Time (UTC):	30 March 2008 at 1338 hrs	
Location:	Romsey Close, Farnborough, Kent	
Persons on Board:	Crew - 2	Passengers - 3
Injuries:	Crew - 2 (Fatal)	Passengers - 3 (Fatal)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	57 years	
Commander's Flying Experience:	8,280 hours (of which 32 were on type) Last 90 days - 44 hours Last 28 days - 20 hours	
Information Source:	AAIB Field Investigation All times in this report are UTC	

The investigation

The Air Accidents Investigation Branch was informed of the accident at 1350 hrs on 30 March 2008 and the investigation commenced early the same evening. The Chief Inspector of Air Accidents has ordered an Inspector's Investigation to be conducted into the circumstances of this accident under the provisions of the *Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996*. This is a preliminary report detailing the facts of the accident; no analysis has been attempted.

In accordance with established international arrangements, the National Transportation Safety Board

(NTSB) of the USA representing the State of Design and Manufacture of the aircraft, has appointed an Accredited Representative to participate fully in the investigation. The NTSB Accredited Representative is supported by a team which includes additional investigators from the NTSB, Federal Aviation Administration and Cessna; Pratt and Whitney (Canada) are also participating fully in the investigation supporting an Accredited Representative from the Transportation Safety Board of Canada.

This bulletin contains facts which have been determined up to the time of issue. This information is published to inform the aviation industry and the public of the general circumstances of accidents and must necessarily be regarded as tentative and subject to alteration or correction if additional evidence becomes available.

History of the flight

The aircraft was engaged on a flight from Biggin Hill, Kent to Pau, France with two crew and three passengers on board. Some doubt currently exists as to the status of each pilot, so for the purpose of this report, the pilot sitting in the left seat is referred to as the commander. The commander called for start at 1317 hrs and, at 1320 hrs, was cleared to taxi to holding point A1 for a departure from Runway 21. No one has been identified who witnessed the aircraft's start or subsequent taxi to the holding point.

At 1324 hrs, ATC instructed the crew to hold at A1 and cleared them for a LYDD 2 departure adding:

‘WHEN AIRBORNE IT’S A RIGHT TURN
DETLING ROUTE THROUGH THE BIGGIN
OVERHEAD MAINTAIN ALTITUDE TWO
THOUSAND FOUR HUNDRED SQUAWK SIX
THREE FIVE TWO’.

The clearance was correctly read back and the aircraft was cleared for takeoff from Runway 21 at 1332 hrs and was observed by the tower controller who stated that ‘everything appeared normal’. At 1334 hrs, one minute after becoming airborne, the co-pilot transmitted:

‘AND VICTOR PAPA BRAVO GOLF ECHO ER
WE’RE MAKING AN IMMEDIATE TURN TO
RETURN TO THE AIRPORT IMMEDIATE TURN
TO THE AIRPORT.’

The tower controller replied:

‘VICTOR GOLF ECHO JOIN DOWNWIND
RIGHT-HAND RUNWAY TWO ONE, THE
BIGGIN QNH ONE THOUSAND, THRESHOLD
ELEVATION’S FIVE ONE SEVEN FEET, WHAT’S
THE NATURE OF YOUR PROBLEM?’

The co-pilot transmitted:

‘ERE WE DON’T KNOW SIR WE’RE GETTING ER
ENGINE VIBRATION WE’LL COME STRAIGHT
BACK.’

The aircraft then manoeuvred to overhead the airfield at approximately 1,200 ft aal heading towards the end of the downwind leg for a left-hand circuit to Runway 21. As the aircraft left the overhead it commenced a continuous descent and, at 1336 hrs, the co-pilot transmitted:

‘AND ER VICTOR GOLF ECHO WE HAVE
MAJOR PROBLEM A MAJOR POWER PROBLEM
IT LOOKS AS THOUGH WE’RE ER GOING IN
WE’RE GOING IN!’

No further radio transmissions from the aircraft were received.

Numerous witnesses reported seeing the aircraft flying low over a built up area, passing over playing fields and houses about 2 nm north-north-east of Biggin Hill Airport. The aircraft was seen to be maintaining a normal flying attitude and some witnesses reported that the landing gear was up and others that it was down. Some described seeing it adopt a nose-high attitude and to bank away from houses just before it crashed. Some witnesses stated that there was no engine noise but others stated that they only became aware of the aircraft, as it flew low overhead, because of ‘the loud noise it was making, as if the engines were at high power’.

The aircraft flew extremely low over the roofs of several houses before its left wing impacted the roof of a house at the end of a residential close adjacent to a small wood. After the initial impact the aircraft struck the ground and caught fire destroying the attached

garage of a neighbouring dwelling. All persons on board received fatal injuries.

A search of the Southern Apron, Taxiway 'A', Runway 21 and the area immediately beyond the end of Runway 21 at Biggin Hill was conducted after the accident. No debris from the aircraft or foreign objects were found which could have contributed to the accident.

Technical investigation

The wreckage was substantially consumed in the subsequent fire and the aircraft was not, nor required to be, equipped with any Flight Recorders (Flight Data or Cockpit Voice Recorders).

Examination of the wreckage, however, did not reveal any evidence of pre-impact restrictions in the flight control circuits and examination of the engines, after disassembly, revealed no evidence of either engine having suffered a bird strike or foreign object damage. Furthermore, no pre-impact damage or failures were found in any of the rotating assemblies or main bearings.

The investigation is continuing and a final report will be published by the AAIB in due course.

ACCIDENT

Aircraft Type and Registration:	Boeing 777-236 ER, G-YMMM
No & Type of Engines:	2 Rolls-Royce RB211 Trent 895-17 turbofan engines
Year of Manufacture:	2001
Date & Time (UTC):	17 January 2008 at 1242 hrs
Location:	Runway 27L, London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 16 Passengers - 136
Injuries:	Crew - 4 (Minor) Passengers - 1 (Serious) 8 (Minor)
Nature of Damage:	Aircraft damaged beyond economical repair
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	12,700 hours (of which 8,500 hours were on type) Last 90 days - 85 hours Last 28 days - 52 hours
Information Source:	Inspector's Investigation
	All times in the report are in UTC

The investigation

In view of the sustained interest within the aviation industry, and amongst the travelling public, it is considered appropriate to publish an update on the continuing investigation into the accident involving a Boeing 777, G-YMMM, which occurred on 17 January 2008. This report is in addition to the Initial Report, published on 18 January 2008, a subsequent update published on 23 January 2008 and a Special Bulletin published on 18 February 2008.

History of the flight

The flight from Beijing to London (Heathrow) was uneventful and the engine operation was normal until the final approach. The aircraft was configured for a landing on Runway 27L and both the autopilot and the autothrottle were engaged. The autothrottles commanded an increase in thrust from both engines and the engines initially responded. However, at a height of about 720 ft the thrust of the right engine reduced to approximately 1.03 EPR (engine pressure ratio); some seven seconds later the thrust on the left engine reduced

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to approximately 1.02 EPR. The reduction in thrust on both engines was the result of a reduced fuel flow and all engine parameters after the thrust reduction were consistent with this. Parameters recorded on the Quick Access Recorder, Flight Data Recorder and non-volatile memory from the Electronic Engine Controller (EEC) indicate that the engine control system detected the reduced fuel flow and commanded the fuel metering valve to open fully. The fuel metering valve responded to this command and opened fully but with no appreciable change in the fuel flow to either engine.

Engineering examination

Extensive examination of the aircraft and detailed analysis of the recorded data have revealed no evidence of an aircraft or engine control system malfunction. There is no evidence of a wake vortex encounter, a bird strike or core engine icing. There is no evidence of any anomalous behaviour of any of the aircraft or engine systems that suggests electromagnetic interference. The fuel has been tested extensively; it is of good quality, in many respects exceeding the appropriate specification, and shows no evidence of contamination or excessive water. Detailed examination of the fuel system and pipe work has found no unusual deterioration or physical blockages. The spar valves and the aircraft fuel boost pumps were serviceable and operated correctly during the flight. The high pressure (HP) fuel pumps from both engines have unusual and fresh cavitation damage to the outlet ports consistent with operation at low inlet pressure. The evidence to date indicates that both engines had low fuel pressure at the inlet to the HP pump. Restrictions in the fuel system between the aircraft fuel tanks and each of the engine HP pumps, resulting in reduced fuel flows, is suspected.

Environmental conditions

During the flight there was a region of particularly cold air, with ambient temperatures as low as -76°C, in the area between the Urals and Eastern Scandinavia. The Met Office described the temperature conditions during the flight as 'unusually low compared to the average, but not exceptional'. The lowest total air temperature recorded during the flight was -45°C, and the minimum recorded fuel temperature was -34°C. The specified fuel freezing temperature for Jet A-1 is not above -47°C; analysis of fuel samples taken after the accident showed the fuel onboard the aircraft complied with the Jet A-1 specification and had a measured fuel freezing temperature of -57°C. The aircraft was operated within its certified flight envelope throughout the flight.

Continuing investigation

The focus of the investigation continues to be the fuel system of both the aircraft and the engines, in order to understand why neither engine responded to the demanded increase in power when all of the engine control functions operated normally. Under the direction of the AAIB, extensive full scale engine testing has been conducted at Rolls-Royce, Derby, and fuel system testing is ongoing at Boeing, Seattle.

The engine test cell at Rolls-Royce was altered to enable the introduction of calibrated restrictions at various locations in the engine and aircraft fuel feed systems to replicate the engine fuel and control system response. The primary challenge at Boeing is to create the environmental conditions experienced on the flight over Siberia, at altitudes up to 40,000 ft, in which to test a representation of the aircraft fuel system. These tests are collectively aimed at understanding and, if possible, replicating the fuel system performance experienced on the day and the potential for formation of restrictions.

In addition, work has commenced on developing a more complete understanding of the dynamics of the fuel as it flows from the fuel tank to the engine.

A data analysis team, working with statisticians from QINETIQ, are reviewing and analysing the recorded data from a large sample of flights on similar aircraft. No individual parameter from the flight of G-YMMM has been identified to be outside previous operating experience. The analysis is concentrating on identifying abnormal combinations of parameters.

The Federal Aviation Administration, the European Aviation Safety Agency, the Civil Aviation Authority and British Airways are being kept fully briefed on the progress of the investigation.

Operational changes

No operational changes are currently recommended by either the AAIB, Boeing or Rolls-Royce.

INCIDENT

Aircraft Type and Registration:	BAe 146-300, G-JEBC	
No & Type of Engines:	4 Lycoming ALF502R-5 turbofan engines	
Year of Manufacture:	1990	
Date & Time (UTC):	6 September 2007 at 1248 hrs	
Location:	En route from Belfast	
Type of Flight:	Commercial Air Transport (Non-Revenue)	
Persons on Board:	Crew - 4	Passengers - 0
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Air Transport Pilot's Licence	
Commander's Age:	52 years	
Commander's Flying Experience:	10,842 hours (of which 5,083 were on type) Last 90 days - 162 hours Last 28 days - 46 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a positioning flight from Belfast, the flight crew became aware of an unusual smell. There was no smoke or haze. The commander elected to put the crew on oxygen. He declared an emergency and diverted back to Belfast. The commander later described how he felt as similar to being inebriated and that he found it difficult to concentrate. The co-pilot initially felt she had a reduced capacity to fly the aircraft, but this feeling quickly passed. One cabin crew member felt light-headed, sick and distressed. The other cabin crew member felt tired and slightly sick. The origin of the fumes was traced to the forward toilet and was probably due to a chemical in the toilet. The fumes may have been as a result of formaldehyde, released as a degradation product of a toilet chemical added during maintenance at Exeter. It

was not possible positively to determine to what extent the symptoms of the crew were a result of the fumes, or of the stress associated with the in-flight fumes emergency, or a combination of both.

History of flight

The aircraft had recently completed a major maintenance 'C' check at Exeter on 4 September 2007. It was flown to Belfast City Airport, the flight being described as normal other than, during the flight, the yaw damper failed. When the crew selected the engine air bleeds ON in the climb, there was a smell of "sweaty socks". This smell was described as "normal when the aircraft has been standing for a while". The smell quickly dissipated and gave the crew no cause for alarm.

On 6 September the aircraft was required at Southampton to replace an unserviceable aircraft, for a scheduled flight to Nice, so it was prepared for a non-revenue positioning flight. The pre-flight procedures were all described as normal and the crew, consisting of the two flight crew and two cabin crew members, went out to the aircraft. The cabin crew performed their security checks, which included a check of the toilets, and they reported that everything appeared, and smelt normal. The aircraft had carried no cargo, or passengers since its 'C' check, and hence the toilets had not been serviced, and the cabin had not yet been prepared for a revenue flight.

The co-pilot was the pilot flying (PF) for the sector and so she completed the internal checks whilst the commander performed the external walkround. The co-pilot noted that, shortly after she selected the APU bleed air ON, she was aware of an unusual smell. She described this as "not being one of the normal smells that you get used to flying the 146". The commander completed his walkround, and he noticed nothing unusual. When the commander returned to the flight deck the co-pilot mentioned to him that she had smelt something unusual. He could not smell anything, and the start up and taxi then continued without any significant events.

When the aircraft lined up for departure, the commander attempted to engage the Thrust Management System (TMS) but it would not engage, indicating that there was a fault with the system. After a short period of troubleshooting the commander elected to continue the flight without the TMS. He planned to have the fault rectified at Southampton.

The takeoff, at 1239 hrs, was a normal, reduced thrust, takeoff with the APU air bleed on, and, as expected, the yaw damper failed. The after takeoff checks were performed passing the minimum sector altitude (MSA)

of 3,800 ft, and the engine air bleeds were selected ON whilst the APU air bleed was selected OFF. Shortly after this the commander became aware of an unusual smell. He also described the smell as not one that he normally associated with his experience of operating the 146. The commander called one of the cabin crew forward and asked her if she could smell anything, but she could not. Passing FL100 the commander turned up the heating and a little while later he again smelt something unusual.

The commander instructed the co-pilot to go onto oxygen. He then called a cabin crew member forward, and instructed her to put both cabin crew members onto oxygen. The cabin crew member could now smell "something".

The commander went onto oxygen, and declared a PAN to Scottish Radar. He requested a descent, initially to FL100, then further to 8,000 ft. He then went through the smoke and fumes checklist although he later described cockpit communications as difficult using masks.

The aircraft diverted back to Belfast City Airport uneventfully and was met by fire crews who assisted the crews in exiting the aircraft. The crew were all taken to hospital, and tested for carbon monoxide poisoning. The tests were all negative and the crew were released.

Medical

The commander described feeling a sensation in the aircraft like being drunk. He felt it was difficult to concentrate, and he felt "fuzzy". He subsequently felt a little faint at one point, shortly after having got out of his seat to open the cabin door to allow the fire service to board the aircraft. The next day he was suffering from a headache, and he felt "woolly-headed". The commander had been involved in a serious fumes incident eight years earlier.

The co-pilot felt she was operating at reduced capacity and she had difficulty in concentrating for the first few moments after putting on her mask, thereafter she felt more normal.

One of the cabin crew smelt nothing unusual. She felt tired, and a bit sick when on oxygen. She had no ill effects the next day.

The second cabin crew member did not smell anything unusual up to the point where the commander asked her for the second time if she smelt anything. At that point she smelt what she described as “sweaty socks”. After going onto oxygen, she felt light-headed and sick. She was also very concerned about the situation and that the flight crew were on oxygen (the cockpit door was open). After landing she needed assistance from the fire crews to get into the ambulance. She was very anxious about the incident and her doctor advised her to spend “a couple of weeks away from the environment” (off work). She had been involved in a fumes incident three months earlier, about which she was still upset.

Examination of the aircraft

Upon entering the aircraft after the incident there was no distinctive smell evident to the investigators. A full examination of the engines and the APU was carried out, including an internal check, using a borescope. These did not show any signs of oil leakage or seal degradation. Previously there had been issues concerning ALF-502 engines and cabin air quality; these engines, in G-JEBC, had been modified with improved seals.

Both air-conditioning packs were also examined; the faces of the heat exchangers were clean and there were no signs of contamination of any of the ducting. The ducting further downstream from the air-conditioning packs was also examined and found to be clean.

A full engine and APU run at various temperatures was carried out with no signs of any unusual odour, or indeed any sign of fumes or smoke in the aircraft.

Due to the report in the technical log of the smell being of a ‘chemical nature’, the toilets were checked as a potential source. On opening the forward toilet door, a very strong odour was immediately apparent; a similar odour was evident in the rear toilet. The surfaces in the toilet were clean and did not show any signs of a spilt chemical. The only area within the toilet compartment which was suspected was the toilet water, due to the use of chemicals within it; samples were taken from both toilets for later testing.

The flight crew of the incident flight were invited back to the aircraft. When the crew were exposed to the air in the forward toilet compartment, the commander reacted to the smell and identified it as being similar to the smell he had experienced in flight. The co-pilot also confirmed that the smell seemed similar to that she had smelt during the flight.

Flight Recorders

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR), capable of recording a minimum duration of 25 hours of data and 120 minutes of audio respectively.

Recorded information

The FDR and CVR were removed from the aircraft and successfully replayed at the AAIB. The incident flight, from before engine start to aircraft shutdown, was recorded by the CVR.

Toilet description

The toilets fitted to G-JEBC were of a recirculating chemical type, each with a capacity of 45 litres. The

toilet is initially charged with 13 litres of a chemical deodorising fluid, usually a diluted mixture of water and chemical. A four litre fluid reservoir is connected at the bottom of the main tank, and is used for the toilet flush. A filter screen separates the main tank from the reservoir. When the toilet is flushed, air enters a fluid reservoir which forces fluid through the flush pipe and around the bowl of the toilet, before the fluid drains back into the main part of the tank.

For toilet servicing, on the ground, a pipe is connected to a ball valve at the bottom of the tank. The service vehicle connects to the outlet of the pipe, via an external connection on the side of the fuselage and the ball valve is opened. The contents of the main tank then empty into the service vehicle. To empty the reservoir, the flush has to be operated whilst the ball valve is still open and the vehicle is connected. Once the toilet is emptied the ball valve is closed.

Replenishment of the 13 litre charge is carried out in two ways. If a service vehicle is available then a fresh water hose is connected to a fill connection at the toilet service panel, which then feeds the fresh water to the toilet tank. A sachet of the deodorising chemical is then put into the toilet tank via the toilet bowl.

If a servicing vehicle is not available, water is poured into the toilet tank via the toilet bowl with the deodorising chemical added, either as a sachet or a dilution of the chemical in the added water.

Toilet compartment ventilation

The toilet compartments on the BAe 146 are ventilated by air supplied from the air-conditioning packs. The conditioned air enters the compartment via an air outlet. The air is only vented from the compartment during flight, when the differential pressure between the cabin

and the outside air is above about 1 psi. The air is vented overboard, through a controlled pressurisation leak, with air taken from around the top of the toilet pan.

A test of the toilet ventilation on G-JEBC found it to be working correctly once the cabin began to pressurise.

Aircraft maintenance

As noted above, the aircraft had undergone a major maintenance 'C' check input at Exeter, which was completed on 4 September 2007. The incident flight was the second flight of the aircraft following this maintenance input, having initially positioned from Exeter to Belfast. Prior to these two flights, the toilets had not been serviced (using normal 'line' equipment) since the 'C' check.

During the 'C' check the toilets were removed from the aircraft as complete modules. The modules were then sent for deep cleaning in workshops and involved the use of a cleaning agent 'Honeybee 76'. When the toilet modules were refitted, the chemical toilet was recharged. As there was no service vehicle available during the maintenance input, the toilets were charged (manually) by adding water and a dilute mixture of the deodorising chemical. The aircraft was still in the hangar at Exeter at this stage and the 'C' check was completed on 2 September 2007. The deodorising chemical used was 'Aqua Kem Blue' which was supplied in liquid form (rather than sachets), and was used at a dilution of 60 ml to 1 litre of fresh water.

Following the incident, and under AAIB supervision, a service vehicle serviced the toilet. The amount of fluid removed from the forward toilet was 16 litres.

After the fresh water had been added, the usual toilet chemical applied to aircraft toilets at Belfast, known

as 'Honeybee Pak 44', was used. This was supplied as a sachet of predetermined quantity, and added to the 13 litres of fresh water charge that had been pumped into the toilet.

Sample testing

The samples were taken to a forensic laboratory for testing. Included with these samples was a sample of neat 'Aqua Kem Blue' and a diluted sample provided by the maintenance organisation at Exeter.

The results of the tests revealed that the three diluted samples, that is those from the toilets on the aircraft and the diluted 'Aqua Kem Blue', were very similar. The only difference was some additional olfactory 'notes' in the pine-like odours given off from the toilet samples. These additional 'notes', however, were not similar to those given off from formaldehyde and were not identified. All the liquids, including the neat 'Aqua Kem Blue', were positive for oxidising agents. Methanol was not detected in any of the samples, suggesting that formulated formaldehyde was not present in the samples in any significant quantity. It was not possible to identify if any other chemical substance was present in the toilet samples, over and above the 'Aqua Kem Blue' which had already been added at Exeter.

The AAIB Inspector who experienced the odour in the toilets at Belfast compared it to the odour from vapours given off from a sample of formaldehyde. Although not conclusive, the smell was very similar.

One of the active ingredients of 'Aqua Kem Blue' is '2-Bromo-2-nitro-2,3 propenediol', commonly known as 'Bronopol'. This chemical is known as a formaldehyde releaser and can produce low concentrations of formaldehyde when it degrades in alkaline aqueous solutions or at elevated temperatures. 'Bronopol' is

commonly used as a preservative in cosmetics, shampoos, medicinal products and toilet sterilisers.

Formaldehyde is a reducing agent used to sterilise biological matter and kill germs. The chemical is used in domestic cleaners, such as washing-up liquid. It is also commonly used as embalming fluid as it fixes the body tissues. The chemical is usually formulated in water with 37% by weight of formaldehyde and 10-15% of methanol. Formaldehyde produces a very distinct strong and acrid odour and is noticeable at low concentrations. As atmospheric pressure drops, such as in the aircraft cabin during climb, the chemical becomes more volatile so fumes would become more noticeable. In low concentrations, formaldehyde does not pose a toxic risk, but it can cause a feeling of light-headedness and irritation to nose, throat, mouth and eyes.

Analysis

The source of the fumes that were detected by the aircraft's crew was most likely from a chemical within the forward toilet. The chemical could not be positively identified in the sample taken from the toilet; however the smell was similar to that of formaldehyde. As formaldehyde and methanol were not detected in the samples taken from the toilet it is unlikely that a product containing formulated formaldehyde had been used. It is possible, however, that formaldehyde was produced as a result of degradation of the chemical 'Bronopol' contained in the 'Aqua Kem Blue' toilet chemical that had been added during maintenance at Exeter. However, the introduction of an additional unknown substance to the toilet cannot be discounted. Similarly, the addition of another substance, such as one containing an alkaline, could have precipitated the release of formaldehyde from the 'Bronopol' in 'Aqua Kem Blue'.

The gas given off from the chemical probably built up

in the forward toilet compartment, whilst the aircraft remained closed up and on the ground at Belfast. It is also possible that during this period the 'Bronopol' in the 'Aqua Kem Blue' degraded, liberating formaldehyde. As formaldehyde is volatile it would have become gaseous and entered the atmosphere of the toilet. The air in the toilet compartment would have remained undisturbed until the toilet door was opened or the air-conditioning packs were switched on. The action of putting the air-conditioning packs to ON would have stirred the air, dispersing the gas through the ventilation paths, including some air entering the cockpit. As the aircraft climbed, the pressure drop in the cabin would have made the chemical more volatile, thereby releasing more fumes.

The CAA Aeromedical Section confirmed that the symptoms suffered by the crew were consistent with the effects of a fumes event, such as would be experienced by a crew experiencing a low concentration of formaldehyde.

The CAA Aeromedical Section were asked if there could be any alternative explanation for the symptoms suffered by the crew. They considered that a possible induction of motion sickness could be caused by the

inoperative yaw damper and lack of a thrust balancing system (TMS), and that this could, possibly, predispose a crew to anxiety. The cabin crew's symptoms may have been exacerbated by hyperventilation.

The CAA report added that, in this case, there was no indication that any of the crew members would have had a particular predisposition to anxiety; feelings of anxiety would have been normal during an event such as this.

In summary, it is likely that this crew suffered from the effects of a low concentration of formaldehyde and it is possible that a normal anxious reaction to the unusual situation aggravated their symptoms.

Safety action

As a result of this investigation, the maintenance organisation has put in place a procedure which requires the chemical toilets on all aircraft to be flushed and serviced following maintenance and prior to any flight. They are also discontinuing the use of 'Aqua Kem Blue'. The operator uses 'Honeybee 76' when deep cleaning the toilet and 'Honeybee 20' when servicing the toilet whilst the aircraft is in maintenance. Neither of these products is believed to contain formaldehyde or 'Bronopol'.

INCIDENT

Aircraft Type and Registration:	Boeing 737-500, SP-LKA	
No & Type of Engines:	2 CFM 56-3C1 turbofan engines	
Year of Manufacture:	1992	
Date & Time (UTC):	4 June 2007 at 1007 hrs	
Location:	On departure from London Heathrow Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 6	Passengers - 89
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	55 years	
Commander's Flying Experience:	15,000 hours (of which 9,000 were on type) Last 90 days - 270 hours Last 28 days - 65 hours	
Information Source:	AAIB Field Investigation	

Synopsis

Just after takeoff from Runway 09R at London Heathrow Airport (LHR), the pilots noticed that most of the information on both of the Electronic Attitude Director Indicators (EADI) and Electronic Horizontal Situation Indicators (EHSI) had disappeared. The aircraft entered Instrument Meteorological Conditions (IMC) at about 1,500 ft aal, and the co-pilot had no option but to fly using the standby attitude indicator and standby compass. He experienced difficulty in following radar headings. The aircraft returned to land at LHR after a flight of 27 minutes.

The investigation determined that an incorrect stand position had been entered into the Flight Management System (FMS) during the pre-flight procedure.

History of the flight

The crew flew from Warsaw to LHR and, after landing, taxied the aircraft to Stand 114 where the engines were shut down at 0838 hrs. During the turnround, the pilots carried out a 'fast realignment' procedure for the two Inertial Reference Systems (IRSs), which required a ground position to be entered. This was done by the co-pilot on the Flight Management Computer (FMC) Control Display Unit (CDU) using the commercial chart Stand 114 position as the reference. However, although the value of the co-ordinates entered was correct, the longitude was entered as East instead of West. The longitude co-ordinate thus entered was 000° 26' 53.72" E, a point 0.886°/33.5 nm to the east of the actual aircraft position.

The aircraft, using callsign Lot 282, pushed back for the return flight to Warsaw and the engines were started, at 0943 hrs. Lot 282 was given taxi instructions and, at 1000 hrs, arrived at the holding point for Runway 09R and stopped on a heading of 224°M. At 1005 hrs, ATC instructed Lot 282 to give way to another aircraft and to taxi to holding point November Bravo 11.

The aircraft was given clearance to line up and was taxied onto the runway. The departure clearance was for a BPK5J Standard Instrument Departure (SID). The co-pilot was the handling pilot. Immediately after takeoff, at 1009 hrs, the pilots noticed that there was almost no information on their EHSIs and EADIs; they described the displays as 'blank', Figure 1.

Approximately 40 seconds after takeoff, the aircraft entered cloud at around 1,500 ft aal and the co-pilot had no option but to fly using the standby attitude indicator and standby compass for attitude and heading reference; the airspeed and altitude indications were unaffected. The autopilots were not available but autothrottle remained available and in use.

The flight deck instrument layout, including the location of the standby instruments, is shown in Figures 2a and 2b.

As the aircraft climbed through an altitude of 3,000 ft, the commander contacted London Terminal Control North East (TCNE) Departures on 118.825 MHz and advised that the aircraft had a 'navigation problem'. The controller asked if the aircraft was able to fly a heading of 055° and the commander replied that they could. The heading was assigned and the commander was instructed to maintain 6,000 ft. However, after about 30 seconds, the controller called Lot 282 and advised that the aircraft appeared to be tracking north. The reply from the commander was unintelligible and the controller said he would call the aircraft back. The controller now dealt with several other aircraft before calling Lot 282 again. He advised the commander that the aircraft was tracking northwest and instructed him to 'FLY A HEADING OF ZERO FIVE ZERO DEGREES THAT'LL BE A RIGHT TURN OF APPROXIMATELY 90 DEGREES'. Lot 282 acknowledged the instruction but, a minute later, the controller noticed the aircraft was tracking



Figure 1
Representation of 'blank' EADI

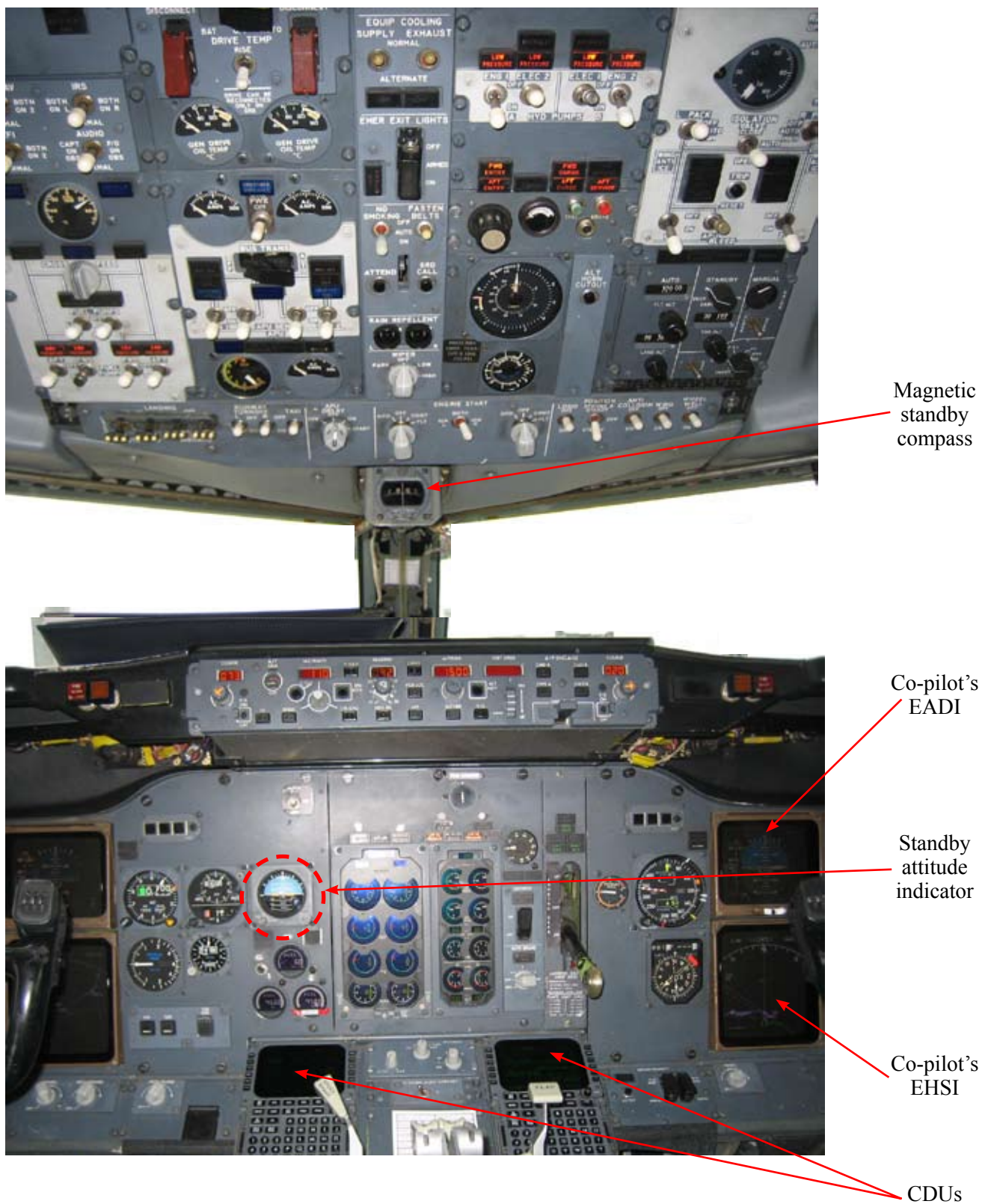


Figure 2a
Flight instruments layout, SP-LKA

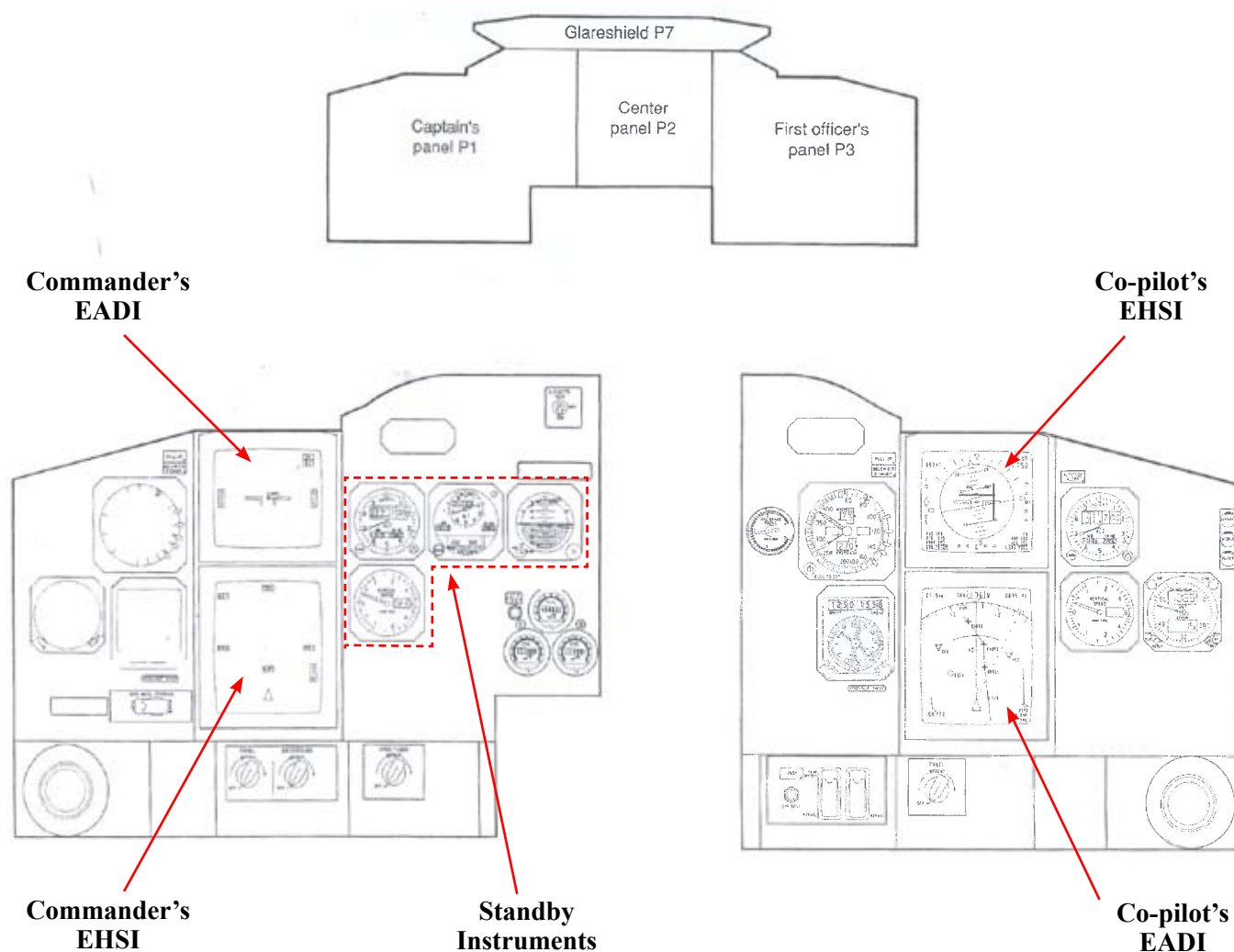


Figure 2b
Instrument panel layout

approximately west. At this stage there were a number of exchanges between Lot 282 and the controller in which it was apparent that the commander, who was making the radio calls, was not able to understand some of the instructions. A transcript of these exchanges is provided at Table 1.

The controller then asked for the crew's intentions and, after another exchange, the commander decided to return to LHR. Heading and altitude instructions were given. The altitude instructions were complied with and gradually the aircraft began to follow the headings.

Figure 3 is a view of the aircraft's radar track, overlaid with some relevant communications.

At 1022 hrs, the controller handed Lot 282 over to a dedicated controller on a discrete frequency. The new controller issued heading instructions and asked the crew if they were able to fly an ILS; the commander replied that they could. Further heading instructions, together with altitude and speed instructions were given. Altitude and speed were complied with but the aircraft continued to respond to heading instructions slowly and erratically. The controller attempted to

TO	FROM	RECORDED INTELLIGENCE
LOT 282	LONDON	AND LOT TWO EIGHT TWO I SEE YOU HAVE NAVIGATION PROBLEMS YOU APPEAR TO BE TRACKING TO THE WEST NOW
LONDON	LOT 282	TURNING R-ER RIGHT ON ER WEST LOT ER TURNING LEFT ON WEST LOT S -ER TWO EIGHT TWO
LOT 282	LONDON	LOT TWO EIGHT TWO CAN YOU CONTINUE A RIGHT TURN A RIGHT-HAND TURN OF ONE EIGHTY DEGREES
LONDON	LOT 282	TURN ER RIGHT NINETEEN DEGREES LOT ER TWO EIGHT TWO
LOT 282	LONDON	LOT TWO EIGHT TWO ONE HUNDRED AND EIGHTY DEGREES TO THE RIGHT
LONDON	LOT 282	TO THE RIGHT ONE EIGHTY DEGREES LOT ER TWO EIGHT TWO
LOT 282	LONDON	AND LOT TWO EIGHT TWO WHAT HEADING DO YOU THINK YOU'RE FLYING AT THE MOMENT
LONDON	LOT 282	NOW IS ER HEADING F -THREE THREE ZERO ¹
LOT 282	LONDON	-KAY LOT TWO EIGHT TWO RIGHT TURN NOW HEADING ZERO NINER ZERO DEGREES
LONDON	LOT 282	TURN ER RIGHT ON HEADING ZERO NINE ZERO DEGREES
LOT 282	LONDON	AND LOT TWO EIGHT TWO I SEE YOU HAVE NAVIGATION PROBLEMS DO YOU HAVE ANY OTHER PROBLEMS FLYING YOUR AIRCRAFT
LONDON	LOT 282	ER ONLY THE NAVIGATION

¹ During this exchange the controller asked the commander what heading he thought the aircraft was on, and the reply was 'THREE THREE ZERO', whereas in fact at this time the aircraft was heading approximately 030°.

Table 1

R/T communications: Lot 282 and North East Terminal Control between 1014 hrs and 1016 hrs

vector the aircraft to the west on a heading of 260°, to allow for an extended final approach track, but the aircraft maintained a heading of south and cut across the localiser course for Runway 09L at 90°. The commander then reported that he had "GLIDESLOPE ONLY, NO DIRECTION". The controller asked the crew to turn left on to a northerly heading, which was achieved, and then on to a heading of 060°, to intercept the localiser. However, the aircraft continued to fly north and again passed through the localiser at 90°; the commander again reported that he had "NO DIRECTION ONLY GLIDESLOPE".

The controller now advised Lot 282 that he would give radar vectors until visual contact with the runway was established. He issued 'start and stop' turn instructions and a further descent clearance. At 1032 hrs, the commander reported "RUNWAY IS THE GROUND IN SIGHT" and was cleared for a visual approach to Runway, 09L. However, the controller noticed that the aircraft continued to track to the south of the airfield and asked the commander to confirm that they were approaching Runway 09L. The commander replied it was not in sight and, a moment later, that he was now visual for Runway 09L. At 1034 hrs, the controller issued a landing clearance for Runway 09L. In



Figure 3

Radar track of LOT 282

the meantime, the ATC Ground Supervisor became concerned that the aircraft appeared as though it might be landing on Runway 09R, and asked for the traffic to be cleared from the runway. In the event, at 1035 hrs, the aircraft landed on Runway 09L and taxied to a parking stand.

Post flight

The passengers disembarked and a maintenance engineer, sub-contracted to the operator, attended the aircraft. The pilots advised him that the navigation systems all appeared to be operating normally and, with no fault now apparent, the aircraft was prepared for

dispatch. However, the locally based engineer was not qualified to clear the Technical Log entry made by the crew relating to the event, and the aircraft was delayed until an appropriately qualified engineer arrived from the operator.

Aircraft navigational equipment description

The aircraft is equipped with an Electronic Flight Instrument System (EFIS) and standby attitude, altitude and airspeed instruments. A direct reading magnetic standby compass is mounted above the glareshield on the windscreen's centre post.

Two independent IRSs are installed and one FMC. IRSs are controlled through a Mode Select Unit (MSU), with system information being displayed on an IRS Display Unit (ISDU) located on the aft overhead panel, Figure 4.

The IRSs provide attitude, heading, acceleration, vertical speed, ground speed, track, present position and wind data to the aircraft systems. They are the sole source of attitude and heading information, with the exception of the standby instruments.

An IRS must be initialised with present position information before it can function in the navigation (NAV) mode. This data is normally entered by a crew member through the FMC CDU, although it can also be entered through the ISDU and the aircraft must be stationary whilst the IRSs align. This may take up to 10 minutes. However, during 'transit' turnarounds, a 30 second fast realignment and zeroing of groundspeed error may be carried out. The procedure for this is to switch both IRSs from NAV to ALIGN, and then to enter the aircraft's current position into the 'box prompts' provided on the Position Initialisation page of the FMC; NAV is then re-selected on the MSU and

alignment is completed after approximately 30 seconds. If an entered position is not within 4 nm of the airport position, a FMS alerting message VERIFY POSITION is displayed on the CDU scratchpad. This message can be cleared by pressing the CLR key on the CDU. Whenever an FMA alerting message is generated, there is an associated amber message light on the pilot's instrument panel and a MSG light on each CDU.

If the aircraft moves before alignment is complete, an FMS alerting message IRS MOTION is displayed in the CDU scratchpad. This message can be cleared by pressing the CLR key on the CDU. The ALIGN light on the MSU will flash and will not stop flashing until the mode select switch is moved to OFF. After 30 seconds the mode select switch may be moved to ALIGN or NAV to reset the alignment.

There are two internal IRS comparison tests. Firstly, if the entered position does not agree with the last position, to within one degree of longitude and half a degree of latitude, then the test will fail. In this case the ALIGN lights will flash to alert the crew. If the same position is re-entered then the alignment process will begin. Secondly, the entered latitude and the system-computed latitude are compared. If this test fails, the position may be re-entered but if it again fails, the ALIGN light and the FAULT light on the MSU will illuminate as a steady light.

If the aircraft is in flight and the NAV mode is lost, attitude and heading information can be recovered by selecting attitude (ATT) on the MSU. After approximately 30 seconds of straight and level un-accelerated flight, the attitude reference will return. Heading can also be recovered by manually entering the current heading, although, if this is done, periodic cross-checks are required to correct for drift.

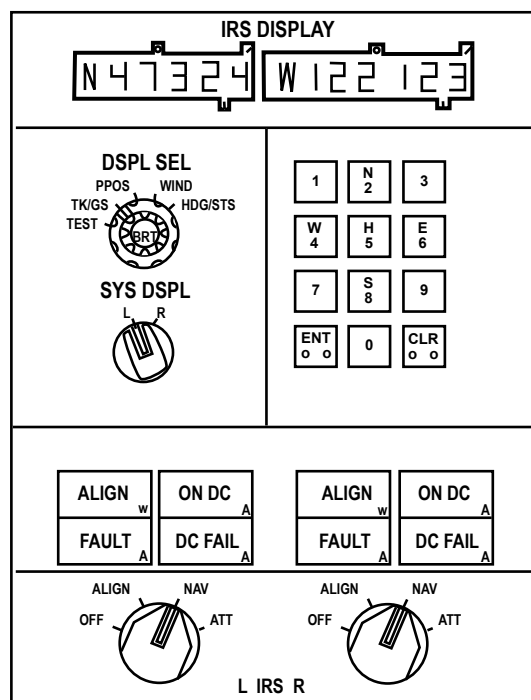
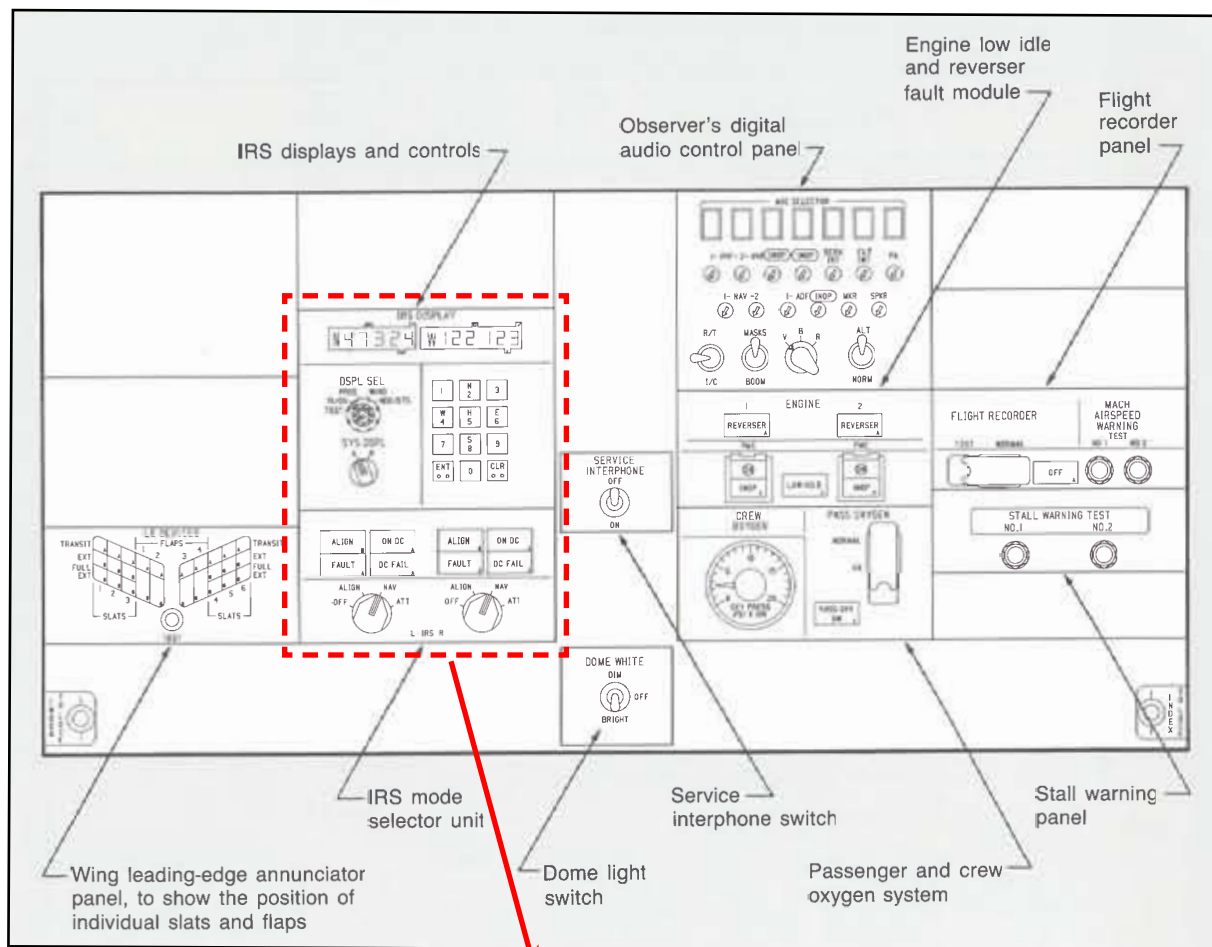


Figure 4

Location of the IRSDU on the aft overhead panel

This particular aircraft was fitted with a single FMC. IRS data is supplied to the FMC and used to calculate the 'FMS position'; no updating from radio sources is possible on the ground. When a TO/GA switch is pressed on takeoff, the FMS position updates automatically but, if the IRS position is not valid, this feature will not work.

The normal display on the pilot's EHSIs for departure would be the MAP mode. To be able to display ILS information on the EHSI, either full compass rose or expanded ILS mode needs to be selected. However, without valid IRS data, the EHSI displayed information is limited to the ILS course (LOC) and beam (G/S) scales. ILS information may also be displayed on the ADI. Although the aircraft was delivered with a Standby Horizon Indicator that could display ILS data, the indicator fitted to SP-LKA at the time of the incident was not capable of displaying such data.

Manufacturer's data

The aircraft manufacturer conducted an analysis of the data from the FDR and concluded that the failures reported were as a result of the aircraft having departed with the IRSs in ALIGN mode. They supplied the following information:

'If the IRU data is Non Computed Data (NCD) as we assumed due to IRU being in ALIGN mode, EFIS will remove IRU related data but it will not display IRU related Flags on EADI or EHSI. With IRU data being NCD, EFIS will remove horizontal line, pitch lines, roll pointer and sky/ground shading from the EADI. Flight path angle, Acceleration, Pitch Limit display and TCAS RA commands are also removed from EADI.'

If the IRU data is INVALID or FAILURE WARN (FW), then EFIS response will be similar to IRU data being NCD except that EFIS will display ATT Flag on EADI, HDG Flag on EHSI. We expect EHSI VOR Flag will also be displayed as HDG data to VHF Nav receivers will be FW.'

At 1006 hrs, the heading and attitude parameters supplied to the FDR became NCD. These parameters did not recover until after engine shutdown at the end of the flight. At 1007 hrs, with the aircraft at the hold prior to takeoff, the FDR recorded a new Flight Management System (FMS) aircraft position, whose co-ordinates related to a point in the vicinity of Stand 114 at LHR. There was no further change of the recorded FMS position after this time.

Aerodrome information

London Heathrow Airport has two parallel easterly runways, designated 09R and 09L. In normal two runway operation, one runway is used for landing aircraft and the other for departing aircraft.

All the international airports in the London area are located close¹ to the Prime Meridian (0°). The aerodrome reference point for LHR is 51° 28.39 N, 000° 27.41 W, and for Stand 114, 51° 28' 17.68" N, 000° 26' 53.72" W. There are a few other major international airports in Europe and one in Africa which also lie within half a degree, east or west, of the Prime Meridian.

Footnote

¹ ie, London Heathrow, London Luton, London Stansted, London Gatwick and London City Airports are all within 30' of longitude of the Prime Meridian.

Radio telephony communications

International standards

The requirements for language proficiency for operational personnel are detailed in ICAO Annex 1. In 2003, ICAO set a deadline of March 2008 for proficiency in Level 4 (operational) and above English for all pilots flying international routes, and ATC controllers serving international airports and routes. The proficiency scale ranges from Level 1 to Level 6, with guidelines published for pronunciation, fluency, structure, vocabulary, comprehension and interaction. ICAO will require that Level 4 pilots are reassessed on their abilities every three years, Level 5 pilots every six years, while at Level 6, no further assessment of a pilot's English language ability is deemed necessary. Thus, the Level 4 (operational) proficiency is considered as a minimum 'stepping stone' to higher levels.

Although the main benefit of high international standards of aviation English is that communications between aircraft and controllers are fully understood, particularly when non-standard words and phrases are used, it also has the benefit of increasing the situational awareness of flight crews in relation to other aircraft, both in the air and on the ground.

For those States not able to comply by March 2008, full implementation is due to be completed by March 2011. The Polish Civil Aviation Office (CAA) are due to specify a date by which they will comply with the ICAO requirement for English language proficiency.

General

Recordings of the communications between the aircraft and ATC were available for the investigation. The quality of the transmission signal was good but a number of the exchanges were misunderstood, probably as a result of language difficulties.

Air traffic control

After takeoff on the incident flight, the commander first contacted TCNE at 1012 hrs and advised that he had a 'navigation problem'. At this time the TCNE sector was busy and the controller was operating under a high workload. The controller issued heading instructions to Lot 282 and continued to control other aircraft in the sector. As Lot 282 tracked north instead of north-east it came into conflict with another aircraft and this resulted in a Short Term Conflict Alert (STCA) being activated. The conflict was resolved by revised instructions being given to the other aircraft.

When the controller realised that Lot 282 was not following its assigned heading, he contacted the aircraft again and issued further heading instructions. However, it became apparent that Lot 282 was having difficulty following these instructions. Later, the controller asked Lot 282 whether there were any other problems and received the reply 'only navigation problem'.

Once the decision had been made that the aircraft would return to LHR, a handover to a dedicated controller was implemented. However, the full extent of the difficulty that the aircraft was having in complying with ATC instructions was not passed on to the dedicated controller. He attempted to vector Lot 282 to the west, to intercept the localiser course for the ILS approach to Runway 09L, but the aircraft did not comply with the heading instructions and tracked south across the localiser for Runway 09L at a 90 degree angle. The controller then attempted to guide Lot 282 back towards the localiser, by giving a north-easterly heading, but this was also unsuccessful. He then started to give 'start and stop' turn instructions and descended the aircraft to 1,500 ft. This put Lot 282 into a position from which the crew could visually acquire the airfield.

Throughout the flight, the crew did not request, and ATC did not offer Lot 282 any weather information or positional information other than, on one occasion, ATC advised the distance to go to Runway 09L.

Recorded information

The aircraft was fitted with a 25-hour Universal Flight Data Recorder (UFDR) and a 30-minute Cockpit Voice Recorder (CVR). Both recorders were removed from the aircraft and successfully downloaded at the AAIB. The CVR circuit breaker was not pulled immediately after the aircraft parked and consequently the CVR recording contained only post-landing cockpit sounds and crew speech. This had overwritten recordings from the incident flight. Data, however, was recovered for the flight from the FDR.

Primary and Secondary Surveillance Radar (SSR) data had been recorded for the incident flight, and provided information about position, altitude and speed. The selected altitude and speed (IAS, TAS and Mach No) originated from the Mode S transponder on the aircraft and form part of the Alternative Downlink Aircraft Parameters (DAP) set of parameters. The other parameters of the Alternative DAP set, ie, roll angle, true track angle and magnetic heading, normally provided by the aircraft's IRUs, were unavailable. Figure 3 shows the aircraft's track (derived from the radar data) together with extracts from the radio transmissions between the aircraft, London Control and Heathrow Director.

A time history of salient parameters from the FDR for the incident flight is shown at Figure 5, starting three minutes before the shutdown at the end of the previous flight. Of note is the following:

- the difference in recorded longitude between the shutdown at 08:40:13 hrs and start-up for the incident flight at 09:44:41 hrs
- the loss of IRU sourced data at 10:06:38 hrs, while the aircraft was in the hold area for Runway 09R
- a step change in the FMS aircraft position at 10:07:47 hrs, which remained constant for the rest of the flight

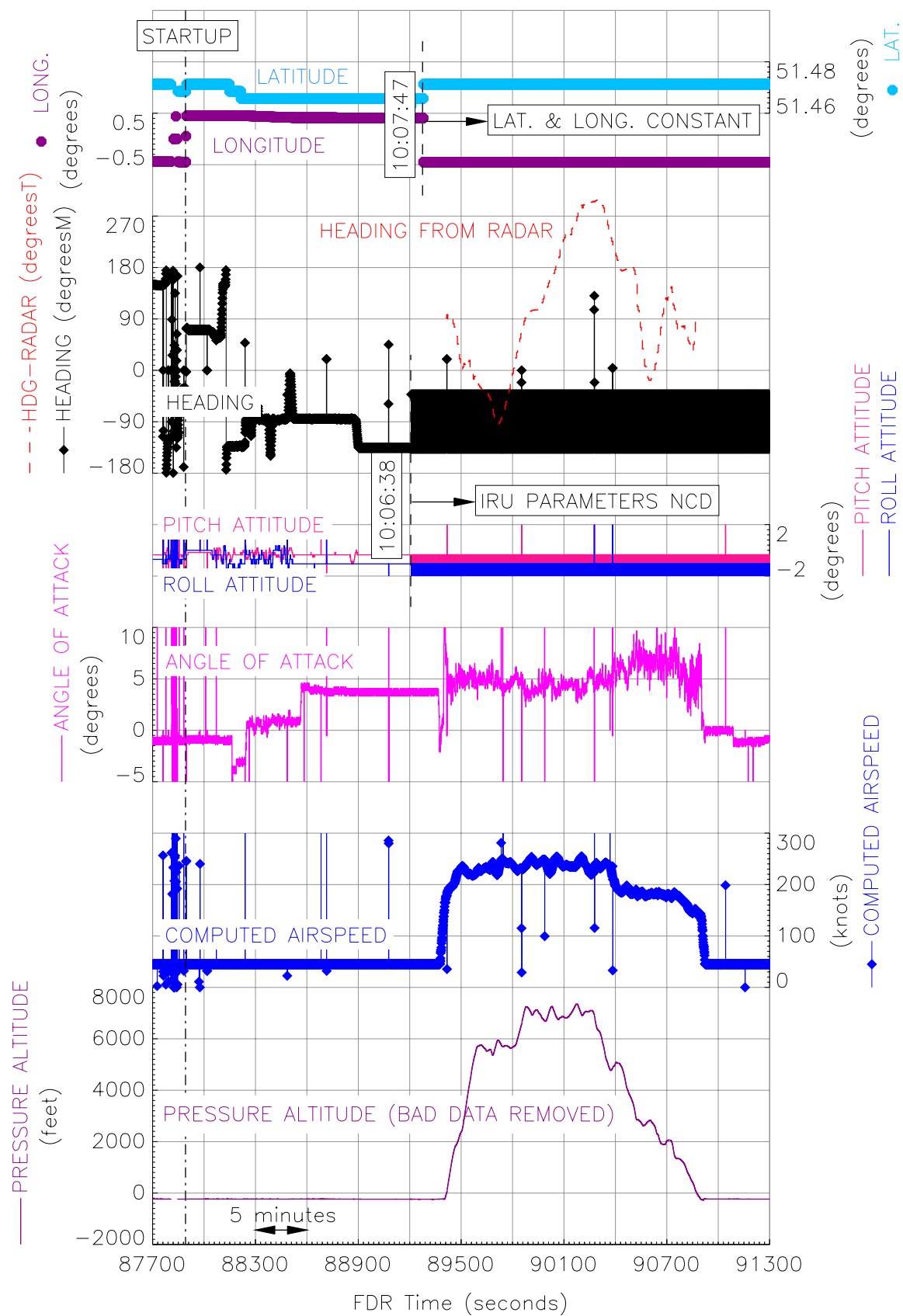
The recorded positions from the FMS at shutdown from the previous flight, together with the FMS position at start-up and at the hold for the incident flight, are given in Table 2 and illustrated in Figure 6. The difference between these points is the change in longitude from West (positioning the aircraft at Heathrow) to East (positioning the aircraft in the River Thames, east of Tilbury). Other positions of note in Table 2 are when the aircraft was at the hold and when this position was updated.

The FMS position is recorded every second on the FDR at a resolution of $2.7466\text{E-}03^\circ$, which equates to 305 m in latitude and 190 m in longitude, at a latitude of 51.47° . This manifests itself as a course and stepped track when

UTC TIME (HH:MM:SS)	FMS POSITION (WGS84)	
	Latitude	Longitude
08:40:13 [shutdown]	N 51°28'06.73"	W 0°26'51.71"
09:44:41 [startup]	N 51°28'16.62"	E 0°26'51.71"
10:07:47 [at hold]	N 51°27'56.85"	E 0°24'23.39"
10:07:48 [updated position at hold]	N 51°28'16.62"	W 0°27'01.59"

Table 2

SP-LKA FMS positions at Heathrow

**Figure 5**

A time history of salient parameters from the FDR



Figure 6

FMS positions at Heathrow

plotted, as the aircraft moves another 305 m or 190 m in latitude and longitude respectively, from the last recorded position. This is seen in Figure 7a, which shows the aircraft's ground track (in red) as it taxied to the stand after the landing from the previous flight. Figure 7a also shows a plot of the ground track derived from groundspeed and heading. The difference between the two illustrates the FMS position error at the end of the flight².

Figure 7b shows the FMS position track (in green) for the incident flight as the aircraft taxied from the stand to the holding point for runway 09R. Figure 7c shows these same positions plotted after being transposed in longitude

(ie correcting for the east/west difference at startup) together with a plot of the ground track derived from groundspeed and heading (blue). A single point (blue) in Figure 7c (adjacent to the terminal) represents the updated FMS position when the aircraft was at the holding area.

Figure 8 shows some FDR parameters in detail, starting with the aircraft at the hold. At 10:06:25 hrs **[A]**, the brakes were released and the aircraft moved slowly forward, turning to the left though 224°M before the heading and other IRU sourced parameters became NCD **[B]**. At 10:07:20 hrs, the commander **[C]** transmits a reply to ATC just before reapplying the brakes and stopping at hold NB11 **[D]**. While waiting at this point, the aircraft's position is updated in the FMS **[E]**. This position remains fixed as the brakes are released 30 seconds later **[F]** and the aircraft lines up and takes off from Runway 09R.

Footnote

² The flight recorder system records heading from the general purpose output bus of either the left or right EFIS, depending on the Captain's selection, which, for this flight, had been switched to the left EFIS. The left IRU is the source of heading, pitch and roll information to the left EFIS.



Figure 7a



Figure 7b

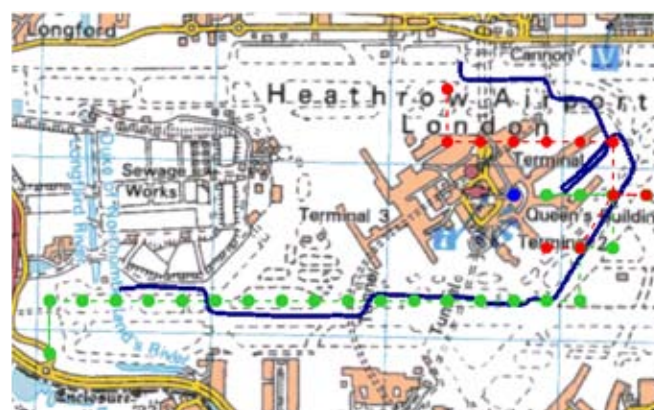


Figure 7c

- GROUND TRACK
- FMS POSITION - PREVIOUS FLIGHT
- FMS POSITION - INCIDENT FLIGHT STARTUP & TAXI
- FMS POSITION - TAXI (TRANPOSED IN LONGITUDE)
- FMS POSITION - UPDATED POSITION AT HOLD

Information from the pilots

The pilots were interviewed by the AAIB some three hours after the incident. The following account of events was compiled using information provided by the crew during AAIB interviews, operator's interviews, through the operator's internal reporting procedures and subsequent questions.

The commander had been flying this aircraft type for this operator for fifteen years. The co-pilot had been flying the type for six years. Everything had been normal on the inbound flight.

A fast realignment was carried out on the stand at Heathrow by the co-pilot before pushback, using the stand position obtained from a commercial chart. There were no abnormalities and the position did not need to be re-entered. There was no problem during the taxi and no attempt was made to re-align the IRSs before departure. At the holding point the attention of the pilots was on the other traffic in the vicinity of the aircraft and not necessarily on the flight instruments.

Everything on the aircraft appeared normal until just after rotation when the EADIs and the EHSIs 'blanked',

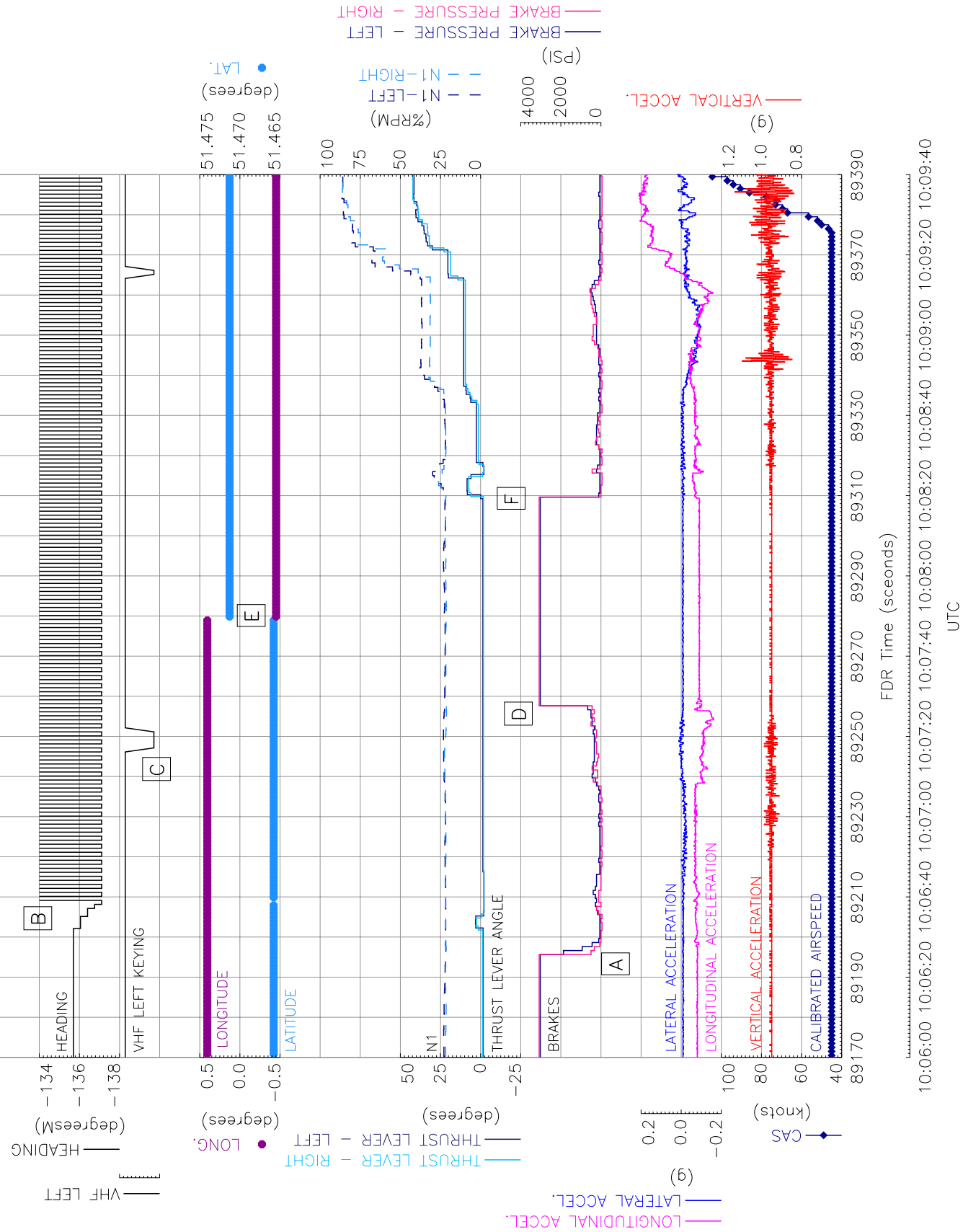


Figure 8
Selected FDR parameters

although the speed tape remained available. Both FMC CDUs also ‘blanked’. There were no associated warnings or cautions at this point, nor any throughout the rest of the flight.

The co-pilot continued to fly the aircraft by reference to the standby instruments. The commander decided not to take control so that he would have extra capacity to deal with the problem. He made contact with ATC and said that the aircraft had a ‘navigation problem’ but did not declare an emergency because he felt that the situation did not warrant it.

The autopilots were not available but the autothrottle was operative. The commander looked up at the overhead panel and noticed that there were no lights on the IRSDU and that the whole unit was dark and appeared to be unpowered. It was decided, when it became apparent that the flight could not continue, that the aircraft would return to LHR. The aircraft was in IMC from shortly after takeoff until a short time before landing. ATC gave the aircraft radar vectors until visual contact was established. The commander considered that ATC were helpful throughout the flight.

After landing, the aircraft taxied to a parking position and, just as it came to a stop, the instruments returned to normal. After shutdown the pilots were told by a cabin crew member that a passenger had been using a mobile telephone before takeoff and considered that it was possible the telephone had interfered with the navigation systems.

Engineering examination

The aircraft operator sent two experienced avionic engineers to LHR and, together with the AAIB, the aircraft manufacturer and the operator’s Maintenance Control staff, carried out very extensive testing of

the aircraft’s navigation systems. No faults were found. The following day, the aircraft was flown on a non-revenue flight to the operator’s maintenance base in Warsaw. A further two days of intensive system testing was carried out but no fault could be found or induced. As a precaution, the operator replaced both IRS units and sent them to the manufacturer’s repair facility in the UK. No faults were found in either unit. The aircraft was returned to revenue service and has been operating satisfactorily with no further navigation system faults being reported.

Analysis

General

There were two main sources of information regarding the events on this flight: the recorded data and the reports from the pilots. In some respects, the information from the two sources was not consistent. The aircraft manufacturer was not able to suggest any failure, or combination of failures, which would have caused the events to occur as the pilots described them, and no technical defects were discovered during the examination of the aircraft and its navigational equipment. In summary, no technical cause for the loss of the navigational data could be found. Thus, there remains a discrepancy between the pilots’ recollections and the recorded events.

The single error made by the co-pilot during the pre-flight preparation initiated the subsequent problems. This was the use of ‘E’ instead of ‘W’ when the longitude co-ordinates were entered into the FMS. The airports around London, because of their proximity to the Prime Meridian, can lead flight crews to make such co-ordinate entry errors of this nature. It is of note that the operator’s route network is such that there are few destinations to the west of the Prime Meridian and hence the majority of longitude co-ordinates that need to be entered would be ‘eastings’.

Because the geographic error was less than 1°, the only alert apparent to the crew would have been a VERIFY POSITION scratchpad message. The co-pilot did not recollect having seen the message, a message that can easily be cleared and which might have been dismissed as an automated response, without consideration of the reason for the message. While the aircraft was taxiing, the IRSs were in NAV mode, evidenced by the taxi route having been accurately recorded as a series of headings and groundspeeds, Figure 7c. However, all the recorded evidence, and the analysis from the manufacturer, suggests that the aircraft took off without the IRSs being in NAV mode. Therefore, it is highly likely that they were either in ALIGN mode or OFF. The investigation has attempted to explain how this might have occurred.

Pre-takeoff

At 1000 hrs, the aircraft stopped short of Taxiway Y on a heading of 224°. At 1006 hrs, the FDR data recorded the IRS derived parameters as NCD. This is the point at which the IRSs were probably selected from NAV mode. Shortly after this, the recorded FMS position changed to that of Stand 114, after which it did not change again for the remainder of the flight. The only source of position information for the FMS at this stage of flight, with the aircraft on the ground, was either from IRSs or from a manual crew entry. The recorded evidence is consistent with a manual entry of the new position into the FMS or the ISDU, but the pilots state that this did not occur.

While taxiing to the runway, the pilots would not have expected to have seen the departure route on their EHSI MAP displays, because they were most likely selected to a short range, with heading up, and their departure route would lay behind them. However, when the aircraft was waiting near the hold, it was on

a heading of 224°, and it should have been possible for the pilots to have seen at least the start of the route displayed. However, if the route was not represented, this might have acted as a mental trigger for a pilot to attempt to re-enter a position. In this situation, should a pilot attempt a fast realignment of the IRSs, he would need to have selected ALIGN before entering the new position, and then re-select NAV; there should be no movement of the aircraft throughout the process until alignment is completed.

At 1005 hrs, ATC issued an instruction to Lot 282 to give way to another aircraft and then to taxi to the hold at NB11. At 1006 hrs, the aircraft started to move slowly and, within a few seconds, the recorded IRS parameters became NCD. Therefore, it would appear that at just the time when the IRSs were apparently being re-aligned, the aircraft started to move. The aircraft stopped moving at 1007:20 hrs and at 1007:50 hrs it was recorded that the FMS position changed. Thus, the realignment of the IRSs while the aircraft was moving would explain why the IRS parameters remained NCD and the FMS position did not update.

The takeoff

When the IRSs are in ALIGN mode (IRSs data being NCD), the EFIS displays will show very limited information, Figure 1. For approximately two minutes before LOT 282 took off, the pilots' displays were probably in this condition. As the pilots were busy watching for other traffic and lining the aircraft up on the runway, it is possible neither one looked at the displays during this period. As the aircraft accelerated along the runway, it is likely that the commander's attention would have been focussed on his ASI. It was probably only when the aircraft rotated on takeoff that the co-pilot would have looked down or seen that no attitude or navigational information was available.

The commander reported that the IRSDU was not illuminated and appeared not to be powered. There would not usually be any lights showing on this panel during flight, unless a failure light is triggered. However, there is also a display on the IRSDU which shows the aircraft's position in digital form, and this may be selected to a number of different information sources. With the IRSs in ALIGN mode for an extended period, it would be expected that the ALIGN lights would flash.

Difficulties experienced by the pilots

The pilots appeared confused by what had occurred and had to fly the aircraft in IMC using only the standby instruments for heading and attitude reference. Pilots of modern EFIS equipped aircraft do not routinely fly their aircraft using a basic instrument presentation and without a map display. When suddenly presented with such a situation, pilots will need time to adapt their instrument scan and a higher level of crew co-ordination to enable them to conduct a safe instrument approach. The commander also had some difficulty with comprehending comprehending and communicating with ATC. At the time, his workload was high and he was under stress, both factors which would have contributed to his problem.

When the co-pilot realised that the normal heading and attitude references were not available, he quickly reverted to using the standby instruments. The commander decided that the co-pilot should continue to fly the aircraft to allow himself extra capacity to manage the failure. After takeoff, with the aircraft in a climbing attitude and about to enter cloud, visual references would have been limited. The standby attitude instrument is small and located on the left side of the flight deck, making it difficult to use from the co-pilot's side. The heading reference was obtained

from the standby compass, an instrument which is relatively easy to read in straight and level flight but difficult in turns. To turn onto a specific heading it is generally necessary to use a timed turn technique. Furthermore, because the compass card is vertically mounted, the direction of turn is often misinterpreted. This was demonstrated when, for the first few heading instructions from ATC, the aircraft turned in the opposite direction. In contrast, the normal instruments were available for altitude and speed, and instructions relating to these were complied with throughout.

During the flight the pilots continued to have difficulty in complying with heading instructions and were not able to fly the aircraft to intercept the ILS course to Runway 09L. To attempt an intercept with the navigation system in this degraded configuration, without direct heading reference, would require a high level of crew co-ordination. In fact, because of the non-compliance with the heading instructions, the aircraft crossed the ILS course at 90°, which would have made the task of intercepting it almost impossible. The pilots had little idea of their position and, after a few minutes, they were entirely dependent on ATC for their navigation. ILS DME range information was available but the pilots were offered no information from ATC, other than track miles to run, about their geographical location. It would have helped their situational awareness if their location relative to the airport and updated weather information had been given to them. Eventually, once the pilots established visual contact with the ground and then the airport, they were able to locate the runway.

Air traffic control

The TCNE departure controller at LHR already had a high workload at the time this incident started and the declared 'navigation problem' was more severe than he

anticipated. He stated afterwards that, if the pilot had said there was an 'instrument problem', then his own response might have been different. Furthermore, the aircraft did not declare a MAYDAY, even when asked specifically if there were any other problems. It is possible that, at this stage, the commander did not realise that his aircraft was not following ATC instructions. When it became apparent to the controller that the aircraft was not complying with heading instructions, it should have been an indication that the problem was more severe than he had thought initially.

The elapsed time from the declaration of the navigation problem until the handover to the dedicated controller was 10 minutes. When the dedicated controller took over from the TCNE departure controller, he did not have a full knowledge about the aircraft's lack of response to heading instructions. He therefore continued to give vectors to the aircraft, expecting that his instructions would be followed. He was also advised by the commander that the aircraft would be able to conduct an ILS approach. When the aircraft failed to comply with the assigned heading, and crossed through the localiser at a range of 14 nm, his plan to establish the aircraft gradually was compromised. He turned the aircraft back towards the airport onto a new intercept heading, but this made the task more difficult because the aircraft was closer to the airport with fewer track miles to run. The commander had advised that he had 'no direction, only glideslope' and, while receiving vectors, the aircraft crossed through the localiser three times. The controller then started to give 'start and stop turn' instructions which eventually succeeded in placing the aircraft in a position from which visual contact with the airport could be maintained.

While the aircraft was being vectored, it was getting nearer to the airport and was descending, under ATC instructions, without following any recognised

procedure. This was an undesirable situation and was only resolved because visual contact was established by the pilots. The situation arose because ATC did not initially understand the nature of the aircraft's problem; this was compounded by the difficulty of obtaining information from the pilots because of their limited command of English. The commander did not declare a MAYDAY, so the aircraft was not treated as an 'emergency' aircraft. However, it should have been possible for ATC to have recognised earlier that the aircraft was not able to comply with instructions, even if the pilots appeared to think otherwise, and to have treated it as though a MAYDAY had been declared.

Aircraft

The position entered by the pilots at LHR had a longitude error of less than one degree; there was no latitude error. The FMC would have recognised the entry made when the aircraft was on stand as incorrect, because the location entered was more than 4 nm from the airport, and would have generated a VERIFY POSITION message on the 'scratchpads' of the CDUs. There is no 'attention getter' for this message and it may be easily cleared by either pilot pressing the CDU CLR key. Scratchpad messages can appear very frequently in some phases of flight. It is likely that they are sometimes cleared by pilots as an automated action, without the content having been given sufficient consideration. On this occasion, it is possible that either the message was not seen, or it was seen but was deleted without any further action being taken. The IRS internal comparison tests would both have been passed, the first because the longitude error was less than one degree and the second because there was not any latitude error. The IRS would, therefore, have completed its alignment and the FMS could have appeared to the pilots to have been operating normally with the EADI and the FMC CDU displaying all the usual information. The EHSI display, assuming it was in MAP mode and set

to a short range, would not have shown the runway and departure route. However, at this stage there is normally only a limited amount of information in view, so it may not have looked noticeably different from usual. Had a cross-check of the departure route been carried out prior to leaving the stand, this would have shown up the error, but otherwise the pilots would probably not have specifically referred to the EHSI while manoeuvring on the ground.

Other

Although much of the difficulty in R/T communication may be explained by the added workload and stress on the pilots, this incident shows the problems that can arise when there is a lack of understanding between controllers and flight crews. The introduction of language proficiency standards should ensure that all operational personnel are qualified to a minimum and competent standard required for the task being undertaken.

The fact that a passenger may have been using a mobile telephone before takeoff is not likely to have had any bearing on this event, as the erroneous FMS position was entered when the aircraft was at the stand, before the passengers had boarded the aircraft. Furthermore, shortly after the time at which the IRS NAV function was lost, the position of the FMS was updated with a position close to the original stand position at Heathrow. This position could only have been manually generated and entered.

Conclusion

A fairly simple error in the pre-flight procedure of entering the aircraft's position into the IRS went undetected and led to a serious incident. Better cross-checking

procedures, either when initially entering data or by conducting a check of the entered route against that displayed on the map, would have prevented the situation from developing.

This incident demonstrates how reliant pilots may become upon the FMS, and how essential it is to ensure that the system is provided with accurate data.

Safety action

In an event such as this, it is clear that ATC may not be able to rely upon pilots for information about the aircraft's status, and their ability to fly the aircraft accurately, with degraded instrumentation. The crew of Lot 282 were not able to communicate adequately the nature and extent of their problem. Following their own investigation into this incident, the air traffic service provider has made several recommendations, one of which is that the circumstances of this event should be used for their internal training purposes. The service provider is also looking at the possibility of liaising with operators to enable controller training instructors to gain experience by observing Line Orientated Flight Training (LOFT) training sessions.

The operator is considering reminding its pilots of the necessity to use extra caution when manually entering latitude and longitude co-ordinates when at locations close to the Prime Meridian. Also, the operator is considering revising its pilot training to highlight the benefits of declaring an emergency in such circumstances.

Because these actions have already been initiated by the organisations concerned, no Safety Recommendations are made.

ACCIDENT

Aircraft Type and Registration:	Boeing 747-443, G-VLIP	
No & Type of Engines:	4 General Electric CF6-80C2B1F turbofan engines	
Year of Manufacture:	2001	
Date & Time (UTC):	20 March 2007 at 0654 hrs	
Location:	London Gatwick Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 17	Passengers - 238
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to underside of the two right engine nacelles	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	54 years	
Commander's Flying Experience:	15,925 hours (of which 4,885 were on type) Last 90 days - 127 hours Last 28 days - 34 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was landing on Runway 26L at London Gatwick Airport at the end of a flight from Barbados. After a stable approach, the crew stated that the conditions became 'quite rough' as the aircraft entered the flare. The aircraft was observed to roll markedly in both directions during the touchdown. The surface wind at the time was 350°/15 kt.

Later that morning, when the next flight crew to operate the aircraft were carrying out their pre-flight checks, damage was found on the underside of both engines on the right wing. The evidence indicated that ground contact occurred during the last landing. It had not been suspected by the operating crew at the time and had not been noticed during the intervening maintenance checks.

History of the flight

The aircraft was landing on Runway 26L at the end of an uneventful scheduled passenger flight from Barbados. The commander, who was pilot flying (PF), reported that, having been given a continuous descent by Air Traffic Control (ATC), G-VLIP was radar vectored on to the localiser for a Category I ILS approach.

By 1,500 ft aal the aircraft was fully configured for landing, with 30° of flap, and stabilised on the glideslope at 142 kt IAS, in accordance with the operator's Standard Operating Procedures (SOPs). 142 kt equated to $V_{REF} + 30 + 7$ kt for the aircraft's landing weight of 226,495 kg (max 285,762 kg), $V_{REF} + 30 + 7$ kt being the approach speed when landing manually with 30° of flap extended with an appropriate allowance

added for the surface wind. The aircraft's centre of gravity was within limits, approximately a quarter of the range from the aft limit.

The flight crew became visual with the runway at about 800 ft aal and with the aircraft on the runway extended centre line, crabbing to the left to compensate for a crosswind from the right. They stated that the aircraft felt stable, although the commander had to make adjustments to the thrust levers to assist the autothrottle's speed control. He disengaged the autopilot and autothrottle at or just before the Decision Altitude and hand-flew the aircraft for the remainder of the approach. The co-pilot informed the commander at about that time that the crosswind was 20 kt from the right and considered that it would remain constant thereafter. However, the commander stated that below 100 ft aal, he was able to reduce the amount of crab-angle that he was using to compensate for the crosswind. The last wind information the crew received from ATC, one minute before landing, was of a surface wind of 350°/15 kt, well within the 32 kt crosswind limit for the aircraft.

After the commander commenced the flare at about 50 ft aal, he recalled that conditions became "quite rough", requiring aileron control inputs in both directions. He stated that the aircraft's right wing dropped significantly at about the time of touchdown, enough for the co-pilot to join him on the controls to make a roll input to the left. The aircraft then appeared to roll too much to the left and the commander countered with a roll control input to the right. The aircraft stabilised and touched down normally just before passing holding point D1.

The co-pilot's recollection was that the touchdown on the runway centreline was firm to heavy and the

aircraft's attitude was "fairly flat", with the aircraft heading slightly to the right of the runway centreline. The right wing then started to lift and, as it continued to do so, the co-pilot became concerned that the engines on the left wing might make contact with the runway. He made an instinctive aileron control input to the right, removing his hands from the control column when he felt a positive input from the commander in the same direction. He thereafter shadowed the control inputs being made by the commander as the aircraft rocking subsided during the landing roll.

During the subsequent taxi to the airport terminal, the flight crew noted YAW DAMPER UPR and YAW DAMPER LWR messages on the Engine Indication and Crew Alerting System (EICAS). They were not aware of having seen these messages prior to the landing.

An ATC controller on duty in the tower's Visual Control Room observed G-VLIP's landing. He commented that the aircraft's final approach was unremarkable until after it had crossed the runway designation marking. It then appeared to oscillate in roll three or four times before touching down firmly, beyond the aiming point but within the touchdown zone. He saw no indication of the wings or engines making contact with the runway surface.

The flight crew of a Boeing 747-400 which landed ahead of G-VLIP, in a similar surface wind of 350°/14 kt, experienced minimal turbulence. They observed G-VLIP land as they taxied back towards the terminal and although it appeared to roll to its right before touching down, they saw no indications that G-VLIP's engines had made contact with the runway surface.

After G-VLIP arrived on stand and the passengers disembarked, the crew boarded a bus and returned to

their crew room before going off duty. The commander made an entry in the aircraft's technical log, regarding the yaw damper EICAS messages but no mention was made to an engineer, who was standing near the engines on the left wing as the crew disembarked the aircraft, of any other fault.

Later that morning, the next crew to operate the aircraft were carrying out their pre-flight checks when the co-pilot noticed that the drain mast underneath the No 4 engine was shorter than it should be. On further investigation he saw evidence of ground contact on the underside of the engine cowling and advised an engineer and the aircraft commander. Similar damage was found on the underside of the No 3 engine cowling. Subsequently, the co-pilot of the previous crew confirmed that there had been no sign of any such damage when he carried out the pre-flight external aircraft checks in Barbados prior to the aircraft's preceding flight.

G-VLIP had received an ATC delay before departing Barbados and during the flight the crew calculated that their Flight Duty Period (FDP) would extend beyond the nominal maximum FDP into the extended period available to the commander, as advised under the Flight and Duty Times Limitation Scheme in the company's Operations Manual. (The FDP is that period between an operating crew reporting for duty for a flight and the aircraft arriving 'on chocks' on the last sector of that duty.) In this case the duty only involved one sector and the 'maximum' FDP was 9 hours 45 minutes. To reduce this extended period, the commander increased the aircraft's speed. In the event, the crew's FDP was 10 hours, which represented 15 minutes into 'discretion'. Neither of the flight crew recalled feeling more fatigued than would be expected at the end of such a duty.

Meteorology

During their pre-flight briefing, the flight crew noted that the weather forecast for Gatwick Airport at their scheduled time of arrival included a possibility of visibility reducing to 800 m in snow and crosswinds gusting to 35 kt. Gatwick Airport's Aeronautical Terminal Information Service (ATIS), timed at 0647 hrs, gave a surface wind of 350°/14 kt, visibility, 7 km in slight rain and snow, few clouds at 700 ft aal, scattered clouds at 1,000 ft aal and broken clouds at 1,600 ft aal. The temperature was +2°C, the dew point was +1°C, the QNH pressure setting was 1008 millibar and the runway surface was described as wet throughout its length.

Aircraft damage

Aircraft damage was restricted to the two right engine nacelles. In one case, this constituted a light score on the underside of each of the two composite engine bay doors either side of their junction, together with light damage to the lower end of the protruding drain mast. In the second case, greater disruption of the drain mast had distorted part of the box structure within the nacelle profile forming the structure of an internal fire-wall. In addition, a main engine oil pipe passing through the fire-wall area was severely dented by the distortion of the box structure. Deeper scoring of the engine bay doors, together with distortion of the nose cowl, was evident on this nacelle.

Aircraft turn-round

Another 747-400 aircraft from the same operator landed and arrived on stand within minutes of G-VLIP, although the scheduled arrival times were approximately 30 minutes apart. G-VLIP positioned on the southern side of an east-west taxiway whilst the other aircraft positioned directly opposite on the north side. G-VLIP was thus parked in a position

fully exposed to the northerly wind whilst the other aircraft was isolated from G-VLIP by the presence of an active taxiway between the two machines. No mention of an abnormal landing was reported by the incoming flight crew to the ground crew during headset communications at the time of arrival of G-VLIP. The flight crew had departed by the time the relevant engineer reached the flight-deck.

G-VLIP was scheduled to depart 3 hrs 50 minutes after its arrival. The other aircraft which arrived at the same time was scheduled to leave 2 hours 40 minutes after arrival. According to the Operator's work plan, one team, consisting of three airframe/engine technicians, was allocated to carry out Daily and Transit checks on the two arriving 747 aircraft. Only one member of that team was qualified to sign the Certificate of Release to Service (CRS) on the type. He concentrated exclusively on G-VLIP, directing the other two individuals to share the tasks on the other aircraft. (For the purpose of this report the person qualified to sign the CRS on the 747-400 type is referred to as the Engineer; other participants are referred to as Technicians.)

The turnround period of G-VLIP was the only time when the team was required to turn round two aircraft at the same time. At the time of arrival of G-VLIP, the Line Maintenance Supervisor was occupied resolving a problem on another operator's aircraft.

During the period G-VLIP was on the stand, the wind was northerly at approximately 14 kt accompanied by sleet showers and the temperature was reported to be +2°C. G-VLIP had no shelter from these conditions and the ground was wet.

As well as the normal specified checks, the Engineer working on G-VLIP identified a yaw damper problem and one main-wheel tyre worn below limits which he subsequently changed. The baggage loaders found that both forward and aft baggage hold doors would not open and required assistance from the Engineer to resolve the problem on both occasions. A series of special checks was required to be carried out on each of the aircraft lavatories during the turn round period which, given the large number on the aircraft, also occupied the Engineer for a considerable period.

It was noted that the damage to the undersides of nacelles on the type could readily pass undetected unless the displaced drain-mast was observed, or a technician deliberately spent time lying on the ground beneath the nacelle.

Significance of damage

Had the aircraft been dispatched in the condition as found, it would have done so with the integrity of a fire-wall compromised. This condition would be regarded as a dormant fault. The damage to the oil pipe, whilst not directly compromising engine operation, could have lead to pipe failure and the loss of engine oil contents.

Pod scrapes can create structural damage to pylon attachments which can be difficult to detect. In this instance, later non-destructive testing inspection did not reveal any such damage.

Turn-round manning

Shortly before this incident, the operator had contracted to provide technical support to a number of other operators passing through the Gatwick base. Although total manning levels were increased to cover this change, the work pattern also changed from coverage of just the daytime period to coverage of the full 24-hour

period. This change in workload reduced the number of personnel available for the task on this occasion. When subsequently interviewed by the operator, both the Engineer and his Supervisor commented that the high workload experienced was not uncommon. The initiation of the contract with another operator had, in their opinion, stretched the minimal manpower available at the station.

Procedures

Landing technique

The flare and touchdown techniques applicable to all Boeing 747-400 landings are described in the Boeing 747-400 Flight Crew Training Manual (B747-400 FCTM). It states:

'Initiate the flare when the main gear is approximately 30 feet above the runway by increasing pitch attitude approximately 2° - 3° A touchdown attitude as depicted in the figure below is normal with an airspeed of approximately V_{REF} plus any gust correction.

- airplane body attitudes are based upon typical landing weights, flaps 30, $V_{REF} 30 + 5$ (approach) and $V_{REF} 30 + 0$ (landing), and should be reduced by 1° for each 5 knots above this speed.*

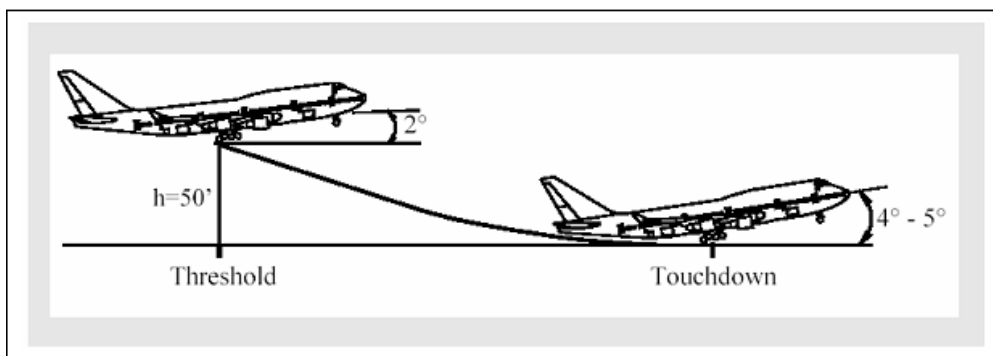
..... A smooth power reduction to idle also assists in controlling the natural nose down pitch change associated with thrust reduction. Hold sufficient back pressure on the control column to keep the pitch attitude constant.'

Crosswind landing technique

The commander stated that he used the de-crab technique for the crosswind landing. This method is also described in the B747-400 FCTM. It states:

'The objective of this technique is to maintain wings level throughout the approach, flare and touchdown. On final approach a crab angle is established with wings level to maintain the desired track. Just prior to touchdown while flaring the airplane, downwind rudder is applied to eliminate the crab and align the airplane with the runway centreline.

As rudder is applied the upwind wing sweeps forward developing roll. Hold wings level with simultaneous application of aileron control into the wind. The touchdown is made with cross controls and both gear touching down simultaneously. Throughout the touchdown phase upwind aileron application is utilised to keep the wings level.'



Ground contact during landing

The aircraft attitude required for contact between the engine nacelles and the ground surface during a landing, as advised in the B747-400 FCTM, is shown in Figure 1. The diagram caters for the different makes of engine fitted to the aircraft type ie General Electric (GE), Pratt & Whitney (PW) and Rolls Royce (RR) and is based on a rigid wing, as opposed to one that flexes.

Flight Recorders

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR) capable of recording a minimum duration of 25-hours of data and 120 minutes of audio respectively. In addition, the aircraft was also equipped with a comprehensive quick access recorder (QAR) system. Parameters included the position of the control column and wheel, rudder surface

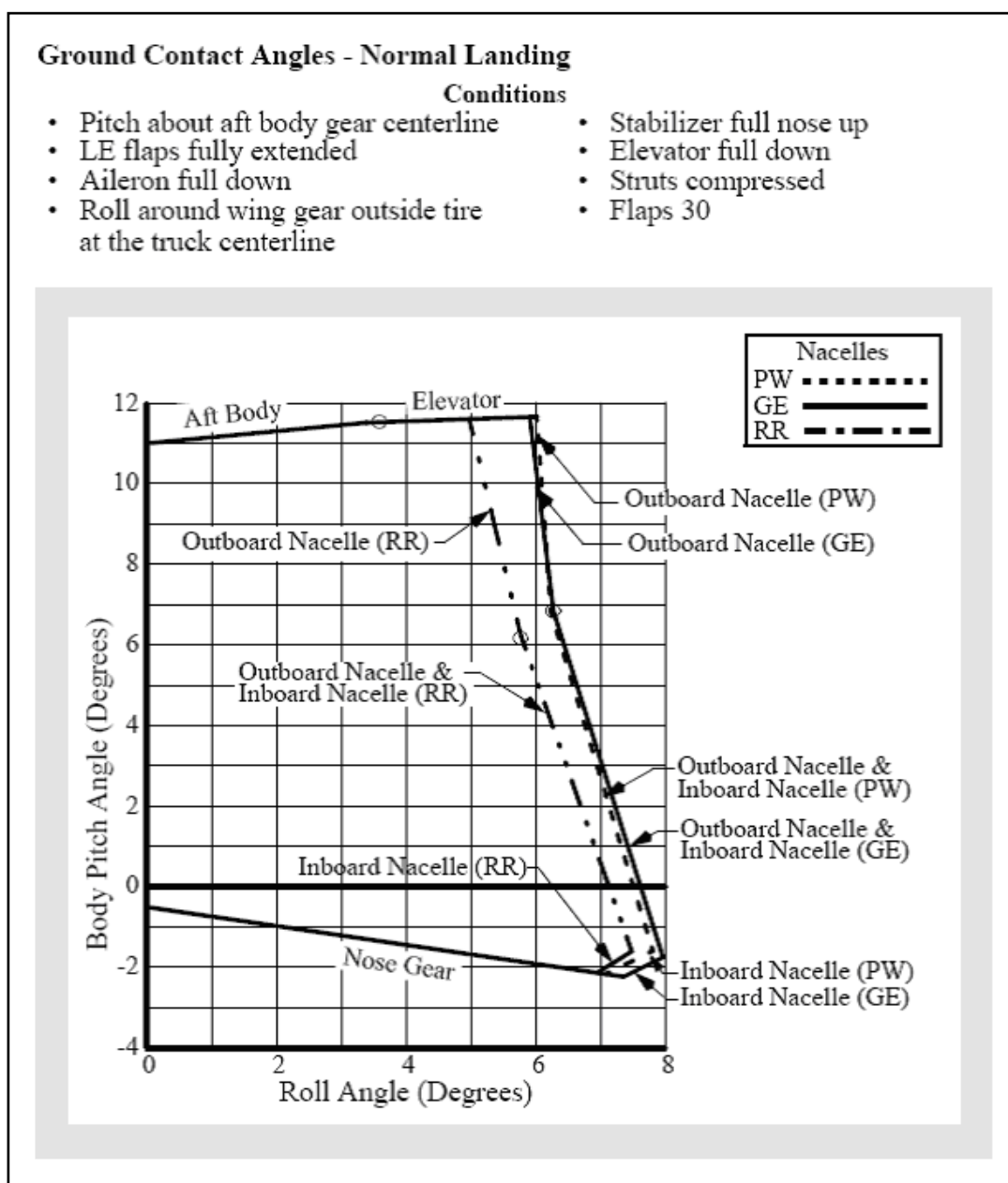


Figure 1

and pedals, pitch and roll attitude, wind speed and direction and landing gear. A plot of the FDR parameters during the landing is provided in Figure 2.

Recorded information

The takeoff, cruise and initial approach phases were uneventful. At about 1,000 ft aal the flight crew had completed the landing checks, with the commander confirming “manual landing four hundred feet”. The aircraft was stabilised on both the localiser and glideslope, with airspeed at 156 KCAS and flap 30° selected. The selected speed set on the Mode Control Panel (MCP) was 147 kt. At 1,000 ft aal, the wind speed and direction, as recorded from the flight management system (FMS), indicated the wind was from the right at 346°/30 kt.

As the aircraft passed through 400 ft aal, ATC cleared the aircraft to land and advised that the wind was 350°/15 kt. At 400 ft aal and 149 KCAS the commander confirmed “automatics coming out” and both the autopilot and autothrust were disengaged. Almost immediately the co-pilot advised the commander that the wind was from the right at 20 kt, which the commander acknowledged. The decision height warning occurred at 200 ft aal, at which time the commander confirmed they were to land. The aircraft had just started to descend below the glideslope at this time. The aircraft continued to descend below the glideslope, until it was stabilised at about 2 dots below the glideslope. The pitch attitude remained in a relatively nose level attitude until the flare.

As the aircraft continued its approach, the commanded roll and actual roll were occasionally out of phase with each other. The drift angle was about 6° during the approach. At about 40 ft aal, left rudder was gradually applied as the ‘de-crab during flare’ technique was used to align the nose of the aircraft with the runway and

right roll was also commanded. At about 25 ft aal the commander started to flare the aircraft. Pitch attitude was increased from 0° to about 2° over two seconds, before gradually reducing to nearly 0° just before the main gear touched down.

As the aircraft neared the ground, right rudder was quickly applied, from 25° left to 16° right in one second and the aircraft coincidentally rolled to 5° right wing down (see Figure 2, point A). Corrective left control wheel and left rudder inputs were made and the aircraft responded by rolling to the left. Countering the left roll, right control wheel was progressively introduced, reaching 83° just before the aircraft touched down (see Figure 2, point B). The control wheel has stops at +/- 90°.

The aircraft touched down with a small amount of left bank (1.5°) and at an almost nose level pitch attitude; airspeed was 145 KCAS and the normal acceleration at touchdown was at 1.43 g. The aircraft started to roll quickly to the right and about two seconds after touchdown the bank angle reached 6.7° right wing down (see Figure 2, point C). The pitch attitude was 1° nose down. A left roll was commanded and the aircraft rolled to the left quickly, before another almost full travel deflection of the control wheel to the right (see Figure 2, point D) was made. The aircraft continued in a rocking motion for a few more seconds before the roll attitude stabilised at about 2° left wing down, with right (into wind) control wheel applied.

As the aircraft was taxied to the terminal, the flight crew had mentioned that the winds were unusual, with the commander adding “the way it lifted the wing like that...the other way”. There was no reference to possible contact of the nacelles.

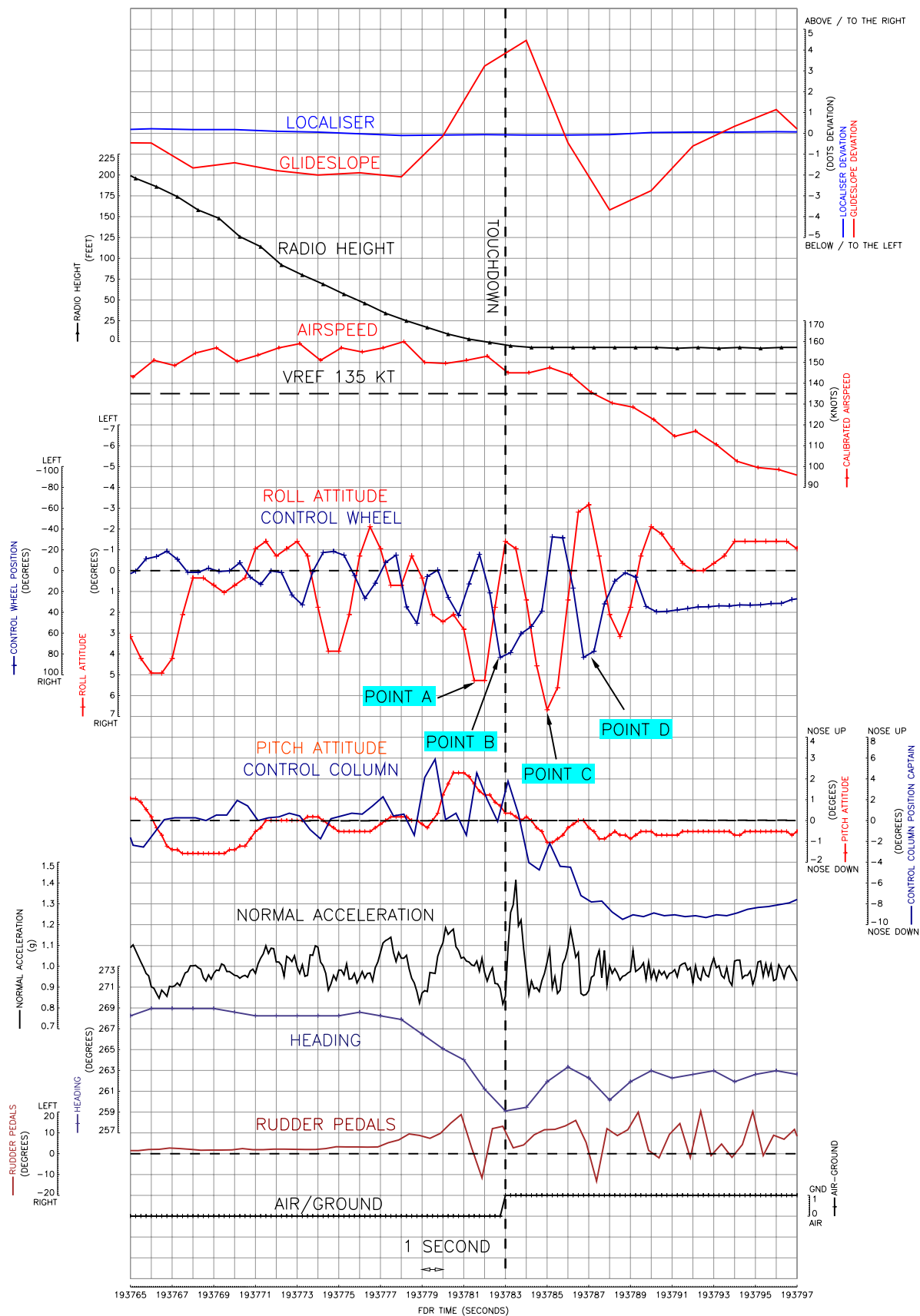


Figure 2
Salient FDR Parameters

Follow-up action

Personnel

The commander was an experienced pilot on the Boeing 747-400 and could not recall having encountered such a problem before. He was also well acquainted with Gatwick Airport, having operated into and out of the aerodrome since 1978. Following the incident, he received further aircraft training in the simulator. Initial assessment of his crosswind technique indicated a tendency to over-control both rudder and aileron during touchdown. By the end of the training session he was achieving smooth and consistent landings in strong crosswinds using the correct technique. The commander returned to line flying duties, with his first duty under the supervision of a training captain.

The co-pilot was also given additional training in crosswind landing techniques. After two hours he was achieving well handled crosswind landings in crosswinds of up to 40 kt, which is twice the co-pilot's limit. The subject of making control inputs during the other pilot's landing was also discussed.

Discussion

G-VLIP landed in wind conditions that were within the limits for the aircraft type and the crew. They were also similar to the conditions experienced by the preceding aircraft, which was the same type, operated by the same company and landed without incident.

G-VLIP's pitch attitude at touchdown was lower than the 4° - 5° nose up attitude recommended in the B747-400 FCTM. However, information from the FCTM also indicated that the respective pitch and roll attitudes at landing (6.7° right bank and 1° nose down) had not exceeded the ground contact envelope of the nacelles. Instead, at a pitch attitude of 1° nose down,

the bank angle required to contact both the inboard and outboard nacelles was approximately 7.8°. The aircraft manufacturer advised that the FCTM ground contact envelope represented a rigid wing rotated about the wing gear outside tyre, with the landing gear struts compressed.

The manufacturer was provided with the FDR data and performed a dynamic load analysis. Results indicated that the sink rate at touchdown had been about 6 ft/sec. This would result in the wing flexing downwards between 1° and 1.5°, about two seconds after touchdown on the main gear. At a pitch attitude of 1° nose-down, the nacelle ground contact bank angle would have been reduced from about 7.8° to between 6.3° and 6.8° two seconds after touchdown. The recorded bank angle of 6.7° had occurred about two seconds after touchdown.

During the landing, the control wheel and roll attitude were seen to be out of phase with each other. This was especially evident after the touchdown. In a classic Pilot Induced Oscillation (PIO), pilot commands are the only factors that influence the motion response of the aircraft. However, when other forces act on the aircraft, such as turbulence and ground contact, it becomes harder to determine whether the aircraft is responding to pilot commands or external influences.

The aircraft manufacturer was asked for an opinion regarding the nacelle ground contact being as a result of PIO. Analysis of the data indicated that there had been a direct cross-wind of approximately 20 kt, with wind variations of +/- 5 kt. The touchdown was firm at 1.43 g and the aircraft landed left gear first, which would have resulted in reactive forces that substantially influenced the aeroplane's motion at touchdown. The manufacturer's conclusion was

that, although the control wheel and roll attitude was out of phase after touchdown, this was not the only factor affecting the aircraft's motion. Based on the FDR data, a combination of a firm touchdown, variable crosswind conditions, ground interactions at touchdown and control wheel inputs all contributed to the ground contact of the nacelles.

The refresher training that the crew received following the incident identified that the commander had a tendency to over-control during the final phase of a landing in crosswind conditions. This observation appears to be reflected in the control inputs recorded by the FDR during G-VLIP's landing. By the end of this training, the commander was achieving smooth and consistent landings in strong crosswinds using the correct technique. This addressed three of the factors deemed to have been relevant in this incident, namely the control wheel inputs, the firmness of the landing and, consequently, the ground interactions at touchdown.

The co-pilot recalled that his instinctive roll control input was made as the aircraft was rolling left after it had reached 6.7° of roll to the right, following touchdown. This coincided with the largest degree of aircraft roll to the left recorded during the landing. Consequently his additional input on the flying controls was probably made after the two engine nacelles on the right wing had made contact with the ground.

Significance of Manning Level and Working Conditions

Use of one individual working alone on one aircraft in the conditions of the day would have been demanding. Although many operators regard such manning as sufficient to carry out the transit check on the type in as little as one hour, this is only realistic when weather

conditions are benign, no faults are identified, no rectifications are required and the engineer has no other responsibilities. Manning of safety-critical functions must, however, take account of adverse circumstances such as those being experienced on this occasion.

The Engineer working on G-VLIP identified the need for a wheel change and was required to jack the aircraft and change a wheel after locating both replacement wheel and jack. He was also required to carry out a special service to each of the lavatories on board. He was ultimately responsible for the other aircraft, while handling interruptions from loaders who were unable to open the freight hold doors of G-VLIP. Given the adverse weather conditions, it could be argued that the workload, including the normal range of checks, was excessive in the prevailing conditions, especially given the period of just less than 4 hours available for its completion. This pressure is considered to have had a detrimental influence on his ability to identify the fact that the aircraft was damaged.

The EASA requirements place a responsibility on the national regulator (in this case the UK CAA as the UK's nominated Competent Authority) to audit the functions of JAR 145 maintenance companies on a two year basis. The audit includes an assessment of the approved organisation's procedures for establishing the appropriate skill and experience levels and the manpower resource availability to cover their forecast maintenance activities. This can be done as a single audit at two yearly intervals, or may be carried out as a rolling audit ensuring that each aspect of the function is reviewed at intervals of no more than two years. This is not a straightforward task. The dramatically fluctuating workload at some line stations can disguise the precise manpower needed at peak times. In the case of this operator at this base, it appears that a substantially increased workload was contracted to be

carried out on behalf of other operators some time after manning levels were last audited.

This particular turn round brought a number of factors together which made it more demanding than usual, not least the environmental factors under which the engineers had to work. It is known that damaged undersides of nacelles have gone unnoticed during turn rounds of large turbofan aircraft in the past and it is possible that even under more favourable conditions this damage may have been missed. Nonetheless, the nature of workload and circumstances made missing this damage more likely. The absence of any flight crew comments, either verbally or as a technical log entry, decreased the likelihood of the damage being detected.

Operator's Response

The operator had originally planned to review the manning implications following the new contract customers at the Gatwick base, in April 2007. As a result of the incident, the review was brought forward and a decision taken to increase total staff and reduce the proportion of contracted staff (perceived to be more likely to leave at short notice than permanent staff). The operator also planned to re-align shift patterns to give a greater overlap of manning in the early morning period when scheduled workload is at its highest.

INCIDENT

Aircraft Type and Registration:	Reims Cessna F406 Caravan II, G-FIND	
No & Type of Engines:	2 Pratt & Whitney Canada PT6A-112 turboprop engines	
Year of Manufacture:	1989	
Date & Time (UTC):	6 September 2007 at 1237 hrs	
Location:	Coventry	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	43 Years	
Commander's Flying Experience:	11,000 hours (of which 250 were on type) Last 90 days - 270 hours Last 28 days - 90 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During a routine asymmetric training flight, a control restriction was encountered. An inadvertent selection of the autopilot is suspected although it has not been possible to evaluate fully the autopilot controller. A defect in the autopilot indicating system contributed to the incident.

History of the flight

G-FIND was being used for a crew training detail with two experienced training captains conducting both left and right seat Operators Proficiency Checks (OPC) on each other. On the incident flight the pilot in the right seat was pilot flying (PF) and was being checked by the pilot in the left who was the aircraft commander.

The incident occurred while the aircraft was at 1,000 ft agl on a simulated asymmetric circuit to Runway 05 at Coventry. The left engine was at zero thrust simulating a feathered condition and the right engine was at 600-700 lbs torque, giving a speed of 140 KIAS.

The PF flew a left-hand orbit for spacing from traffic near the end of the down wind leg. Shortly after G-FIND rolled out of this orbit, the PF noticed an uncommanded roll to the right and corrected with left aileron assuming that it was due to turbulence. The PF required excessive force on the control wheel to maintain control with limited control wheel deflection available. He estimated he had 20° left deflection of the control yoke and could not turn the yoke any further. He restored the simulated

failed engine and handed the commander control to confirm the problem and check it was not related to one set of the dual controls. The commander confirmed that in his estimation 20°-30° deflection to the left was the maximum aileron control available and then returned control to the PF. The PF declared a MAYDAY with G-FIND now rolling slowly to the right and turning towards the final approach track. The commander visibly checked the airframe for any asymmetric flap or other abnormal panels but all appeared normal.

The PF decided to return to the airfield and allowed the right turn to continue by reducing the amount of opposite roll force he was applying. G-FIND was placed in a descending right turn from the down wind leg towards final approach to Runway 05. The shortened route on to finals placed G-FIND behind two light training aircraft which were considerably slower than G-FIND. As the PF was attempting to roll out of the turn the commander called Coventry tower to request that the aircraft ahead be sent around and if possible to turn to the south away from G-FIND. One of the aircraft did so immediately however the other did not respond and G-FIND overtook it at a distance of approximately two wingspans.

The PF on G-FIND continued to require extreme physical force to control the aircraft. During the turn onto finals he attempted to use rudder to assist with directional control but it seemed to be jammed in the neutral position. During the latter stages of the turn onto finals the pitch force also became excessive. The PF elected to land with approach flap rather than change configuration and potentially degrade the situation.

At approximately 300 ft agl the crew felt G-FIND lurch and regained partial control in pitch and roll or though the rudder pedals still appeared to be jammed. The PF noticed the pitch trim had run away to full nose-up trim.

G-FIND was landed successfully on Runway 05 approximately 90 seconds after the first control problem began. During the landing rollout the PF handed control to the commander again for an assessment of the controls. The commander found the rudder pedal movement restricted with no more than one inch of travel available in either direction.

The crew taxied G-FIND to its normal parking position using differential power and brakes. After shutdown they noticed the electric trim switch assembly on the PF's side had broken loose from the control yoke.

Commander's comment

During the pre-flight full and free control check carried out by the PF, the trim wheel for the pitch trim had moved. The commander had assumed that the PF had moved the trim switch either deliberately or accidentally and so had not mentioned it at the time. He recalled that during the incident the PF asked him to look around for anything unusual but the commander stated that he did not check the autopilot mode annunciations located above his artificial horizon.

The commander also stated that during the incident, the PF had pressed the autopilot disengage switch on the right control yoke.

PF comment

The PF stated that during the pre-flight checks he had not actioned the trim switch either accidentally or deliberately. He is also certain that he did not press the autopilot disengage switch during the incident as he did not think the autopilot was engaged. He recalled asking the commander to look for any anomalies and intended for this to include the mode annunciations over the artificial horizon. He could not recall any incident where he may have knocked the autopilot engage switch.

Aircraft examination

The AAIB examination began on the morning following the incident. When the aircraft was first viewed, most of the central floor panels had been removed.

Despite the close grouping of cables and springs in the forward part of the aircraft, all control functions were found to be unobstructed and no foreign objects were found anywhere in the region of the total under-floor control run length which could have lead to mutual interference.

The aircraft was jacked and the landing-gear retracted. Control and autopilot functional checks were carried out but no control jamming or restriction was detected. On selection of yaw damper it was noted that rudder-free travel became very limited and no visual indication of yaw-damp engagement was evident. It was noted that the illumination bulb of the yaw damp selector button was not operating and the autopilot mode indicator was operating in dim or night mode, regardless of ambient light levels.

With auto-pilot selected, the aileron servo responded to a position signal from the unpowered instrument gyro system and drove the roll control to full travel. Attempts to resist this movement using the pilot's control column revealed unexpectedly high forces.

The aircraft engines were subsequently run, supplying vacuum power to the gyros. The aircraft was taxied and manoeuvred on the ground with various autopilot modes selected. No unexpected control inputs occurred. During the ground tests it was noted that the left knee of the pilot in the right seat is very close to the autopilot activation switch. This would be especially so in asymmetric flight with the left engine at idle.

MOR reports on previous Rheims Cessna 406 aircraft incidents were studied and a number of flying control issues were noted, three of which remained unresolved. A fourth event, to aircraft G-SFPB involved an uncommanded autopilot engagement which could not be overcome by operation of the right control column switch although disconnection was achieved via the commander's switch. When subsequently engaged, the autopilot failed to function correctly and created a number of strong and inappropriate control effects. A series of further control problems occurred culminating in the commander finding it necessary to keep his autopilot disconnect button permanently depressed to ensure the autopilot remained inactive.

Subsequent testing and examination of G-SFPB revealed wiring damage and arcing between adjacent cables associated with the autopilot where a cable loom passed through a hole in the shaft on which the control spectacle was mounted. Movement of the column had caused chaffing of the cables against the sides of the hole. Once the affected cable region was repaired, no further associated problems were reported.

Examination of the corresponding area of G-FIND revealed that, unlike the situation on G-SFPB, the relevant cables were not routed within the shaft and thus did not exit via a corresponding hole. Instead a long, very flexible pre-coiled cable was routed externally from the centre/underside of the control wheel to the instrument panel. Checks of electrical insulation and continuity on the autopilot associated cable looms through the aircraft (G-FIND) were nonetheless carried out. No faults were found.

The power supplies to pitch and roll servos, together with those to the yaw damper and to the pitch trim actuator were disconnected and the aircraft was

test-flown in purely manual mode. A reproduction of the circumstances of the incident flight (ie use of asymmetric power) was also carried out at a safe height. No control problems were encountered. The aircraft was returned to service, with all electrical actuators and the pitch trim servo disconnected, operating in purely MANUAL mode. No further control problems have been reported.

Component examination

The autopilot control unit was determined to have been manufactured in the USA to a design developed over 20 years ago and is no longer in production. Technical support for it is limited to repair stations who routinely replace a significant number of components without normally diagnosing the reasons for technical failure. The expertise for such critical diagnosis no longer appears to exist. A full and comprehensive defect investigation on the unit could not therefore be carried out.

Aircraft controls

The aircraft type has conventional cable operated flying controls and trimmers. It is also equipped with electric pitch trim and an autopilot operating in pitch and roll axes, incorporating a yaw damper. Autopilot servos driving elevator and aileron circuits are electrically powered and incorporate break-out clutches enabling pilot input to override the automatic control system. The pitch trim actuator is situated in the rear fuselage and responds to both the control column mounted electric trim switch and to pitch trim demands sensed by the autopilot.

The autopilot modes are controlled by illuminated push-buttons situated on a control panel mounted on the aft face of the control console on the aircraft centreline. This console is located below the power, propeller and condition levers. The sources for pitch roll and heading

information are the gyros of the P1 attitude and heading indicators. These gyros are powered by engine driven vacuum pumps. The status and mode of operation of the autopilot and yaw-damper functions are shown by an illuminated mode indicator positioned on the instrument panel, above the attitude indicator, directly in front of the P1 position. The mode indicator has a light sensitive system automatically giving BRIGHT (day) indication and DIM (night) indication.

All flying control and trim cables as well as cables for the three control functions for each engine are routed beneath the cabin floor along the central trough of approximately one foot square cross-section situated between the longitudinal webs carrying the inboard seat rails. The area between those webs, extending from the instrument panel to the wing centre section, thus contains 24 closely grouped cables. The rudder and aileron control cables on the type are flexibly connected by bias springs also situated in this area. There is also close positioning between cables where they pass vertically upwards just forward of the pilot's seats in the region of the engine control console.

Autopilot engagement

The autopilot fitted to G-FIND is engaged by a push switch located below the power levers between the pilots. It is one of a cluster of 12 auto-flight related switches. During the AAIB's initial inspection of G-FIND it was noticed that this switch requires only a very light pressure to activate. The light on this panel associated with the autopilot engage switch had failed.

Discussion

The initial event of which the PF was aware was an uncommanded roll which he thought was due to atmospheric turbulence. When the roll continued, he realised there was a control problem. To respond to this

and level the wings, it was necessary to apply roll control input sufficient to both arrest an established rate of roll as well as achieving a roll rate in the reverse direction. This would have required significant roll control forces to produce the required control surface deflections acting against aerodynamic loads.

Tests on the aircraft demonstrated that high forces were required to 'break-out' the autopilot servo clutches and to overcome and reverse the control system roll deflections when inadvertent autopilot engagement took place with a steering demand present.

If inadvertent autopilot operation had occurred on the occasion of the initial control problem, the pilots would have needed to move the controls against the sum of the mechanical (autopilot servo) and aerodynamic (aileron) forces. This would have required a large total force. The effective non-functionality of the mode indicator (ie its operation in DIM during strong daylight conditions), coupled with the positioning of the autopilot control panel low down outside the scan of either pilot, would have removed the obvious cue that the autopilot system was operating and applying inputs to the flying controls.

Forceful movement of the pilot's control column to return the aircraft to a wings-level attitude would have been difficult to carry out without causing some degree of deflection in the fore and aft direction, applying inadvertent pitch control input. If the autopilot was functioning whilst this was occurring, the controller would have acted in the same way as when it detected an out-of-trim condition whilst operating in its normal mode. Thus the trim actuator would have operated, causing the pitch trim wheel to rotate.

Rudder pedal operation by the crew would not necessarily

have taken place early in the sequence of events but later on, particularly as the power was restored to a symmetrical condition, some rudder pedal movement would be expected. Had the autopilot been engaged at the time, the yaw damper would have been in operation. Tests showed that a high degree of rudder restriction was produced when yaw damper was in use. The pedal movement restriction reported by the crew would have been even greater on the ground at low taxiing speeds when the pedal forces required to achieve nosewheel steering were additional to any forces from the yaw damper, if it was engaged.

Most of the effects of inadvertent autopilot engagement described above broadly reflect the pilots recollections of the event. In view of the lack of any evidence of control problem, defect or restriction found during a detailed examination of the flying control system and the continued satisfactory operation of the aircraft in purely MANUAL mode, the basic controls of the aircraft appear not to be at fault. It is therefore likely that the autopilot was operating when this control problem occurred.

The lack of any facility to evaluate all the variables of the electronic functions of the autopilot controller prevents the elimination of the possibility of an intermittent fault on that unit. Equally the possibility of crew members accidentally achieving autopilot engagement by inadvertently applying pressure to button/s or dropping charts, note-pads or other loose cockpit equipment in such a way as to inadvertently strike buttons on the controller, cannot be ruled out. Either way, the absence of an effective crew warning of autopilot status and the absence of any subsequent evidence of control system defect in the aircraft increases the likelihood of this being an accidental and undiagnosed autopilot engagement.

Subsequent actions

The operating company have contracted an appropriately approved design organisation to develop an autopilot system modification which introduces a new disconnect facility. This is planned to involve a prominent switch and warning light, adjacent to the mode indicator and thus in the normal scan of the pilot occupying the left seat. The switch will enable a pilot to isolate all three servos and the trim actuator from their power supplies, enabling the aircraft to be returned easily to purely manual flight should inadvertent operation of the autopilot system occur.

In addition, the training organisation associated with the aircraft operator has reviewed procedures to raise awareness amongst flight crews of the possibility of accidental autopilot engagement and the importance of considering this possibility if control problems are encountered.

INCIDENT

Aircraft Type and Registration:	AS332L2 Super Puma, G-REDN	
No & Type of Engines:	2 Turbomeca Makila 1A2 turboshaft engines	
Year of Manufacture:	2004	
Date & Time (UTC):	14 December 2007 at 1000 hrs	
Location:	Aberdeen Airport, Scotland	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	39 years	
Commander's Flying Experience:	7,400 hours (of which 5,400 were on type) Last 90 days - 125 hours Last 28 days - 34 hours	
Information Source:	Aircraft Accident Report Form submitted by both pilots and operator's own incident report	

Synopsis

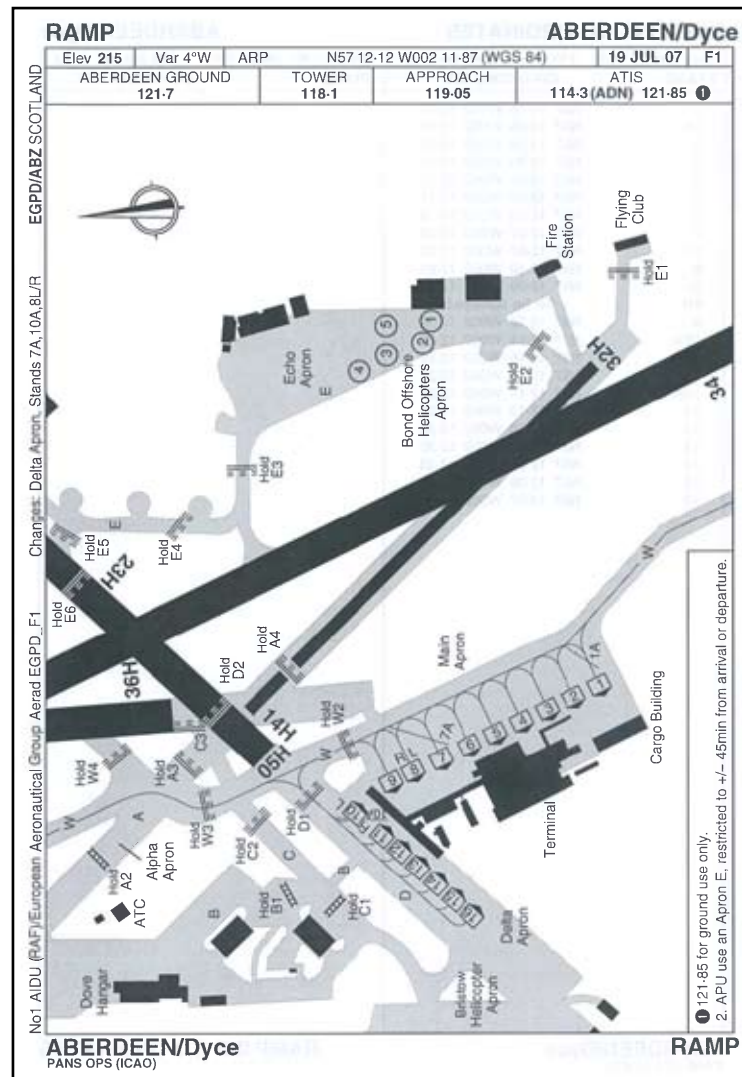
During a ground taxi, the crew felt a control restriction when attempting to turn left and realised that the nose wheel locking pin had become engaged. Collective pitch was increased in an attempt to disengage the pin by reducing the weight on the nosewheel. The aircraft subsequently rolled and pitched to excessive attitudes before control was regained.

History of the flight

After landing on Runway 23, the co-pilot, who was the pilot flying (PF), taxied the helicopter to the apron. The crew had been instructed to disembark their passengers on Spot 5 (Figure 1) and then taxi to nearby Spot 3 to shut down.

Whilst taxiing from Runway 23 to Spot 5, the aircraft completed various turns in both directions without incident. On Spot 5 the chocks were fitted and, with the rotors running, the passengers disembarked. The commander took control for the taxi to Spot 3, as he had a better view of other aircraft positioned nearby. It is unclear when he actually took control and which of the pilots actioned the taxi checks; however, the commander stated that the checks but completed before he commenced the taxi. He initially steered to the right without difficulty but when he commenced a turn to the left there was no response from the helicopter.

The crew checked and then realised that the nosewheel



Taken from:
AERAD Terminal Charts

Figure 1

lock had engaged but attempts by the co-pilot to release it were unsuccessful. The commander stated that he increased collective pitch with the intention of reducing the pressure acting on the pin, so that it could be released. In doing so he felt the helicopter become unstable and so continued to lift it into the hover, this being done with the Automatic Flight Control System (AFCS) disengaged. The helicopter rolled and pitched before it could be brought into a stable hover where the AFCS was then engaged by the commander using the engagement button positioned on the cyclic. The helicopter was hover taxied the rest of the way to Spot 3 where it landed safely.

Flight data

Data was successfully downloaded from the aircraft's HOMP (Helicopter Operations Monitoring Program) and Solid State CVR systems by the operator. This was analysed along with film of the incident captured by two CCTV cameras overlooking the apron.

The data showed that whilst taxiing from Spot 5, the aircraft turned right through about 150° onto a heading of 326°M. The turn was initiated by the selection of approximately 50% right yaw pedal, progressively reversed to almost full left pedal, stopping the turn and starting the attempted turn to the left as the helicopter

approached Spot 3. The helicopter turned left through about 10°. CCTV footage indicates that this appears to have been achieved with the aircraft skidding to the right. Recorded data shows a developing roll of 4° right, with collective power simultaneously being applied. The helicopter's two rear wheels broke contact with the ground and its tail moved right, through approximately 20°, the front wheel remaining in contact with the ground. It then lifted into the hover, rolling 9.1° to the right before pitching about 15° nose-down.

Nosewheel locking pin

The nosewheel locking pin, when engaged, prevents the helicopter's nosewheel rotating. It is normally placed into the locked position prior to take off and is kept locked when landing at offshore installations. The pin is unlocked after landing at onshore locations to enable manoeuvring during ground taxi.

The nosewheel locking pin lever is painted black and is located between the pilots' seats, just aft of the brake lever, which is painted red. Both levers are aligned fore and aft when in the 'OFF' position (Figure 2).

The nosewheel locking pin is engaged by raising the lever and rotating it to the right (Figure 3), the pin then dropping under spring pressure and entering into a fixed hole on the nosewheel leg when the nosewheel is centred. This also causes a flag (see Figure 4) to drop below the body of the aircraft in front of the wheel indicating the pin has been applied. The flag will drop as soon as the lever is rotated, even if the pin has not engaged into the fixed hole in the nosewheel leg.

The locking pin is released by rotating the lever and pushing it down, causing a spring to force the pin out of the hole and allowing the body of the nosewheel to rotate freely. If the handle is not pushed fully down to release the locking pin it is possible for the pin to re-engage when the wheels align fore and aft.

Company checklist procedures

Normal operations are conducted using an Abbreviated Normal Checklist. The checklist is a challenge and response procedure with the pilot not flying (PNF) reading the list and completing any actions required.



Figure 2



Nosewheel locking pin -
engaged

Figure 3 (left)

Warning
flag



Figure 4 (right)

Crew duty times

The crew's duty period started at 0600 hrs with the incident happening some four hours later. During this period they completed two sectors, each of approximately 1.5 hours duration.

This was the fifth consecutive day on duty for both pilots, prior to which they had had eight days off. During these duty days, the commander had amassed 24.40 hours duty time and the co-pilot 30 hours. This was the fourth consecutive early duty start for the commander and the third for the co-pilot.

Analysis

The aircraft was able to turn normally during its taxi from Runway 23 to Spot 5 which suggests the nosewheel locking pin was in the unlocked position. Nothing in the checklist calls for the pin to be re-engaged after parking; the pre-taxi checks also require a check that the pin is in the unlocked position.

Had the nosewheel locking pin been set to the locked position with the nosewheel offset to the right when the aircraft was parked on Spot 5 the pin would have been unable to engage. The helicopter would have been able

to continue a turn to the right when it recommenced its taxi. When the aircraft then turned to the left, however, the pin would have engaged as the nosewheel passed through the central position, preventing the helicopter continuing the turn. The forces exerted on the aircraft by the application of left yaw pedal whilst the helicopter was unable to turn would have created a rolling moment, exasperated by the increase in collective pitch application. This is probably the reason the helicopter rolled to the right when it was sufficiently light on its wheels.

It seems that the most likely cause of the nosewheel lock having been set is that the lever was placed in the engaged position instead of the parking brake after parking on Spot 5. The helicopter would probably have remained stationary without the parking brake being set due to the apron being flat and chocks being put in place quickly after it parked.

It is recognised that the levers may be confused due to their proximity, which has led to attempts to differentiate between them by colour. Identification of the mistake through the use of the checklist was unsuccessful probably as the result of the change in PF role at that point. It is unclear exactly when the checklist was actioned and it is possible a check of the locking pin position was overlooked. Fatigue may have been a contributory factor due to the early start of this and the previous duty periods, although they were of a relatively short duration.

Safety actions

The operator has carried out a thorough investigation of the incident and its safety department has made several recommendations. These include:

- changes to the checklist relating to the nosewheel locking pin
- reinforcing amongst crews the need for discipline when using checklists
- improved training on the use of the nosewheel locking pin and in particular the actions to be taken should it be found to be inadvertently locked during taxi
- introduction of procedures for ground crew to check the locking pin flag position prior to taxi
- proposed improvements to the positioning and ground handling of aircraft on the company apron to provide better clearance between them
- improvements to the handling of data after an incident or accident

In view of these recommendations, no further Safety Recommendations are made.

ACCIDENT

Aircraft Type and Registration:	Bolkow 207, D-ENWA	
No & Type of Engines:	One Lycoming O-360-A1A piston engine	
Year of Manufacture:	1965	
Date & Time (UTC):	27 August 2007 at 1535 hrs	
Location:	Near Stapleford Aerodrome, Essex	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - 1 (Fatal)	Passengers - 1 (Fatal) 1 (Serious)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	43 years	
Commander's Flying Experience:	158 hours (of which 24 were on type) estimated Last 90 days – 11:10 hours estimated Last 28 days – 6:25 hours estimated	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft took off from a private airstrip with two adults and a young child on board. It failed to gain safe height and speed and stalled, crashing 270 m beyond the end of the strip. Only the adult passenger survived the accident. The aircraft was correctly configured for takeoff, and there was evidence that the engine was operating normally. Recorded data showed that the pilot had attempted to climb the aircraft above obstacles before achieving a safe climb speed. There was insufficient height for the pilot to recover once the aircraft had departed from controlled flight.

History of the flight

The aircraft was based at a private farm strip about 2 nm

east of Stapleford Aerodrome in Essex. The pilot had intended to fly a local pleasure flight, accompanied by his partner and their three-year-old daughter. It was to be his passengers' first flight in the aircraft, which the pilot had acquired in September 2006.

Witness accounts indicated that there were no obvious problems encountered during the pre-flight sequence. The aircraft taxied to the southerly end of the strip (orientated approximately 03/21) in preparation for a northerly departure. The adult female passenger occupied the forward right seat and the young child was secured in a car safety seat which itself was secured to the aircraft's rear right seat.

The aircraft was seen taking off by the landowner, who was an experienced private pilot. He saw the aircraft become airborne about halfway along the 680 m strip and start its climb. He described the climb as appearing slow, and described what appeared to be some lateral instability, evidenced by minor wing rocking. The aircraft was also seen by witnesses at a stable complex, which was under the immediate takeoff flight path. All the witnesses described the aircraft as flying lower and more slowly than aircraft usually did when taking off from the strip, and also that the engine was running normally.

The aircraft crashed a few seconds later, in the grounds surrounding the stable complex, just before reaching the M25 motorway which ran alongside the grounds. Witnesses at the stables did not see the final seconds of the flight but were alerted by the sounds of the crash and almost immediate explosion. However, the strip landowner had kept the aircraft in view and described that, having gained little height since takeoff, the aircraft appeared to start a turn to the right, but this was followed immediately by a sharp left wing drop, and the aircraft then descended rapidly before disappearing behind trees. A further witness who saw only the last stages of the flight also described seeing the aircraft for a brief moment as it appeared between trees, flying very low. He also described seeing the left wing drop and a rapid descent.

The surviving adult passenger provided valuable information regarding the events leading up to the accident, though she did not recall the very last seconds of the short flight. She was not a pilot or a regular passenger, and had not flown in D-ENWA or from the strip before. She reported that the pre-flight activities were normal as far as she could tell, and that the pilot appeared to be his normal self, with no obvious concerns about the aircraft. He used a printed checklist and carried out engine run-up checks before takeoff. The passenger

recalled being apprehensive about the takeoff, being aware of the trees at the end of the strip, so was looking down rather than ahead during the takeoff itself. It was shortly after lift off that she sensed that the aircraft was no longer climbing and looked up to see the trees ahead. She did not hear any unusual noises from the engine, nor notice any other indication that it was not running normally. Her last recollection was looking at the pilot and asking “what’s wrong?” The pilot looked at her and was evidently concerned, but replied “I don’t know.”

No witnesses saw the actual impact. The aircraft came to rest inverted, a short distance beyond the initial impact site, and a fire started almost immediately at the front of the aircraft. People from the stable yard rushed to the scene, and extinguishers were bought from the nearby buildings whilst the emergency services were alerted. Fire rapidly took hold of the aircraft before anyone could get close enough to assist the occupants, and once it did so it was too dangerous for anyone to approach. The survivor appeared through the smoke, clearly in a dazed state, but able to stand. Although disorientated, she was calling for assistance, clearly aware that people were trapped within the wreckage. She attempted to get to them, but was restrained by the first people on the scene, an action which almost certainly saved her from much more serious injury from the now substantial fire.

The accident site

The accident site was in a field, the north-eastern edge of which bordered the M25 motorway. It was 270 m from the northern end of the airstrip. Between the end of the strip and the accident site the terrain consisted of rising ground on which there were a number of tall trees, paddocks, stables and farm outbuildings. The accident site was approximately 30 ft above the northern end of the strip.

Engineering examination

Examination of the accident site showed that the initial impact in the field was made by the aircraft's left wing tip. This was rapidly followed by its left main landing gear and the propeller. The fuselage came to rest inverted 23 m from the point of the initial impact and was consumed by a post-impact fire. At the time of the initial impact the aircraft was banked and rotating to the left and had a steep nose down attitude consistent with spinning to the left. The speed of the aircraft was low, in the order of 45 to 50 kt. From the direction of the wreckage trail the general track of the aircraft was 020°(M). Both propeller blades showed clear evidence of being driven at high power by the engine at the point of impact with the ground.

Examination of the trees between the strip and the accident site did not show any evidence of them having been struck by the aircraft.

A detailed examination of the flying control system found no disconnections. The wing flaps were found to be set at 15°, the normal takeoff position. The pitch trim was found to be set at a position slightly forward of neutral. The engine and propeller were taken to an overhaul facility for examination. External and internal examination showed no evidence of a failure, disconnect or partial seizure within either the engine or the propeller mechanism. Both units were in very good mechanical condition. Evidence from the engine and propeller control systems showed good evidence that the engine throttle was fully open, the fuel mixture was set at full rich, the carburettor heat was set to the 'cold' position and the propeller was set at full fine pitch. Witness marks within the propeller mechanism showed that at impact the pitch angles of the two propeller blades had coarsened slightly from the full fine pitch angle. This is consistent with the speed at which the aircraft was flying.

The electrically operated stall warning horn, mounted on the right side of the instrument panel, was recovered undamaged. When tested it was found to function satisfactorily. It was not possible to test the stall warning vane that was mounted in the wing leading edge due to damage from the post-impact fire.

Pilot information

The pilot gained his Private Pilot's Licence (Aeroplanes) in December 1999 after training on Cessna 152s. At the time of the accident, his licence was valid, and he held a current certificate of revalidation of his Single Engine Piston (Land) rating as well as a current JAA Class two medical certificate. In late 2000 he joined a Cessna 172 group based at North Weald. In 2001 he completed a full-time course of study for the Airline Transport Pilot's Licence theoretical examinations but did not subsequently pursue a career in civil aviation.

The pilot had acquired D-ENWA whilst it was still based at Melle in Germany, and it was flown by an experienced Bolkow 207 pilot to North Weald Aerodrome in September 2006. Under the terms of a 'Notification to Pilots' (Number II-4/95) issued by the German Federal Office of Civil Aviation, the pilot was entitled to fly the German registered aircraft in the UK on the basis of his CAA licence, providing that it was only flown in visual flying conditions, and during the hours of daylight.

The pilot had no previous experience on tailwheel aircraft, so he undertook a tailwheel conversion course on D-ENWA. This was conducted at an approved training organisation, by an instructor who was very experienced on tailwheel aircraft. The pilot logged five hours flying during the course, of which one hour was solo. This course was started on 25 October 2006 and ended with the solo flight on 9 December 2006. The instructor who

conducted the training reported that the pilot achieved a satisfactory standard in handling the aircraft. He also described the pilot as being enthusiastic towards his flying whilst apparently being aware of his limitations in terms of experience.

The course flying was conducted from a level, 800 m paved runway and did not include short or soft-field takeoff techniques. The pilot apparently did not ask for any extra advice concerning strip operations and the instructor stated that, as far as he was aware, the pilot intended to continue operating the aircraft from North Weald, which has paved runways. He did not know that the pilot was in fact, intending to base the aircraft at a farm strip. The instructor said that, had he known this, he would have been able to tailor the course accordingly.

The pilot's personal flying logbook was recovered from the aircraft wreckage. Although incomplete, an estimate of flying hours was possible, assisted by the aircraft logbook and records from the farm strip and other sites. The flying hours given for the pilot are believed to be accurate to within 5% of total. Including the conversion course, the pilot had flown some 24 hrs on type over 35 flights during a period of 10 months.

The pilot had taken off from the strip on 11 occasions prior to the accident. On only two of these was it reasonably certain, based on historical wind data, that takeoff had been made in the same direction as on the accident flight. On two further occasions it was a possibility, as winds were light and variable. On all other occasions takeoff was made in the opposite, southerly direction.

The pilot had not routinely practised circuits in the aircraft. After his tailwheel course finished on 9 December 2006, his next flight was to the farm strip,

via Earls Colne Airfield, on 16 December. He did not fly D-ENWA again until 9 April 2007. From then on, he only once logged more than one takeoff and landing per flight, that being on 18 April 2007 when he flew to Sibson aerodrome near Peterborough and logged four landings before returning to the strip.

Meteorological information

The probable weather conditions at the time of the accident were provided in a report by the Met Office. There was a large high pressure cell affecting the area, giving rise to a dry, light north-westerly to northerly airflow, of limited instability. There would have been scattered 'fair weather' cumulus clouds at about 4,000 ft amsl, and a visibility of between 25 and 40 km. There was no reported weather in the vicinity of the accident site. The surface temperature would have been about 19°C.

The possibility of unusual wind effects was considered. The mean surface wind at the time was estimated as being from 320°(M) at 5 kt. Thermal activity would have been sufficient to induce surface variations in the wind direction and speed. However, as the airmass was not excessively unstable, the maximum gusts would be that of the gradient wind, which was 12 kt. Variations in wind direction were possible, as seen in the meteorological reports from London (Stansted) Airport, 14.5 nm to the north. It was therefore considered that the wind direction at the accident site could also have varied by as much as 40° either side of the mean 320°.

Video evidence from a Police Air Support Unit helicopter supported the Met Office estimates. The video, which commenced about 20 minutes after the accident and whilst smoke was still issuing from the wreckage, showed a fairly consistent surface wind direction of 320°, occasionally veering for short periods to about 350°.

A section of footage showing the farm strip windsock enabled a wind estimate there of 340°(M) at 5 to 8 kt. Therefore, it is probable that the headwind component for takeoff was about 5 kt.

Historical wind data was obtained for each takeoff made by the pilot in the accident aircraft. In the case of the farm strip takeoffs, the data is from North Weald Airfield, 5.3 nm to the north. In general, the pilot flew only on light wind days, normally in less than 10 kt. On the four occasions that he flew from the farm strip in more than 10 kt of wind (to a maximum of 17 kt), the wind was almost directly aligned with the strip's southerly takeoff direction.

Recorded information

Track log¹ data was downloaded from a GPS unit recovered from the aircraft. The frequency with which the data points were logged by the GPS unit was dynamically controlled by algorithms in the unit's controlling software, based on rates of change of height, track, and ground speed.

The data provided the average speed of the aircraft during six consecutive segments of the accident takeoff. During the first 50 m segment the average ground speed had been 12 kt, 28 kt during the following 120 m segment, 42 kt over the next 175 m segment, 53 kt over the next 250 m, 50 kt over the next 211 m and 46 kt over the final 50 m segment. The last three segments were recorded after the aircraft had taken off, with heights of about 30 ft, 100 ft and 100 ft recorded respectively. The average climb rate between the 30 ft and first 100 ft point was 555 ft/min. The impact point was about 80 m from the final GPS position. Figure 1

shows a visual plot of the flight path for the final three segments and the ground impact position.

In addition to the accident flight, data was recorded for the five previous takeoffs. These were: the farm strip, Northweald and Bembridge on 16 August 2007, the farm strip on 18 August 2007, and Tibenham on 20 August 2007. Figure 2 shows the average ground speed and altitude data from all six takeoffs. Figure 2a shows the three recorded takeoffs from the farm strip (with the accident flight annotated), whilst Figure 2b shows the other three takeoffs, which were from paved runways. The individual plots are not aligned with any datum, but have been overlaid to allow direct comparison. An estimate of the point of lift-off is shown, based mainly on estimated headwind component.

Of the six takeoffs recorded by the GPS, it is likely that only one had a headwind component exceeding 10 kt. This takeoff is shown in Figure 2a as the blue plot of 18 August 2007 (headwind component about 15 kt). The other strip takeoff, on 16 August 2007 was with little or no headwind component. Of the hard surface takeoffs shown at Figure 2b, two were made at airfields with paved strip lengths of 837 m and 1,250 m (Bembridge and Tibenham) and one at North Weald, with 1,920 m available. The headwind component for these takeoffs is estimated to have varied between nil and 9 kt.

Pathology

Post-mortem examinations of the pilot and his daughter were carried out by an aviation pathologist. Amongst the pilot's significant injuries were fractures to both lower legs, a spinal injury and evidence of a relatively minor head injury. Although it could not be established for certain, the spinal injury may have caused some paralysis and the head injury had the potential to render the pilot unconscious. There was no evidence

Footnote

¹ A track log contains a sequence of data points, with each point containing time, aircraft position, instantaneous groundspeed, track and GPS altitude.

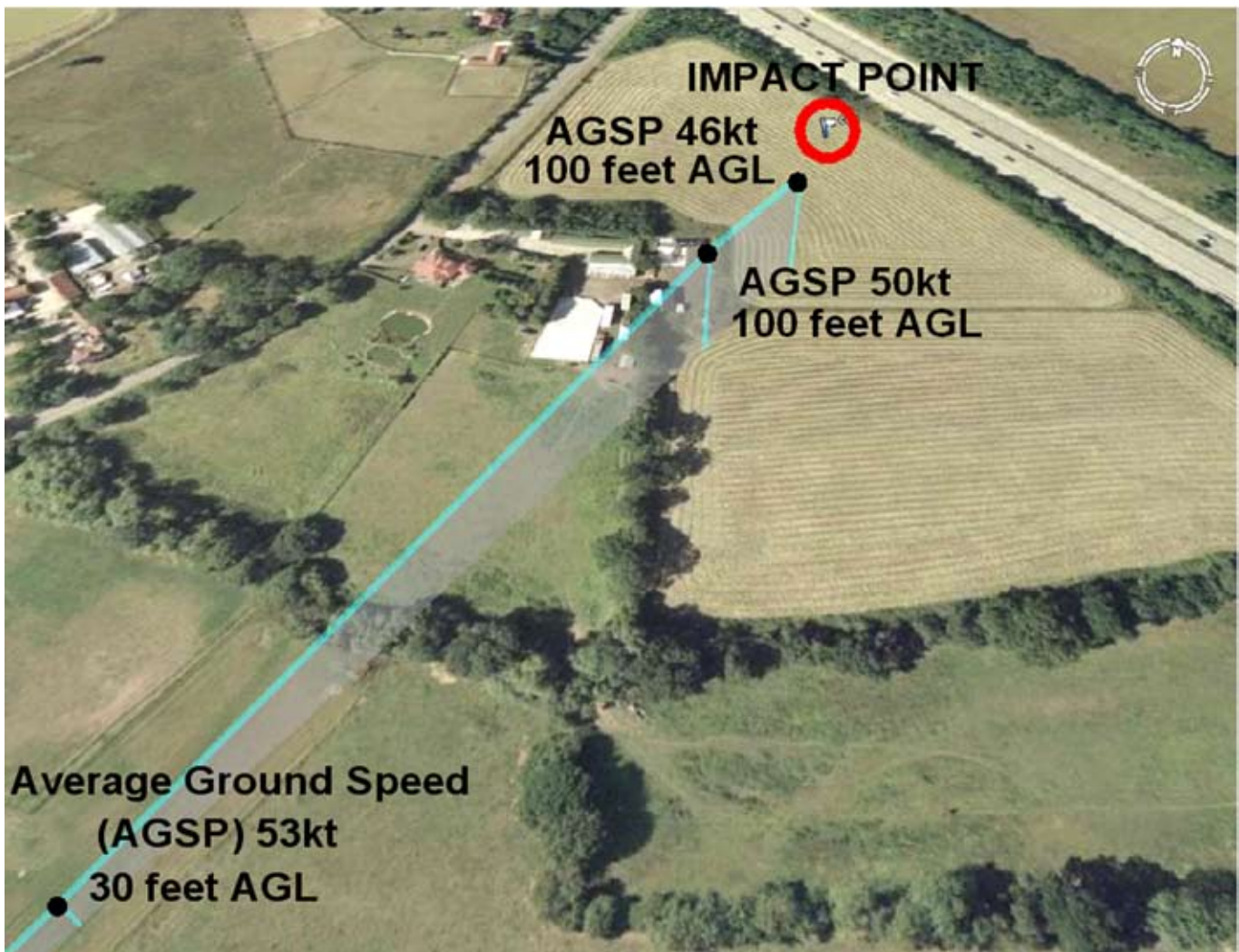


Figure 1

Visual plot of GPS data

of a pre-existing medical condition that could have contributed to the accident. The pathologist concluded that both the pilot and his daughter (who had remained secured in the car safety seat) had died from the effects of the post-crash fire.

Survivability

Despite the severe impact, the accident was survivable, but for the effects of the fire. The female passenger survived the accident with a laceration wound to her forehead, bruising, (some of which was consistent with wearing a seat harness at impact) and cuts. She could

not recall details of the final moments of the flight or the immediate post-crash events. Her first recollection was of sitting on the ground being attended by people from the stable yard. The survivor was therefore unable to say how she had escaped from the aircraft.

The aircraft was equipped with safety harness at each front seat position, and car-type lap straps for the rear seats. The front seat harnesses were of a four-point arrangement, with two lap straps and two shoulder straps meeting at a quick release fitting (QRF). Both front seat QRFs were recovered, along with a limited

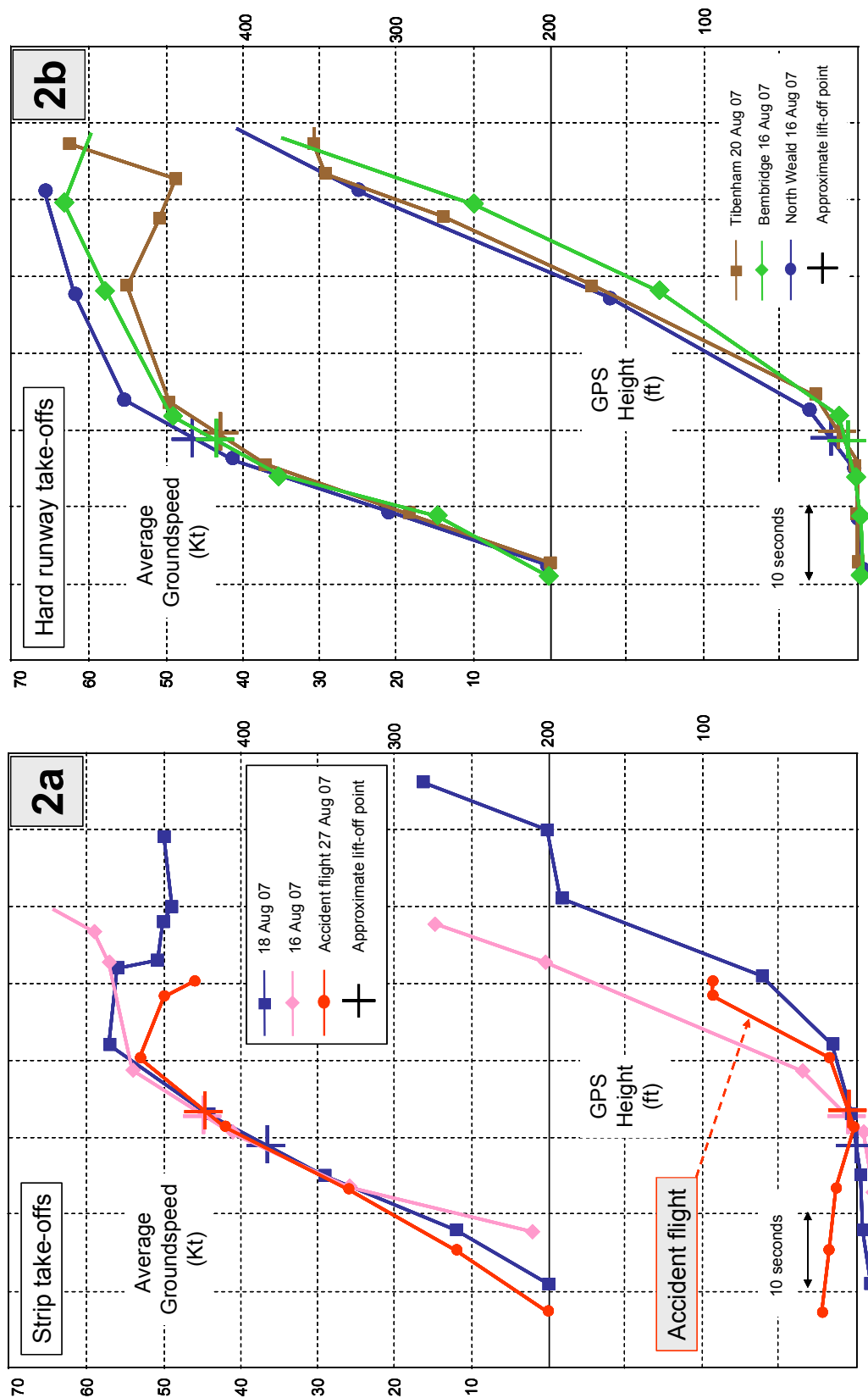


Figure 2

GPS data from previous takeoffs

amount of seat belt material. Each QRF, permanently attached to one lap strap, had recesses for the remaining strap lugs, which could be released simultaneously by rotation of the central part of the QRF against a light spring pressure. The front seat harnesses were anchored at three points (one for each lap strap and a combined point for the shoulder straps) to a transverse metal frame, which formed the internal rigid structure of the seat back. In the accident aircraft, the permanently attached lap straps were on opposite sides of the two QRFs, giving a symmetrical arrangement. However, when the harness arrangements on two other Bolkow 207s were examined, in each case the QRF was permanently attached to the right hand lap strap of both front seats.

When found, one QRF had the lugs still attached for the remaining lap strap and the right shoulder strap, but the left shoulder strap lug was missing. The other QRF had none of the free lugs still attached. Both QRFs were damaged by fire but, apart from some initial stiffness, operated correctly. Two shoulder strap lugs were found separately, with some seat belt material attached. One of these could positively be identified as belonging to the survivor's (right seat) harness; however it was not possible to determine which QRF was associated with which seat.

The farm strip

About the time that the pilot was undergoing his tailwheel conversion course, he negotiated an agreement to base his aircraft at the farm strip. The strip owner did not require any form of competency check to operate from the strip, but did brief the pilot on strip procedures. The person who administered the strip operation said that the pilot had informed her that he had sought expert advice on the suitability of the Bolkow 207 for strip operations, and she had the

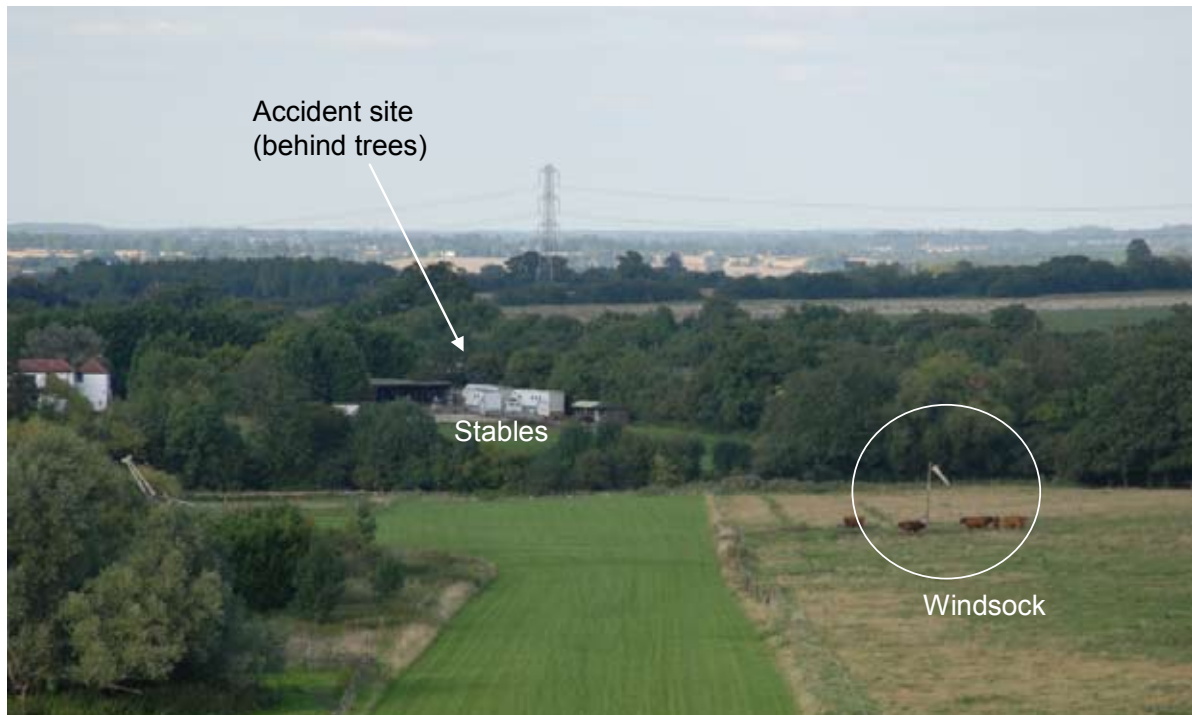
impression that this had been the instructor who had completed the pilot's tailwheel conversion.

The strip itself was 680 m from hedge to hedge, with an overall down slope of 1.6% in the northerly takeoff direction. The orientation of the strip was 028°/208°(M) and the mean elevation was 230 ft. A tree line crossed the upwind boundary, with further tree lines beyond, including on either side of the M25 motorway. The trees at the end of the strip were about 30 to 40 ft tall, but higher to either side. The taller trees in the vicinity reached an estimated 60 to 70 ft. The M25 ran in a cutting, approximately 290 m from the departure end of the strip. Beyond this was a large field, with power lines. Figure 3 shows the view from the police ASU helicopter whilst hovering over the strip, looking towards the accident site. The pylon is at a distance of 1,000 m from the strip.

Aircraft performance

Mass and balance calculations were made using the aircraft's known empty mass and estimates of the mass of the persons and additional items on board. From the aircraft's recent flying and fuelling history, it was estimated that about 22 imperial gallons were on board at the time of the accident, which was about half the fuel capacity of the aircraft. The estimated takeoff mass was 2,300 lbs, with centre of gravity at the forward limit. The maximum takeoff mass was 2,640 lbs.

A combined aircraft Operating Handbook and Flight Manual was recovered from the pilot's home, and a home-made plasticised check-list in English was found in the aircraft wreckage. As the aircraft was previously based in Germany, it is likely that the checklist was made by the pilot himself. Information from those who had flown with the pilot suggested that he routinely used the checklist. Part of a further plasticised document

**Figure 3**

Departure end of the strip

was recovered, which contained aircraft performance information and leading particulars. This document is also presumed to have been constructed by the pilot, as it was in English and bore his printed name.

The Flight Manual gave performance data for an aircraft of maximum mass in still wind conditions. At maximum mass in the ambient conditions, the distance required to clear a 50 ft obstacle was calculated as 493 m. However, this was for a hard, level runway, and did not include a safety margin. Although not specifically stated in the Flight Manual, the manufacturer's performance figures are only valid if the recommended flying techniques are used. The plasticised performance document found in the wreckage was damaged, but did include two performance figures, one believed to be a landing figure, and the other believed to be that of the takeoff distance to 50 ft, which was given as 480 m. This figure equated to the Flight Manual figure for a takeoff at a

temperature of 15°C. From the layout of the surviving part of the document, it was thought unlikely that it included any additional takeoff performance data, such as from grass runways.

For takeoffs from grass runways, it is widely recommended that a factor of 20% (a figure quoted in Civil Aviation Authority (CAA) publications and elsewhere) should be added to the Flight Manual figures, to account for the increase in rolling resistance and therefore ground run. This would increase the total distance required to clear a 50 ft obstacle to 591 m. Additionally, although private flights are not obliged to add further additional safety factors to the calculated performance figures, the advice from the CAA is to do so. A factor of 33% is recommended, to allow for variations in weather conditions or pilot performance. This would further increased the takeoff distance required by an aircraft at maximum mass to 786 m.

The Flight Manual gave an expected climb rate of 700 ft/minute at the best climb speed of 70 kt with the flaps up. The advice was to retract flaps from the takeoff setting only after clearing obstacles and achieving a safe altitude.

D-ENWA had recently undergone its annual Certificate of Airworthiness (C of A) inspection. This was carried out at a maintenance facility in Hampshire, under the supervision of the same person who had ferried the aircraft from Germany. He was a light aircraft engineer, CAA approved flight test pilot, and also a Bolkow 207 owner with considerable experience on the type. When the owner of D-ENWA delivered it to the maintenance facility, he expressed a concern that the aircraft may not be performing correctly. He thought that this may have been engine-related, but did not give any reasons for his concern. However, nothing was found which could have contributed to a lack of power. As part of the German C of A process, a flight test was conducted on 9 August 2007, 18 days before the accident. This test included a check of the aircraft's rate of climb through an altitude gain of 3,000 ft. Although the test report was passed to the pilot and has not been found, the test pilot was confident that the performance achieved by D-ENWA was typical of the type. This assessment was also passed verbally to the pilot.

Takeoff techniques

The normal takeoff technique for the Bolkow 207 was described in the Operating Handbook. It was to allow the aircraft tail to come up to the horizontal position during the takeoff roll, and to lift off at about 55 kt. The aircraft was then to be levelled just above the ground until reaching the climb speed of 70 kt. This is the technique the pilot would have learnt during his tailwheel conversion course.

The 'short field' technique differed from the normal technique; the Operating Handbook included the following information for a short field takeoff:

'Maintain a tail-low attitude (tail wheel on the ground) during take-off roll and let the aeroplane fly itself off at a speed of approx. 43 to 49 KTS'

and

'Push control column and keep aeroplane just above the ground until reaching a flying speed of 70 KTS'

For both types of takeoff, the recommended climb speed was 70 kt. This takeoff method would also be applicable to soft field takeoffs, or any occasion when it was deemed desirable to lift off as soon as possible (such as poor surface condition).

A friend of the pilot and fellow C172 group member who had flown with the pilot in D-ENWA on a few occasions, described his impressions of the strip and the pilot's techniques. He described the pilot as very diligent in his approach to flying, and appeared to be comfortable operating from the strip. He reported a noticeably better takeoff and climb performance from hard runways than from the strip. He felt that the strip did not allow room to accelerate to the climb speed, and would personally have preferred a longer strip to operate from. He thought that the pilot would generally climb the aircraft at a lower airspeed until clear of the trees before accelerating to the climb speed.

Aircraft stalling characteristics

According to the Operating Handbook, the aircraft tended to drop a wing when stalling with power applied and a slight sideslip. Recovery from the wing drop

could be made by timely application of aileron and rudder, combined with a relaxing of 'up' elevator input. With power off, the aircraft tended to naturally adopt a natural nose-down attitude as a result of flow separation until speed was regained. According to the Operating Handbook, the aircraft stall speed in straight and level flight with 15° flap, idle power and at maximum weight, was 54 kt. With power applied, the stall speed would be expected to be slightly lower. The aircraft was fitted with a stall warning indicator on the upper right side of the instrument panel, which was designed to operate at 5 to 8 kt above the actual stall, producing both visual and audible signals.

D-ENWA was deliberately stalled during its post C of A inspection flight test on 9 August 2007. The test pilot reported that the aircraft's stalling characteristics were as expected, and the aircraft readily recovered if the correct techniques were used. Speaking generally of the type, he described power-on stalls as being likely to generate a wing drop (usually the left wing), which could be quite sudden.

After a Bolkow 207 landing accident in May 2002, a test pilot from the CAA's Flight Department flew a Bolkow 207 with the intention of investigating the type's stalling characteristics. He reported that the aircraft was docile in the stall with no greater tendency to roll than other aircraft of that era. With 15 degrees of flap, an aircraft mass of 2,025 lb, and idle power, the stall warning occurred at 57 kt and the aircraft stalled at 55 kt, exhibiting a slight right wing drop. During further slow speed flight with go-around power set, it was noted that the aircraft did not depart from controlled flight despite the speed decaying below 50 kt, indicating that the stall speed had significantly reduced due to the airflow resulting from the applied power.

Analysis

General

From witness accounts, evidence from the crash site, and recorded data, it is clear that the aircraft failed to gain a safe height and speed after takeoff. It appears to have suffered a power-on stall, during which the left wing dropped and the aircraft descended rapidly from a height of about 100 ft. At the low height at which the aircraft stalled, it would not have been possible to regain controlled flight before the aircraft struck the ground.

The pilot had been correctly qualified to operate the German registered aircraft and to use it to carry passengers. He had also undergone training to familiarise himself with the characteristics of tailwheel aircraft and the Bolkow 207 in particular. However, during this training the pilot apparently did not request instruction or advice in short or soft field operations, and did not receive additional training in these specific techniques.

Technical examination

The aircraft was badly damaged in the accident, and much of the airframe was consumed in the post-crash fire. However, it was possible to state that the aircraft was correctly configured for takeoff, with an appropriate takeoff flap setting, trim setting and propeller pitch selection. A detailed examination of the engine revealed nothing that would contribute to a power loss. On the contrary, the engine appeared in good condition internally, and examination of the propeller blades showed that a high engine power was applied at the time of the accident. The propeller pitch change mechanism was also subject to a detailed examination and no pre-existing faults were found.

Accounts by eye witnesses, including the surviving passenger, indicated that the engine appeared to

be operating normally at a time when the aircraft was already in difficulty. Although the pilot had previously expressed some concern about the aircraft's performance, this had presumably been resolved to his satisfaction, otherwise it is unlikely that he would have embarked on a flight from the strip with his family on board. The C of A test flight showed that the aircraft's performance was typical of the type. Recorded GPS data from recent takeoffs showed a broadly consistent level of performance during the ground roll, and the aircraft was seen to lift off on the accident flight at a reasonable point along the runway.

The stall described by witnesses is typical of the type of stall which occurs when engine power is applied. In this case the aircraft would be expected to stall at slightly lower airspeed, and be more likely to suffer a wing drop. Such stalls, though delayed in onset when compared to power-off stalls, are normally more pronounced when they do occur.

The loss of airframe components meant that it was not possible to rule out a partial power loss due to other causes, such as an airframe fuel supply problem (though it is known there was adequate fuel on board for the planned flight). However, the available evidence supports the conclusion that the aircraft's engine and propeller combination was developing a significant amount of power at impact, and that their operation was not a contributing factor in this accident.

Aircraft performance

The performance data in the Operating Handbook was valid for hard runways only, and required factoring to produce equivalent figures for a grass runway. It must be presumed that the pilot was aware of the need to factor the figures since this is well publicised, though the performance figures on the card recovered from the

aircraft were not factored. Nevertheless, the aircraft was capable of taking off from the grass strip on the day of the accident.

The performance data also assumes a standard level of pilot performance; it does not include an allowance for incorrect or variable techniques. Although not mandatory, if such a factor had been applied (as recommended by the CAA), the takeoff distance required at maximum weight would have exceeded that available by about 100 m. However, the aircraft was an estimated 340 lbs below its maximum weight, was taking off down-slope and had the advantage of a slight headwind component, so it should have been capable of taking off safely².

Takeoff technique

When the pilot carried out his tailwheel conversion course he would have learnt the normal takeoff technique in which the tail is raised as the aircraft accelerates and the aircraft lifts off at around 55 kt IAS. However, the short field technique differed in that the aircraft was kept in a tail-low attitude until lift off; this was described in the Operating Handbook. Using this technique, the aircraft would become airborne at the slowest possible speed, but also only just above its stall speed and in a high-drag attitude. In both cases the correct technique was to accelerate just above the runway until reaching the climb speed of 70 kt.

While an aircraft of this kind is just above the ground after takeoff, it benefits from the advantage of 'ground effect' which impedes the development of vortices associated with high-lift conditions, and therefore less induced drag results. However, if the aircraft is flown

Footnote

² The adequacy of the strip length is discussed in this report only with respect to this accident. It is not unusually short for a private strip and other types frequently operate from the strip without difficulty.

out of ground effect without first accelerating, induced drag increases markedly as these vortices develop. If the aircraft does not have sufficient power, it may be unable to climb further, or may fail to clear obstacles under the takeoff flight path. This scenario is a potential risk area for all aircraft, but is normally associated with tailwheel aircraft because of their natural tail-low configuration. By accelerating to the best climb speed, a much improved ratio of lift to drag is achieved, allowing the aircraft to climb safely and efficiently.

The GPS data, when corrected for the light headwind, showed that the aircraft's average airborne airspeed was well below the recommended climb speed, the average over the last 50 m segment being about 51 kt. Although the aircraft did climb initially, this appears to be at the expense of airspeed, which reduced during the period of recorded airborne data.

The recorded data also showed previous occasions when the initial climb profile exhibited similar characteristics to the accident flight. This is most notable in the data for 18 August 2007. Although on this occasion the aircraft was climbing into a stronger headwind (about 15 kt), this alone would not account for the significant sustained drop in groundspeed combined with almost level flight over a 10 second period. The takeoff on 16 August was made in very light crosswind conditions so any headwind effect would have been minimal. On this occasion airspeed was also low and increased only slowly as the aircraft climbed.

It is probable that the pilot of D-ENWA had adopted a strip takeoff technique in which he elected to fly the aircraft away from the ground at low airspeed before accelerating to the normal climb speed. Even if the aircraft had been a few knots above the lift off speed, as is probably the case on the day of the accident, there

would have been reduced climb performance and little margin above the stall. Any attempt to increase the climb rate would risk placing the aircraft further into the low speed / high drag scenario already described.

It is not known at which point the pilot adopted this takeoff technique. It is probable that he had been using the technique for some time without appreciating the potential danger, and it may be the reason for the apparent lack of performance which he reported at the time of the aircraft's C of A check.

The takeoff technique which the pilot is believed to have used would have degraded the aircraft's overall takeoff performance, and brought it closer to obstacles under its flight path. The pilot's decision to adopt the technique is presumed to be due to his perception that the strip would not allow the correct technique to be used, and still be able to clear the trees at its end. This may have been heightened when taking off in a northerly direction by the downward slope of the strip, which may have created an illusion that the trees were higher than they really were. Additionally, the stable complex would have been sensitive to noise, which would have been a further incentive to achieve a reasonable height as soon as possible. Although the pilot did not routinely fly in strong winds, the lack of significant headwind (probably only 5 kt) on the day of the accident may also have been a contributory factor.

The stall

From the surviving passenger's account, it is clear that the pilot was aware that the aircraft was not performing correctly, but that he did not know why. With the engine running normally, the lack of performance would have been confusing if the pilot had not fully appreciated the dangers of attempting to climb at too low an airspeed. At low height and with the trees ahead, his natural instinct

would have been to try to climb by raising the nose (the trees to each side being higher). If this had been his reaction, the effect would have been to further degrade the aircraft's climb performance and place it closer to the point of stall.

A forced landing into the field in which the aircraft crashed would not have been an option by the time the pilot realised the aircraft was not performing as expected. The only available landing area at that stage was in the large field beyond the motorway. The pilot would have been aware of the presence of the motorway, and the need to maintain height in order to clear it. The shortest route to the area would have required a right turn through about 20°, and it may be this was the reason the aircraft was seen to start a right turn. Unfortunately the aircraft slowed to a point where it stalled before the pilot could reach the open area.

Conclusion

The aircraft failed to achieve a safe height or speed after takeoff and stalled. The available evidence indicated

that the pilot's takeoff technique was incorrect, in that he attempted to climb above obstacles under the takeoff flight path before accelerating the aircraft to a safe speed. The aircraft was correctly configured for takeoff, and there was evidence that the engine was operating normally.

The pilot was known to be diligent and conscientious, but it is unlikely that he sought professional advice on takeoff techniques applicable to the private strip, so he was probably unaware of the dangers associated with the takeoff technique he had adopted. Faced with a confusing and deteriorating situation so soon after takeoff, the pilot probably attempted to reach an open area beyond the M25 motorway, but the aircraft stalled before he could do so. Once the aircraft had stalled, there would not have been sufficient height to regain controlled flight.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28R-201T, Turbo Cherokee Arrow III, G-JMTT	
No & Type of Engines:	1 Continental TSIO-360-FB piston engine	
Year of Manufacture:	1978	
Date & Time (UTC):	9 April 2007 at approximately 1050 hrs	
Location:	9 nm south of Oban (North Connel) Airport, Argyll and Butte, Scotland	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - 1
Injuries:	Crew - 2 (Fatal)	Passengers -1 (Fatal)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	56 years	
Commander's Flying Experience:	324 hours (of which 43 were on type) ¹ Last 90 days - unknown Last 28 days - 2 hours ²	
Information Source:	AAIB Field Investigation	

Synopsis

The commander was planning to return to Andrewsfield Airfield, Essex, from Oban Airport after a weekend of touring with his family. The weather was poor and the commander (who was not IMC or instrument rated) said to the Air/Ground operator at Oban that he would depart "to have a look at the weather" and then return to Oban if it was not suitable. The aircraft departed Oban at 1035 hrs and the Air/Ground operator lost sight of it shortly thereafter due to the poor visibility as it headed west at approximately 1,000 ft amsl. The commander subsequently transmitted to Oban that he was changing to the en-route ATC frequency. Nothing was subsequently heard from the aircraft by any other ATC agency. The wreckage of the aircraft was discovered by a farmer the

following day in the hills, 9 nm south of Oban Airfield. No technical fault with the aircraft was found apart from evidence of a pre-impact failure of the vacuum pump which would have caused the Attitude Indicator to become unreliable. The characteristics of the final flight path, particularly the high airspeed, the rapid descent and the rate of turn, were consistent with a loss of control following spatial disorientation in IMC. The vacuum

Footnote

¹ Hours on 13 September 2006 (last entry in the commander's logbook) plus 7 hours logged in the co-pilot's logbook which refer to him as the commander. This does not include his previous microlight flying or twin engine training, as noted, by him, at the beginning of his logbook.

² From aircraft log sheet.

pump failure, the commander's lack of instrument flying training and his apparent high blood alcohol level, all contributed to the spatial disorientation. This report contains four Safety Recommendations relating to the maintenance of vacuum pumps.

Background information

G-JMTT departed Andrewsfield Airfield, Essex, where it was based, for Oban (North Connel) Airport, Argyll and Butte, at 1155 hrs on Friday 6 April 2007, for a weekend of touring. On board were three occupants; a married couple and their daughter. The aircraft was owned by a syndicate of five people which included the father and daughter, both of whom were pilots. The father went away most Easter weekends in the aircraft and had reserved it, in the syndicates planning diary, several months in advance. Due to the father's greater flying experience and due to the fact that he was seated in the left seat, he was assumed, for the purposes of this investigation, to be the commander, and the daughter, in the right seat, to be either a passenger or acting to assist the commander. However, it had become the practice of these two pilots always to occupy the same seats, with the daughter sometimes being pilot-in-command whilst still occupying the right-hand seat. It is therefore not possible to state with certainty which of the two was in command, but throughout this report, for simplicity, the father will be referred to as the commander and the daughter the co-pilot. The mother occupied a seat in the rear of the aircraft. The occupants sat in these seats on all subsequent flights. The aircraft landed en-route at Blackpool Airport, Lancashire, at 1344 hrs for a refuelling stop and departed at 1451 hrs; it landed at Oban at 1630 hrs.

On 7 and 8 April 2007, G-JMTT and its three occupants flew out of and returned to Oban once per day. After landing on 8 April 2007, the aircraft was refuelled to full

by the Air/Ground Operator (AGO), in preparation for its return journey the following day. That evening all three occupants went to dinner at a local hotel, where they were seen to consume alcohol.

History of the flight

On the following day, 9 April, the three occupants arrived at Oban at around 1000 hrs and were witnessed by the AGO to go straight to G-JMTT and load their luggage. They then went to the airfield's office where the AGO had obtained Met Forms 214³ and 215⁴ and the southern UK TAFs from Met Fax⁵. On reading the weather information, the commander noted that it was clearer in England and said in conversation with the AGO he was not instrument rated. The AGO did not ask if he had an IMC rating. He then said to the AGO that he would get airborne "to have a look at the weather" and if it was not suitable he would return to Oban. The AGO said that this would not be a problem and if they did so they would not incur any additional landing charges.

The Airport Manager and the AGO saw G-JMTT, start up, taxi out and observed an engine check being carried out before it took off at 1035 hrs. After takeoff, they saw it fly due west before losing sight of it in the poor visibility, at approximately 1,000 ft amsl. After approximately five minutes, the AGO received a transmission from the commander saying that they were at 1,500 ft amsl and were changing to the en-route frequency. The AGO gave them the

Footnote

³ Met Form 214 is a spot wind chart showing wind speed and direction and temperature for standard levels up to FL240. It is updated four times a day.

⁴ Met Form 215 is a low level weather chart and text showing a graphical display of areas of different weather up to FL100. It is updated four times a day.

⁵ Met Fax is a service provided by the Met Office that allows the user to receive a copy of the latest aviation weather information direct to a fax machine.

appropriate Scottish ATC frequency and informed them that they were unlikely to receive a reply until they were further south; this was due to the high terrain. The commander acknowledged this but did not read back the frequency. Due to the AGO's concerns about the weather he phoned Scottish ATC, at approximately 1155 hrs, to enquire whether G-JMTT had made contact with them; it had not.

The commander had not filed a flight plan for the return flight to Andrewsfield, nor was he required to do so. The AGO believed that he was planning to stop at Blackpool for fuel, as he did on the outbound journey, but he had not booked to land at Blackpool, although this was required. The next day, 10 April 2007, at 1340 hrs, a farmer who was out in the hills above his farm came across the wreckage of an aircraft. He returned home and contacted the police who arrived at the scene at 1524 hrs. The wreckage was later confirmed to be that of G-JMTT.

Aircraft description

G-JMTT was an all-metal low-wing Piper PA-28R-201T aircraft (See Figure 1), powered by a single turbocharged Continental TSIO-360-FB piston engine and a two-bladed variable-pitch Hartzell propeller. It had retractable landing gear and was configured with four seats and dual flying controls in the front. It had a maximum takeoff weight of 2,900 lb and a



Figure 1

Piper PA-28R-201T, G-JMTT

published cruise speed of 147 kt at 6,000 feet with a power setting of 75%.

G-JMTT was equipped with three gyroscopic instruments to assist with instrument flight: a vacuum-driven Attitude Indicator (AI), an electric Horizontal Situation Indicator (HSI), and an electric Turn Coordinator (all shown in Figure 2). The vacuum pressure to the AI was supplied by an engine-driven Parker Airborne 211CC vacuum pump. The level of suction supplied by the pump was indicated on a suction gauge located on the right side of the instrument panel (No 8 in Figure 2). A warning light on the upper left side of the instrument panel (No 7 in Figure 2) illuminated if the suction dropped below a level sufficient to operate the AI. An optional backup/auxiliary vacuum pump was not fitted to G-JMTT.

The aircraft was also fitted with a Century III autopilot which used the vacuum-driven AI as its attitude reference source. The autopilot (AP) had four modes: Roll, Heading, Altitude and Pitch. Altitude mode was a pitch mode that used the pressure from the altimeter to command the AP to maintain the pressure altitude at the time the mode was engaged. If the AI instrument failed and supplied erroneous attitude information to the AP, then the AP would not function correctly and would not be able to hold a heading or an altitude.

Aircraft operating weight

The basic weight of G-JMTT was 1,849 lb and the Maximum Takeoff Weight (MTOW) was 2,900 lb. The total useable fuel capacity was 72 US gallons which equates to 432 lb. The combined weight of the three occupants was approximately 672 lb. The personal belongings recovered by the police from the crash site weighed 128 lb. The aircraft departed Oban with full fuel so it therefore had an estimated takeoff weight of 3,081 lb which was 181 lb above the MTOW.



Figure 2

G-JMTT cockpit instrument panel before the accident

Instrument descriptions: (1) Airspeed Indicator; (2) AI; (3) Altimeter; (4) Turn Co-ordinator; (5) HSI; (6) Vertical Speed Indicator; (7) Vacuum pump pressure warning light; (8) Suction gauge

Maintenance history

The aircraft was maintained in accordance with the Light Aircraft Maintenance Schedule (LAMS). The aircraft's last maintenance was an annual inspection which was completed on 27 February 2007 when the aircraft had logged 3,474 hours. At the time of the accident the aircraft had logged approximately 3,490 hours and the engine 1,391 hours. The vacuum pump was installed on the engine on 2 June 1995 when the engine had logged 397 hours, so the pump had been in service for 11 years 10 months and had accumulated approximately 994 hours at the time of the accident.

Weather information

Aftercast

An aftercast was obtained from the Met Office. It stated that the synoptic situation at 1200 hrs on 9 April 2007 showed a warm front orientated north to south over

western Scotland and into northern England. A generally fresh, westerly flow prevailed over the area. The front reached Oban at 1130 hrs and although weak was associated with outbreaks of slight rain and drizzle, from what was an extensive layer of cloud with a base that was variable but low. Rain and drizzle were, the report indicated, most likely over the mountains of Scotland, especially on windward (west facing) slopes. Below the cloud base, visibility would be reduced in precipitation and areas of mist. Hill fog would have been extensive in the region, especially on west facing slopes. In summary, the report stated that between 1000 hrs and 1200 hrs Oban would have experienced varying visibility in the range 4,000 metres to 10 km and greater. Hill fog would have been extensive over the surrounding hills, with visibility less than 200 metres. The cloud was likely to be scattered or broken stratus with a base varying from 400 ft to 1,500 ft, and a top of 2,000 ft with broken or overcast stratocumulus with a

base varying from 2,000 ft to 3,000 ft, and top varying 5,000 ft to 7,000 ft, scattered or broken layers of altocumulus between 7,000 ft and 9,000 ft and little or no altocumulus in thin, well-separated layers between 9,000 ft and 20,000 ft. The mean sea level pressure was 1014 mb rising to 1015 mb during the period 1000 hrs to 1200 hrs in the Oban area. The 0° C isotherm was likely to have been at 5,900 ft. It is likely that airframe icing conditions existed in the height range 5,900 ft to 9,000 ft and possibly in the range 5,500 ft to 9,000 ft.

At 1000 hrs and 1100 hrs there were automatic reports from a station some three miles north-east of Oban. These reports indicated a light west-south-westerly flow, with temperature of 10° or 11° C, and dew point of 10° C. The temperature and dew point data are indicative of low cloud and/or mist conditions.

Oban (North Connel) Met information

There were no TAFs or METARs available for Oban. However, an observation was taken at 0930 hrs on 9 April 2006, by the AGO. This indicated that the surface wind was from 230° at 12 kt, the visibility was 7 km, there was no significant weather, although there had been recent rain and drizzle. There was scattered cloud at 500 ft aal and broken cloud at 1,000 ft aal. The temperature was 11° C and the mean sea level pressure (QNH) was 1015 mb.

Airfield information

Blackpool Airport

Blackpool Airport was operating as a 'Prior Permission Required' (PPR) airfield from 6 to 9 April 2007 due to forecast congestion over the Bank Holiday weekend and as such NOTAM number C1565/07 was issued. When the commander of G-JMTT requested permission to land at Blackpool on 6 April 2006, ATC asked him for his PPR number; he did not have one. ATC subsequently obtained one from the handling company and G-JMTT was given

clearance to land. A PPR number for G-JMTT's return journey was not issued prior to it departing Oban.

Oban (North Connel) Airport

Oban was also a PPR airfield, and aircraft landing at Oban were required to give at least three hours notice. When G-JMTT landed at Oban on 6 April 2006, without such permission, the AGO raised the matter with the commander, who expressed surprise.

Visual Flight Rules

The rules for VFR flight in the UK are published in the UK Aeronautical Information Package, section ENR 1-2-1. It states:

'1 VFR Flight

VFR flights shall be conducted so that the aircraft is flown in conditions of visibility and distance from clouds equal to or greater than those specified in Table 1 below:

Table 1

<i>Airspace Class</i>	<i>F or G [uncontrolled airspace]</i>
<i>Height</i>	<i>Below FL 100</i>
<i>Distance from cloud</i>	<i>1500 m Horizontally and 1000 ft Vertically</i>
<i>Flight visibility</i>	<i>5 km (3)</i>

Notes:

(1) Or if at 3000 ft or below and flying at 140 kt or less: Clear of Cloud and in Sight of the Surface.

(3) Or if at 3000 ft or below:

*either: any aircraft flying at more than 140 kt:
Clear of Cloud and in Sight of the Surface in a
Flight Visibility of 5 km.*

or: any aircraft flying at 140 kt or less: Clear of Cloud and in Sight of the Surface in a Flight Visibility of 1500 m.'

However, Part A, section 1, sub-section 1 to Schedule 8 of the Air Navigation Order states the following:

'Privileges:

(1) Subject to paragraph (2), the holder of a Private Pilot's Licence (Aeroplanes) shall be entitled to fly as pilot in command or co-pilot of an aeroplane of any of the types or classes specified or otherwise falling within an aircraft rating included in the licence.

(2) He shall not:

(c) unless his licence includes an instrument rating (aeroplane) or an instrument meteorological conditions rating (aeroplanes), fly as pilot in command of such an aeroplane:

(i) on a flight outside controlled airspace when the flight visibility is less than 3 km;

(ii) on a special VFR flight in a control zone in a flight visibility of less than 10 km except on a route or in an aerodrome traffic zone notified for the purpose of this sub-paragraph; or

(iii) out of sight of the surface;'

Pilots' licences

Part of the Private Pilot's Licence (PPL) syllabus included an appreciation of instrument flying. During this element of the syllabus the student pilot has his external vision artificially restricted so as to simulate flying in IMC. During the PPL skills test, the pilot is required to demonstrate a rate 1 turn (3°/sec) through

180° using an appropriate angle of bank under simulated IMC, in order to show that he can safely regain Visual Meteorological Conditions (VMC) if he inadvertently encounters IMC.

Commander's licence

The commander gained his UK (PPL) on 10 March 1980 and it was valid for life. This permitted him to fly in VMC only. He had been observed flying in cloud, on occasions, by witnesses at Andrewsfield and with members of the syndicate.

The last entry in his logbook was 13 September 2006. However, after this date there were seven entries in the co-pilot's logbook that state the commander of these flights was the commander of the accident flight.

Co-pilot's licence

The co-pilot gained her JAR PPL on 4 October 2000; but, it was not renewed and expired on 3 October 2005. She renewed her Single Engine Piston (Land) rating on 23 July 2005 and this rating was then valid until 8 September 2007.

Prior to 2000 the CAA issued a UK PPL which was valid for life. In 2000 the CAA started issuing JAR PPLs which only had a five year validity. The CAA did not send out renewal reminders in 2005 to pilots who had obtained their JAR PPL in 2000. As a result, numerous pilots were later found to be flying on expired licences. In late 2006 the CAA started sending out renewal reminders to remedy this problem.

Medical information

Commander

The commander had held a JAA Class II medical certificate since March 1997. This carried a limitation requiring him to wear corrective lenses.

In December 2002, as a result of a heart condition, the commander was required to have an annual exercise Electrocardiogram (ECG). His last exercise ECG was in August 2005 and his Class II medical certificate was renewed on 1 November 2005. This expired on 1 November 2006. As he had not submitted a new exercise ECG he was declared medically unfit by the CAA on 15 January 2007. This was an administrative procedure that would highlight the fact that he had not done a recent exercise ECG if he applied for a new medical.

Co-pilot

The co-pilot held a valid JAA Class II medical certificate which was due to expire on 13 September 2010. This carried a limitation requiring her to wear corrective lenses.

Medical examination

Post-mortems were carried out on all three occupants by two Crown Office pathologists. They concluded that the cause of death was as a result of multiple injuries and the crash was not survivable.

Conclusive examinations for disease were not possible, but there were no obvious visible signs of disease affecting the occupants. Screening for drugs was negative in all three occupants: but both the commander and the co-pilot had positive readings for alcohol. The commander had a muscle alcohol concentration of 104 mg/100ml. The toxicologist regarded this as being equivalent to a blood alcohol concentration of 99 mg/100 ml. The co-pilot had a muscle alcohol concentration of 50 mg/100ml. The toxicologist regarded this as being equivalent to a blood alcohol concentration of 48 mg/100 ml. The pathologists and toxicologist could not entirely exclude the possibility that some of this alcohol may have been produced post-mortem as part

of normal decomposition, although it was thought that this was unlikely to be a significant amount. The third occupant's muscle sample tested negative for alcohol.

Part 5 of the Railways and Transport Safety Act 2003, 'Aviation: Alcohol and Drugs,' states the following in paragraph 93:

'Prescribed limit:

(1) A person commits an offence if—

(a) he performs an aviation function at a time when the proportion of alcohol in his breath, blood or urine exceeds the prescribed limit.'

The prescribed blood alcohol limit is 20 mg/100 ml.

Alcohol and flying

Flying an aircraft is a highly demanding cognitive and psychomotor task that takes place in an inhospitable environment where pilots are exposed to various sources of stress. The majority of the adverse effects produced by alcohol relate to the brain, the eyes, and the inner ear, three crucial organs to a pilot.

It is advised to have a minimum gap of eight hours between consuming even a moderate amount of alcohol and flying. It is difficult to define a 'moderate' amount as individuals metabolise alcohol at different rates. However, it has been said that the average person metabolises one unit of alcohol every one to two hours, which suggests that any more than, for example, two pints of medium strength beer, ie four units, would perhaps require eight hours to metabolise out of the average person's system. Some people may be slower to metabolise the alcohol. This eight hours gap does not mean that a pilot would be in the best physical condition to fly, or that his blood alcohol concentration

would necessarily be below the legal limits. A more conservative approach is to wait 24 hours from the last use of alcohol before flying and this is especially true if intoxication occurred. Folk-law cures such as cold showers, drinking black coffee or breathing 100% oxygen cannot speed up the elimination of alcohol from the body.

According to some studies, the number of serious errors committed by pilots dramatically increases at or above concentrations of 40 mg/100 ml blood alcohol. This is not to say that problems do not occur below this value. Some studies have shown decrements in pilot performance with blood alcohol concentrations as low as 25 mg/100 ml.⁶

Recorded data

The aircraft was not equipped with any crash protected recording devices, nor was it required to be so equipped. However, examination of installed equipment that has been damaged during an accident can yield some recorded information. The aircraft was fitted with a Garmin GNS 430 panel-mounted GPS unit. This unit has a moving-map display and a built-in communication and navigation radio. On examination, it was found that the internal battery that maintained the unit's memory had become detached during the accident, erasing the aircraft's last recorded position and last selected communication and navigation frequencies.

The aircraft was also tracked by the Lowther and Tiree radar installations.

There are two types of radar, primary and secondary. Primary radar detects the position of an aircraft by

rapidly sending out pulses of radio waves through its rotating radar 'head' and processing the returned signals that have bounced back off aircraft. This gives distance and bearing of the aircraft from the radar installation, but no altitude information. Secondary radar works in a similar fashion but in this case the pulses of radio waves are actually communication messages that are being sent to equipment on the aircraft. The aircraft system responds to these messages by transmitting an assigned identity code and pressure altitude (if selected) in hundreds of feet back to the radar installation. Secondary radar provides distance and bearing information as well as aircraft identity and altitude but is reliant on the aircraft systems being operational. Secondary radar tracking can be lost if the aircraft suffers an electrical power failure, or the aircraft system is switched off, or if the aircraft attitude is such that there is no direct path between the radar head and the antenna on the underside of the aircraft.

Both Lowther and Tiree have primary and secondary radar heads. Due to the distance between the aircraft and these radar installations, combined with the terrain in between, the radar tracks do not cover the accident flight from beginning to end. Figure 3 shows the departure airfield, the radar tracks recorded by the Tiree and Lowther radar installations and the location of the accident site. It is worthy of note that the two tracks do not exactly coincide. This is an illustration of the magnitude of the random errors that are involved with radar returns when used at this very small scale, and shows why a detailed description of the manoeuvring of the aircraft from point to point would not be valid. Similarly, speed calculations derived from these points are prone to large errors. The strength of the radar data, when used at this very small scale, is in the motion trends.

Footnote

⁶ Medical Facts for Pilots, FAA Publication AM-400-94/2 by Guillermo Salazar, M.D. and Melchor Antuñano, M.D.

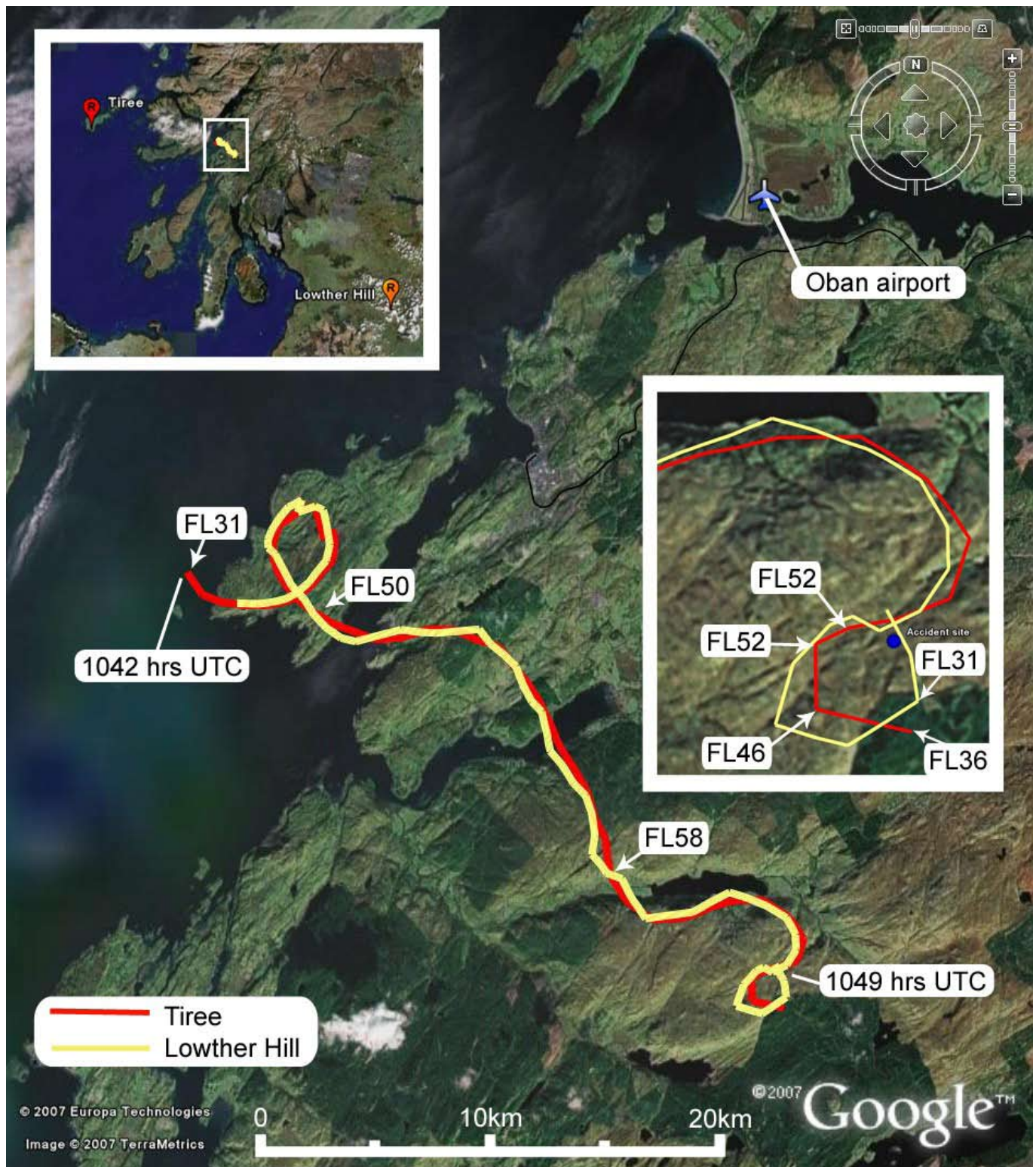


Figure 3
Overview of recorded radar tracks

Figure 4 shows the altitude data from secondary radar returns and the speed calculations derived from the positional information. All times quoted are in UTC, one hour behind the local time. All altitudes quoted are corrected for the air pressure at sea level of 1015 mb at the time but are only approximate due to the limited 100 ft resolution of radar altitude data. This gives altitude above the mean sea level (amsl) and not height above ground level.

The radar returns started at 1042 hrs with the aircraft approximately 7.5 nm south-west of Oban Airport. Terrain would have obscured any aircraft in the area between this first contact and Oban Airport below roughly 2,200 ft, with patchy coverage above this. The radar tracks showed the aircraft in a climbing left hand turn, passing through 3,300 ft. The aircraft did a complete circle over the Isle of Kerrera, 8 nm south-west of Oban, and then took a wandering path

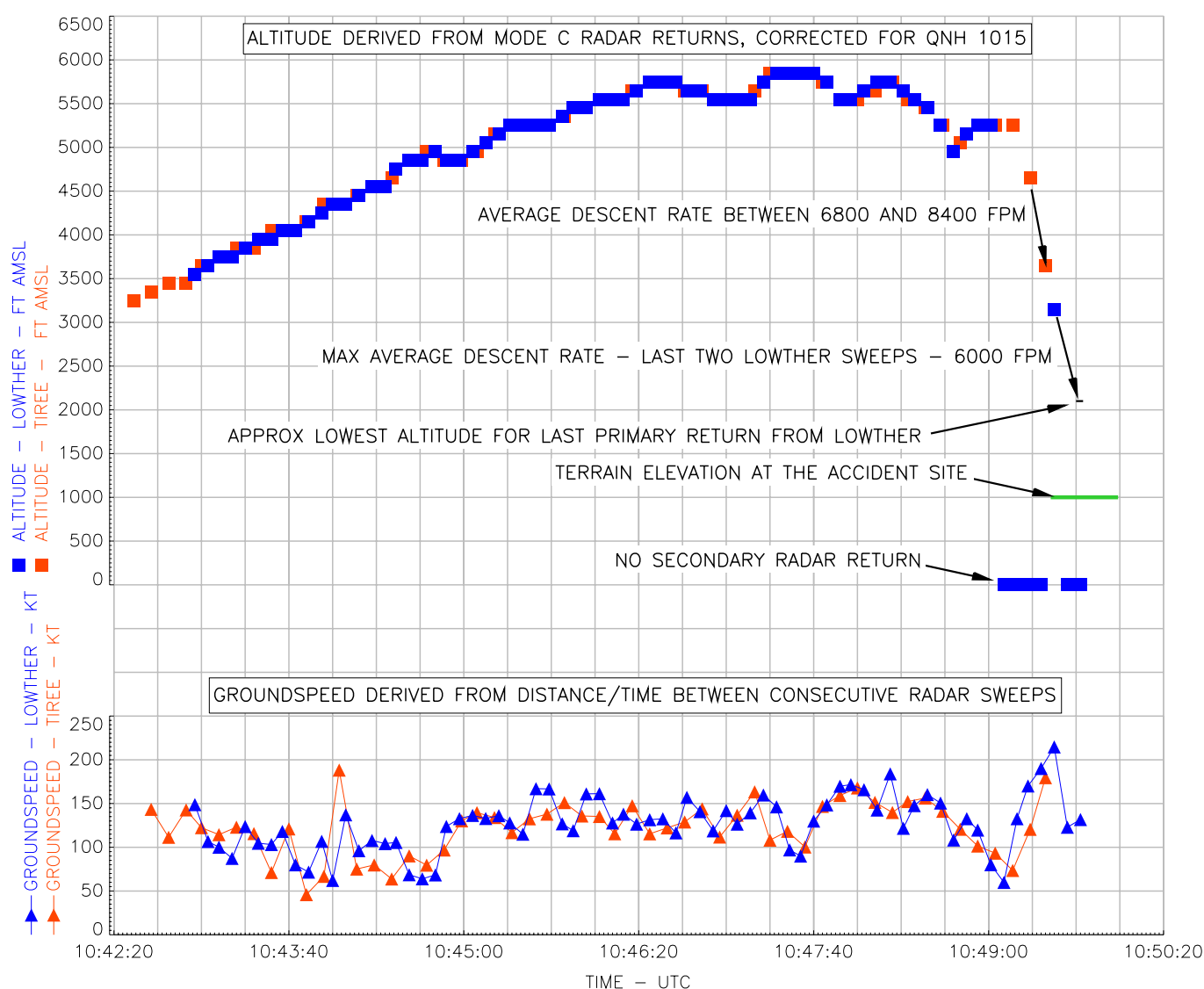


Figure 4

Altitude and time information for the Lowther and Tiree radar tracks

centred on a south-easterly track, carrying on the climb to approximately 5,800 ft and then varying in altitude between 5,600 ft and 5,900 ft. At 1048 hrs the aircraft altitude reduced to 5,300 ft. The radii of the turns during the roughly south-easterly track had been reducing during the flight. Approximately 30 seconds after levelling at 5,300 ft the aircraft entered a left turn with a radius of approximately a quarter of a nautical mile. Tiree radar recorded that the altitude during this turn dropped from 5,300 ft to 4,700 ft and then to 3,700 ft in under 16 seconds, indicating an initial descent rate of between 3,800 and 5,300 feet per minute (ft/min), accelerating to between 6,800 and 8,400 ft/min. This altitude loss was during a period when Lowther had lost secondary radar tracking of the aircraft for over 23 seconds. Lowther secondary radar then picked up a final secondary return at approximately 3,200 ft, further round in the turn. This was followed by two primary returns, showing the aircraft tracking north before dropping off radar entirely at 1049 hrs. It is calculated that Lowther primary radar can detect aircraft down to approximately 2,100 ft at the last radar return point. This limits the altitude loss between the last secondary return and the last primary return, 11.6 seconds later, giving a maximum descent rate of 6000 ft/min. This shows a reduction in the descent rate just before the track was lost.

Again using the calculated 2,100 ft line of sight limit of Lowther Hill radar at the point when the track was lost, the aircraft had 1,100 ft or more further to descend before reaching the terrain. Also of note is that analysis of the accident site indicated a southerly track on impact. This would indicate that in the last 1,100 ft or so of flight the aircraft manoeuvred so as to carry out at least half a complete turn, possibly additional complete rotations, and end up 150 metres to 350 metres in the reverse direction of its last recorded track.

The availability of altitude information shows that there was electrical power available on the aircraft throughout at least the first half of the final turn and rapid descent manoeuvre. The combination of a good primary radar return but no secondary return from the same radar head, as was the case with the end of the Lowther Hill track, shows that the line of sight between the radar head and the aircraft was good and that there must be another explanation for the loss of the secondary radar return. The loss of secondary radar returns from one radar head when it is present from another radar head, as was the case just prior to the last valid secondary radar return recorded by Lowther Hill, shows that the loss is not associated with a problem with the aircraft transponder. This combination of good line of sight between radar and aircraft and an operational transponder on the aircraft, may indicate that the attitude of the aircraft hid the aircraft secondary radar transponder antenna from the Lowther Hill radar installations. This can be accomplished by presenting more than usual of the top of the aircraft to the radar. This is indicative of a pitch and roll attitude that is normally only encountered during high speed turns or unusually high pitch attitudes climbing away from the radar or large nose-down attitudes in descent towards the radar.

In summary, the radar data shows the aircraft climbing to, and holding, a relatively stable cruise altitude but with no set direction. Turns were initiated, culminating in a relatively tight turn associated with a large descent rate and unusual aircraft attitudes. Electrical power was available at least until nearly the end of the last recorded turn, well after the tight descending turn was initiated. Given the location of the end of the radar track relative to the accident site location and disparity between the direction of the last recorded track and the estimated impact direction at the accident site, the aircraft carried out at least one further half turn between loss of the

radar track and impact. It is also possible that it carried out further complete turns or other manoeuvres below radar coverage. The time between the loss of radar track information and impact is not known.

Accident site and wreckage examination

The aircraft crashed on a hillside near Bragleenmore Farm, approximately 9 nm south of Oban Airport. The accident site elevation was 963 feet on undulating terrain with a nearby hill with a peak of 1,433 feet. The initial impact crater was consistent with the aircraft having made a high speed nose-down impact with a slight right bank. The fuselage had suffered severe disruption at initial impact and remnants of the cockpit and the engine travelled a further 32 metres before coming to rest. The wreckage field extended for a maximum distance of 95 metres with the lighter objects having travelled furthest, angled eastwards in the direction of the surface wind at the time. The aircraft's direction of travel at impact, as estimated from the line of travel of the major wreckage, was 178°(M). The features of the wreckage site were consistent with an aircraft impact speed of between 140 and 200 kt with a descent rate significantly more than a normal approach rate of descent for landing.

Both wings had sheared off at the fuselage and the wing fuel tanks were completely disrupted resulting in a loss of all remaining fuel. The engine had separated from its mounts and the propeller had also separated from its crankshaft flange. All major aircraft components were accounted for and there was no evidence of any pre-impact separation.

Following the on-site examination, the aircraft wreckage was recovered from the hillside and transported to the AAIB's facility at Farnborough for a more detailed examination.

Detailed wreckage examination

Flight controls

The roll controls on this aircraft type consist of two control wheels that are connected to each other and control the aileron positions through a series of torque tubes, sprockets, chains, control cables, pulleys and bell cranks. Pitch control is via an all-moving stabilator connected to the control columns through a series of cables, pulleys and push-pull rods. There were numerous separations within both of these control systems but all were attributable to overload failures which were consistent with the airframe break-up. There was no evidence of a pre-impact disconnection. The rudder is controlled by two cables connected directly to the rudder pedals. Both cables and their attachment points were intact. The stabilator trim barrel was found in a position corresponding to 0.6° of nosedown trim. The rudder trim assembly was found in a position corresponding to 1.5° of right rudder trim. Disruption to the mechanical flap control system precluded a determination of the flap position at impact.

Instruments

The flight instruments were all severely damaged and most of the instrument faces had separated from their casings. The main altimeter subscale indicated a pressure setting of between 1013 and 1014 mb. The standby altimeter subscale indicated a pressure setting of approximately 1017 mb. Both of these settings were close to the reported aftercast pressure settings of between 1014 and 1015 mb for the time of the accident. The instrument faces were examined for witness marks that might indicate any pre-impact readings but no reliable witness marks were found. The AI had broken up and dislodged the gyroscopic rotor from its housing. The rotor did not exhibit any evidence of rotational scoring, but the rotor housing had a helical score around its inner

circumference that could have been caused by the rotor during the instrument break-up while the rotor was still spinning. The warning lights, including the vacuum pressure warning light, were examined but all the bulbs had broken and there were no remaining tungsten filaments, so a determination of pre-impact illumination could not be made.

Other component examinations

The throttle, propeller and mixture control levers were all bent and in the near forward position, but the disruption and damage to the throttle quadrant made these unreliable as indications of their pre-impact positions. The magneto switch was set to BOTH and the key had broken off. The autopilot control panel and computer were too severely damaged to enable testing to be carried out. The electrical wiring was examined and there was no evidence of any significant non-impact related short-circuits. The pitot tube hole was clear and the pitot heat wires were securely connected to the tube. The pitot heat switch was damaged preventing its position from being determined. The static port was clear, but the pitot-static plumbing system was too severely disrupted to enable any further examination. The plumbing for the fuel system was also severely disrupted; the fuel lines had broken into multiple pieces. The fuel tanks had also broken into several pieces. The fuel drains were in the closed position and the fuel filler cap seals were in a satisfactory condition. The throttle body fuel control unit had shattered into multiple pieces so no fuel samples were recovered.

Powerplant examination

The engine was taken to an approved overhaul facility for a strip examination. It had suffered significant impact damage, including partial separation of the oil sump and separation of the No 6 cylinder head from the cylinder barrel. The engine accessories also

had varying degrees of impact damage and had all separated from the engine accessory gearbox. The propeller governor and turbocharger had also separated from the engine. The engine could be rotated freely by hand once a fractured part of the engine crankcase was pulled away from the internal counterweight. The engine was sufficiently lubricated and there was no evidence of any pre-impact mechanical failure or evidence of overheating. The spark plugs were in satisfactory condition. One magneto was too severely damaged to be tested, but the other one was rig-tested and operated normally. The turbocharger driveshaft rotated freely. The only anomalies uncovered during the engine examination were the damaged and twisted base packing seals from the No 3 and No 5 cylinders. However, the worst case effect of this would have been minor oil leaks, but none had been reported.

The propeller assembly and the crankshaft propeller flange had separated from the engine. Both propeller blades were free to rotate within the hub due to impact failure of the pitch control links. As a result, both blades had rotated approximately 180 degrees within the hub. Propeller blade No 1 was bent aft near the shank and bent forward approximately 8 inches from the tip. Blade No 2 was bent aft from the shank to the tip. It also had deep leading edge gouges, whereas blade No 1 did not. Blade No 2 had some chordwise scratches between the mid-section and the tip, although it also exhibited roughly similar lengthwise and multidirectional scratches. The propeller hub was disassembled and compression damage on one side of each blade's preload plate was observed; this was very pronounced on the No 2 blade. The preload plates were sent to the propeller manufacturer for examination. The propeller manufacturer reported that no reliable pre-impact blade angle could be determined from the numerous witness marks on the preload plates.

The crankshaft and separated crankshaft flange exhibited evidence of tensile failure over approximately half the circumference and compression failure over the other half of the circumference. There were also cracks in the nitrided layer on the tensile side of the base of the flange. These were predominantly parallel, occasionally somewhat spiral in nature, and extended well into the flange itself.

Vacuum pump examination

The Parker Airborne 211CC vacuum pump fitted to G-JMTT was examined by the AAIB and then separately

by the component manufacturer. A component diagram of the pump is shown in Figure 5. The pump is driven directly by the engine's accessory gearbox which, through a drive coupling, turns a carbon rotor with carbon vanes that slide in and out by centrifugal force. A photograph of the rotor and vane assembly is shown in Figure 6. The rotor and vane assembly of the pump from G-JMTT had shattered into multiple pieces (see Figure 6). It was important to determine if the rotor had broken while the aircraft was in the air or as a result of ground impact. The rotor is driven by a metal shaft assembly which connects to a plastic coupling which is connected to a

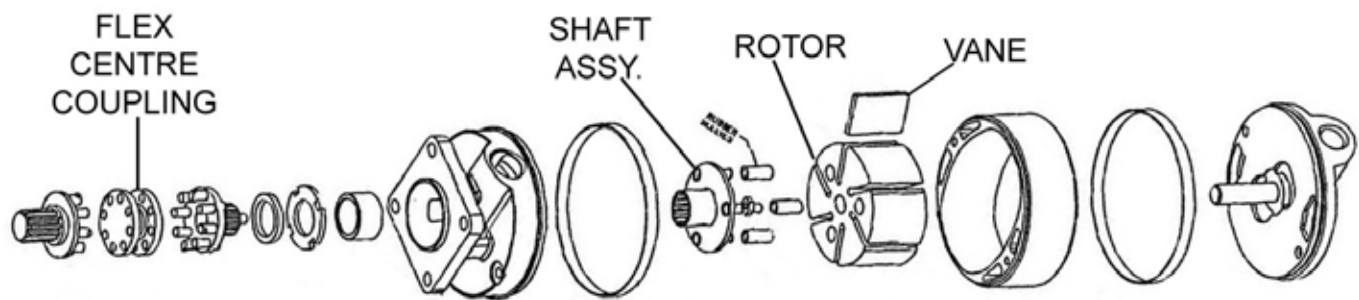


Figure 5

Parker Airborne 211CC Vacuum pump component layout

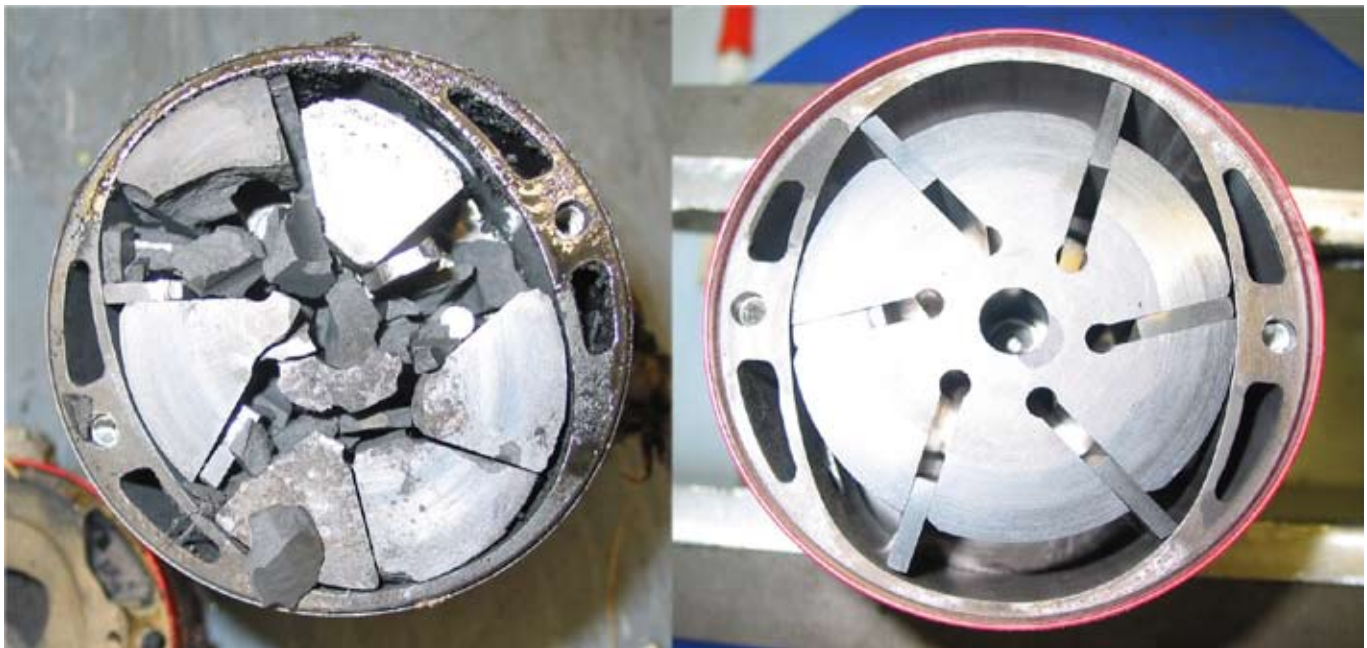


Figure 6

Damaged vacuum pump rotor and vanes from G-JMTT on left; intact version on right

plastic flex centre coupling. This flex centre coupling serves two purposes: first, it absorbs torsional vibrations from the accessory gearbox drive and second, it contains a necked-down centre diameter which works as a shear point to prevent engine damage in the case of a pump failure. The flex centre coupling in G-JMTT's vacuum pump had fractured at the midpoint of its shear section due to torsional overload (see Figure 7). This can occur

as a result of impact; however, both fracture faces had rub marks which indicated continued rotation of the engine-driven end after the coupling fractured (see Figure 8). The component manufacturer concluded that this rotational rubbing of the fracture surface indicated that the coupling fractured some time prior to impact, possibly even before the accident flight.



Figure 7

Fractured flex centre coupling from G-JMTT's vacuum pump



Figure 8

Rub mark on one of the fracture faces of the flex centre coupling

The vacuum pump examination also revealed that there was significant carbon/fluid streaking emanating from the shaft assembly. The carbon bearing, rotor and vanes generate carbon dust particles as they wear. The component manufacturer reported that when liquids such as engine oil or engine cleaning liquids mix with the carbon dust, they create a thick slurry which increases friction leading to premature failure of the air pump. Some causes of liquid contamination are a leaking accessory drive pad seal or engine cleaning liquid being sprayed onto an unprotected air pump.

Only part of the pump's serial number was still visible, revealing the letters '10AK'. '10' represents the month of manufacture, October, and 'AK' represents the year of manufacture, 1994. The flex centre coupling was also date-stamped '1994'. The maintenance records revealed that a vacuum pump with serial number 10AK4837 was fitted to G-JMTT's engine on 2 June 1995, so, this is probably the same vacuum pump and it had logged approximately 994 hours at the time of the accident.

Effect of vacuum pump failure

On G-JMTT the vacuum pump was used solely to supply vacuum pressure to operate the AI. Insufficient vacuum or no vacuum will result in the gyro rotor within the AI slowing down. As the gyro slows it will lose its gyroscopic rigidity and start to topple. As this happens the attitude indication, as shown by the picture of the artificial horizon on the instrument face, will start to give false indications of pitch and roll. If the autopilot was engaged it would follow these false readings. A sudden vacuum pump failure will result in an immediate loss of vacuum pressure but minutes could pass before the AI gyro has slowed sufficiently to start giving erroneous indications. The loss of vacuum pressure should, however, be apparent to the pilot by a zero reading on the suction gauge and illumination of the vacuum pressure failure light.

Previous accidents involving vacuum system failures

A search of the AAIB's database did not reveal any accident reports relating to vacuum system failures. However, a search of the NTSB⁷'s database revealed 62 accident/incidents between 1982 and June 2007 in which the vacuum system was listed among the causal factors. Of these 62 accidents/incidents, 40 were listed as severity 'Fatal'. In many of these accidents, the pilot reported loss of vacuum pressure over the radio before losing control in IMC conditions.

Maintenance requirements for vacuum pumps

Aircraft and equipment manufacturers sometimes identify items of service information, such as a Service Bulletin or a Service Letter, as either 'Optional' or 'Mandatory'. This judgement, by the manufacturer, is not necessarily agreed or endorsed by the National Airworthiness Authority where the aircraft is registered. The UK CAA has stated that there are some circumstances when such service information is deemed mandatory by association. This is the case when an Airworthiness Directive (AD) makes reference to such a Service Bulletin or Service Letter as being the means of compliance with the AD. The CAA takes the view that, even bearing in mind any other statements or comments, only service information supported by an AD is mandatory.

The aircraft was maintained in accordance with the LAMS which states in item 7 of section 3:

*'Overhaul, additional inspections and test periods shall be those recommended by the organisation responsible for the type design.'*⁸

Footnote

⁷ NTSB is the National Transportation Safety Board of the U.S.A.

⁸ Light Aircraft Maintenance Schedule (LAMS) – Aeroplanes, CAP 411, Issue 2.

The aircraft manufacturer was responsible for the type design and its service manual for the Arrow III lists under the 1,000 hour Inspection period⁹:

'Replace engine or electrically driven vacuum pump(s) (Read Note(s) 5 and 25).'

Note 5 differs slightly from this in that it states:

'Replace as required or at engine overhaul'.

Note 25 refers to a 500 hour replacement time for the auxiliary electric backup vacuum system, but this was not relevant to G-JMTT as no backup system was fitted. The Arrow III service manual also contains a statement in Note 28:

'When servicing or inspecting vendor equipment installed in Piper aircraft, it is the user's responsibility to refer to the applicable vendor service publications.'

The vacuum pump is considered to be vendor equipment.

The vacuum pump manufacturer published Service Letter (SL) 58 on 31 May 2002 (now superseded by SL 58A dated 23 March 2006) which listed 'mandatory' replacement times for Airborne air pumps¹⁰. The Service Letter, under the heading 'Background', stated that:

'in the absence of air pump mandatory replacement times provided by Airframe Manufacturers, Airborne is providing these mandatory replacement times'. This could be interpreted to mean that the Service Letter was only applicable if the airframe manufacturer had not provided replacement requirements, which was not the case. However, under the heading 'Compliance' it then stated 'Airborne air pumps must not be operated beyond the Airframe Manufacturer's specification for mandatory inspection intervals or mandatory replacement times or Airborne's mandatory inspection intervals or mandatory replacement times, whichever comes first.' Thus the intention of the Service Letter was that when the airframe manufacturer provides replacement times, the most restrictive requirement should apply. The 'mandatory' replacement for the air pump model 211CC was listed in the Airborne Service Letter as '500 aircraft hours or 6 years from date of manufacture, whichever comes first.' The underlining is as contained in the Service Letter.'

The CAA did not make this Service Letter mandatory by issuing an AD, but required aircraft owners to assess, and where appropriate, comply with the maintenance instructions from the type design holder. The CAA stated to the AAIB that on the basis of Note 28 in the Arrow III service manual it is the responsibility of the aircraft's owner to be aware of publications relating to components and therefore to be aware of and comply with the vacuum pump manufacturer's Service Letter 58A. Therefore, the vacuum pump on the Arrow III should be tracked in the 'Time limited task and component change record' document (CAP 543). However, this was not done by the owners or by any of

Footnote

⁹ Piper Service Manual for PA-28R-201/201T (part No 761 639), publication date 27 February 2004.

¹⁰ There are no significant differences between Service Letter 58 and Service Letter 58A. An electronic copy of Service Letter 58A can be obtained at <http://www.parker.com/literature/Literature%20Files/ag/NAD/pdf/Service%20Letters/SL-58A.pdf>

the maintenance organisations¹¹ of G-JMTT. The AAIB ascertained that other maintenance organisations were also unaware of Service Letter 58A. Further, some vacuum pump suppliers, who would normally supply such information to their customers, were also unaware of the Service Letter.

The maintenance manual for a 'New Piper Aircraft' PA-28R-201 Arrow¹² (aircraft with serial numbers 2844001 and up) lists a Special Inspection for aircraft fitted with Airborne Dry Air Pumps to have the engine-driven vacuum pump replaced after 500 hours. This instruction is in line with the 500 hour requirement in Service Letter 58A.

The FAA issued a Special Airworthiness Information Bulletin (SAIB, CE-05-15) on 10 November 2004 advising registered owners of single or multi-engine piston aircraft of the need to maintain pneumatic system components that power air-driven gyro instruments properly. In this SAIB the FAA highly recommends that:

'if Parker Hannifin-Airborne Division air pumps and other components used in pneumatic systems that power air-driven gyro instruments are installed in your airplane, then you should follow the applicable Airborne maintenance, inspection, and replacement instructions.'

The CAA stated to the AAIB that they concur with this recommendation.

Footnote

¹¹ The aircraft had been maintained by the current maintenance organisation since 2006; there had been three other maintenance organisations involved since 2002. The vacuum pump life limits had been introduced in 2002 and should have been tracked in the aircraft records from that time.

¹² Piper Airplane Maintenance Manual for PA-28R-201 (Part No 761-895), publication date 21 December 2005.

Search and rescue

On the morning of 10 April 2006, one of the syndicate members became concerned as he was unable to contact the commander on his mobile phone. Having got the takeoff time for G-JMTT from the Airport Manager at Oban he telephoned the commander's office to see if he had left any message. They informed him that they had not heard from him but they were expecting him in for a meeting at 0900 hrs. The syndicate member then telephoned Andrewsfield to see if they had heard from G-JMTT; they had heard nothing. He then telephoned the Distress and Diversion (D and D) cell at West Drayton, Middlesex and informed them that G-JMTT was overdue and they informed Scottish D and D at Prestwick; who instigated full overdue action at 1408 hrs.

At 1450 hrs D and D received a telephone call saying that wreckage had been found 9 nm south of Oban. As a result the search was called off.

Analysis

Conduct of the flight

The commander had been declared medically unfit by the CAA prior to the accident, and therefore was not entitled to exercise the privileges of his licence. The co-pilot's licence had expired, but as she had renewed her skills test it is likely that this was an oversight on her part. This was an oversight which was made by a number of other pilots at about that time, in part due to the change from CAA to JAA licences in the year 2000. The pilots flew in weather that was outside the privileges of their licences and no prior permission was obtained for either the landing at Blackpool or at Oban. Furthermore, the aircraft appears to have taken off from Oban 181 lb in excess of its MTOW.

The weather at takeoff and the forecast for the first part

of the flight over south-western Scotland was not suitable for the intended Visual Flight Rules (VFR) flight. It is possible that the aircraft climbed in a hole in the cloud over the Isle of Kerrera. Once the aircraft had climbed to height the pilots would not have been able to keep in sight of the surface, as the privileges of their licences required them to do.

It is unlikely that the aircraft was unduly affected by airframe icing as it was above the forecast icing level of 5,500 feet for less than 2 minutes and 30 seconds.

It is not possible to determine whether the autopilot was engaged during the flight; however, whether it was or not, the inaccurate attitude information provided by the AI would have adversely affected the ability of the pilot, or the autopilot, to control the aircraft. G-JMTT appears to be under reasonably precise control until the last left turn, which is relatively rapid and where the aircraft starts to descend. The loss of secondary radar returns, during the final moments of the flight, could have been as a result of the aircraft being in an unusual attitude. This also suggests that control of the aircraft had been lost.

Accident site and wreckage examination

The accident site and wreckage spread were consistent with a high-speed nose-down impact. It was not characteristic of an attempted landing. There was some evidence, from the estimated impact attitude and impact flight path angle, that the pilot may have been trying to regain level flight shortly before impact occurred.

There was no evidence of a pre-impact structural failure or a pre-impact problem with the flight controls. It is likely that there was adequate fuel on board, and the engine examination did not reveal any anomalies that would have affected its operation. There was evidence

that the propeller had detached from the engine due to a bending load applied to the crankshaft in the initial impact. The propeller exhibited insufficient evidence of rotational energy for the investigation to eliminate engine failure, but an engine failure would not have directly resulted in a loss of control. From an altitude of 5,000 ft the aircraft could have glided a distance of approximately 6 nm down to 1,000 ft, at a moderate descent rate of 1,000 ft/min. Thus the only evidence found during the wreckage examination that could have directly contributed to the loss of control was the evidence from the failed vacuum pump.

Vacuum pump failure

The vacuum pump manufacturer determined that the rub marks on the fracture faces of the flex centre coupling indicated that the fracture had occurred prior to impact while the engine was still turning. The failure could have been triggered by a worn vane that broke or as a result of excessive friction build-up from the liquid contamination, or a combination of both. The source of the liquid contamination could not be determined, but the vacuum pump had been in use for more than 11 years and for approximately 994 hours, well in excess of the 6 year and 500 hour time limits mandated by the pump manufacturer in their Service Letter 58A.

The aircraft owners and several aircraft maintenance organisations were not aware of Service Letter 58A, which was not mandated by an Airworthiness Directive. The instructions for vacuum pump replacement in the Arrow III service manual were open to interpretation and not consistent with SL 58A. One interpretation of the text in the manual was that the engine-driven vacuum pump should be replaced at the 1,000 hour inspection period. However, Note 5 states that it can be replaced as required or at engine overhaul. The Parker Airborne 211CC vacuum pump cannot be inspected for wear

without disassembling it and this is not permitted in the field. An external visual inspection of the pump would not reveal that a pump was close to failing. Therefore, the only safe solution, particularly if the aircraft is to be operated in IMC and there is no backup system, is to comply with the limits specified in SL 58A. The AAIB therefore recommends that:

Safety Recommendation 2007-002

The Civil Aviation Authority should publicise the vacuum pump replacement requirements in Parker Airborne Service Letter 58A and recommend that operators and maintainers of such aircraft which will be operated under Instrument Flight Rules, comply with the limits specified therein.

The CAA has advised that the existing requirements contained in the Light Aircraft Maintenance Programme and in the Light Aircraft Maintenance Schedule will be publicised in a Letter to Owners/Operators and by an article in an issue of the General Aviation Safety Information Leaflet (GASIL).

The aircraft manufacturer has published a 500 hr limit for Airborne vacuum pumps in its *New Piper Aircraft Arrow Service Manual*. It has not retrospectively applied this limit to older Arrow aircraft. However, the same type of Airborne vacuum pump could be fitted to both. The vacuum pumps should be treated the same, regardless of which aircraft type they are fitted to. The AAIB therefore recommends that:

Safety Recommendation 2007-003

The New Piper Aircraft Company should revise their maintenance manuals to ensure that the maintenance requirements for vacuum pumps are consistent across their product range.

The problem of inconsistent or inadequate maintenance requirements for vacuum pumps could apply to other aircraft manufacturers. The AI is the primary instrument for safe flight in IMC. When the AI is vacuum-driven the vacuum pump becomes an important component for safe flight in IMC. Therefore, all aircraft manufacturers should evaluate the maintenance and replacement instructions recommended by vacuum pump manufacturers, and then incorporate these requirements in the aircraft's maintenance manual. The AAIB therefore makes the following Safety Recommendations to EASA and the US FAA:

Safety Recommendation 2007-004

The European Aviation Safety Agency (EASA) should mandate compliance with vacuum pump maintenance and replacement requirements, to ensure that aircraft fitted with vacuum-driven Attitude Indicators can be safely operated in Instrument Meteorological Conditions when such aircraft are certified to do so.

Safety Recommendation 2007-005

The US Federal Aviation Administration (FAA) should mandate compliance with vacuum pump maintenance and replacement requirements, to ensure that aircraft fitted with vacuum-driven Attitude Indicators can be safely operated in Instrument Meteorological Conditions when such aircraft are certified to do so.

Spatial disorientation

From the aftercast it is possible that the pilots were flying between layers of cloud. If they were flying in cloud it would have been necessary for them to fly by sole reference to the flight instruments. Although the pilots had received basic instrument flying familiarisation training, their experience level made it unlikely that they would have been able to control the aircraft accurately in IMC for any length of time.

With the absence of outside visual references, physical sensations can produce compelling perceptions of the aircraft's attitude and manoeuvres that differ markedly from those indicated by the flight instruments and spatial disorientation can occur. This tends to be more likely when recent and/or total instrument flying experience is low and in a high stress situation, or with alcohol in the pilot's blood.

One type of vestibular illusion, commonly known as the 'leans', is where the pilot may have a conscious knowledge of his genuine orientation from his instruments or the outside world, yet retains a very compelling false feeling of leaning for a considerable time. If there are no instruments to give the pilot any visual input, the aircraft could easily enter a turn that develops into a spiral dive and accelerates, as seen in the final moments of the radar returns.

Alcohol was measured in the pilots' muscle at a level which would be significantly in excess of the equivalent blood levels stipulated in the Railways and Transport Safety Act 2003. Whilst the toxicologist and pathologists accepted that some of the alcohol detected may have been produced post-mortem, they believed it was unlikely to be a significant amount, especially as the third occupant exhibited no evidence of alcohol. If these levels genuinely reflect the amount of alcohol present in the blood at the time of the accident, it is possible that they may have produced some decrement in performance which may have been prejudicial to the safe conduct of the flight.

While it is not known when the vacuum pump failed, the effects of the failure probably started to manifest themselves with erroneous AI indications just before the aircraft entered the left turn, approximately 24 seconds before the radar track was lost.

The circumstances of the accident to G-JMTT could alternatively be explained by some form of brief and temporary incapacitation of the pilot, brought on by a medical or toxicological symptom, without this necessarily leaving any evidence. Due to the disruptive nature of the impact it was not possible to tell if there was any medical reason, in the form of disease, for the accident. The commander had a medical history of a heart condition which may have caused some form of incapacitation.

The flying conditions, added to the probable failure of the AI, are likely to have led to an increase in stress to all the occupants. This could have led the commander to become distracted and/or incapacitated due to the stress of the situation.

Search and rescue

The pilots had not filed a flight plan or booked into Blackpool for the return journey. As a result no ATC agencies were formally aware of the flight. Had the pilots filed a flight plan, overdue action should have been initiated one hour after G-JMTT's ETA at Blackpool.

Conclusion

The aircraft crashed after control was lost while in IMC. The characteristics of the final flight path, particularly the high airspeed, the rapid descent and the rate of turn, were consistent with the effects of spatial disorientation. The pilots were not IMC or Instrument Rated, and alcohol was present in both pilots. It is likely that the accident resulted from loss of control as a result of the pilots following unreliable indications from the AI, whilst in IMC. The AAIB has made four Safety Recommendations relating to the maintenance of vacuum pumps.

The pilots were not IMC or Instrument rated. Had they

been flying under VFR conditions, in sight of the surface, they would probably have been able to maintain control of the aircraft.

ACCIDENT

Aircraft Type and Registration:	Piper PA-34-200T Seneca II, G-BEVG	
No & Type of Engines:	2 Continental Motors Corp TSIO-360-E piston engines	
Year of Manufacture:	1975	
Date & Time (UTC):	12 December 2007 at 1210 hrs	
Location:	Sibson Airfield, Peterborough	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 2
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to propellers and nose	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	55 years	
Commander's Flying Experience:	6,500 hours (of which 500 were on type) Last 90 days - 30 hours Last 28 days - 10 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot, with additional AAIB enquiries	

Synopsis

Following a normal touchdown with 'three greens' indicating that the landing gear was locked down, the nose landing gear (NLG) collapsed, causing both propellers and the aircraft's nose structure to contact the ground. No technical cause was determined for the collapse, although the NLG mechanism reportedly exhibited evidence of wear and a lack of recent lubrication. The aircraft had made approximately 45 flights since an Annual Inspection where a pivot bolt, which reportedly exhibited signs of wear, was recorded as having been changed in accordance with a FAA Airworthiness Directive AD No 2005-13-16.

History of the flight

Following an uneventful flight from Kemble, the aircraft landed on Runway 24 at Sibson in light winds with no significant crosswind component. The normal 'three greens' indication had been obtained on lowering the landing gear, and the touchdown was described as smooth. However, almost immediately, a muffled bang was heard, the nose lowered and the propellers contacted the ground. The aircraft continued along the runway in this attitude with the pilot applying left rudder in an attempt to clear the side of the runway, but, a lack of momentum resulted in the aircraft coming to rest to the left of the centre line. The magnetos, switches and fuel were turned off and the aircraft was evacuated.

On raising the nose of the aircraft during the subsequent recovery operation, the NLG leg swung down under gravity and locked into position. The battery master switch was turned on and the 'three greens' indication was confirmed. The aircraft was towed clear of the runway without further event.

Nose landing gear operation

The nose landing gear (NLG) of the Piper Seneca is of the forward retracting type and is hydraulically operated. When retracted, the leg is held up by hydraulic pressure in the actuator and, when extended, it is held in the down position by a geometric downlock mechanism. There are no locking hooks for either position. When the NLG is fully extended, it is prevented from collapsing by the drag link assembly, Figure 1. The offset drag link centre pivot is below the line between the drag

link outer pivot bolt centres and prevents the drag link assembly folding when the landing gear is under load. The geometry of the NLG is such that the aircraft's weight on the nosewheel applies a compressive load to the drag link assembly which tends to drive it more firmly into the safe overcentre condition when the gear is properly extended. Conversely, it will tend to cause the drag link to fold, and the NLG to retract, if the load is applied when the drag link assembly is not fully overcentre.

Examination of the aircraft

When the aircraft nose was lifted clear of the ground by maintenance personnel following the accident, the NLG deployed under the influence of gravity and the drag strut adopted the normal overcentre position without any apparent problem. A series of retraction tests

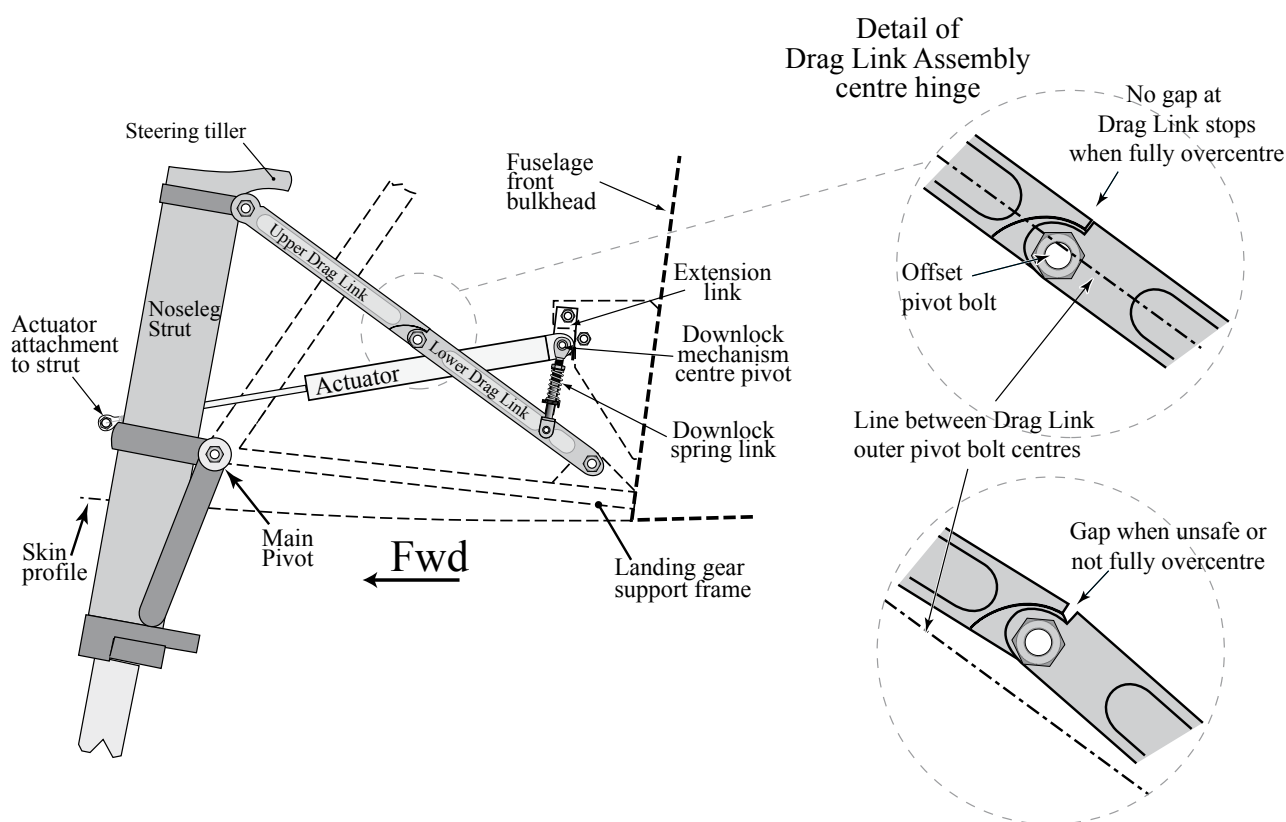


Figure 1

PA-34 nose landing gear side view showing main components in extended position
(Steering mechanism and download spring omitted for clarity)

showed that all three landing gear assemblies operated satisfactorily. A subsequent, detailed examination of the landing gear by a local maintenance organisation revealed no broken or damaged components, although a degree of wear was observed in the bushings and bolts in the drag link and in the aft attachment of the actuator to the structure. Additionally, it was observed that the grease on the gear components appeared old, which may have caused a degree of stiffness in the linkage.

Maintenance history

The aircraft's documentation recorded that an Annual Inspection had been completed on the aircraft on 22 May 2007. It underwent another Annual Inspection in September 2007, by the same maintenance organisation eight flying hours later, as a condition of sale by the owner who had recently acquired the aircraft. Following this inspection, an application for the issue of a non-expiring EASA Certificate of Airworthiness and an Airworthiness Review Certificate was made on 3 October 2007. A 50-hour Inspection was also recorded as having been completed on 29 October. At the second Annual inspection, it was recorded that minimal additional work was required following the recent previous inspection. The aircraft's log books indicate that the aircraft had made approximately 45 flights since the inspection in May.

The maintenance documentation also indicated that the bolt attaching the nose gear upper drag link to the trunnion block had been replaced in accordance with Airworthiness Directive (AD) No 2005-13-16 at the May 2007 inspection; this was one of the bolts showing evidence of wear. Lubrication of the landing gear components is required to be carried out during an Annual Inspection.

Previous occurrences

A number of Piper Seneca series of aircraft nose landing gear collapses have been investigated by the AAIB. Eight of the most recent are listed below, together with the AAIB Bulletin Reference Nos:

Registration	Date	AAIB Bulletin
G-BOSD	19 June 1999	12/2000
G-BOSD	28 February 2000	12/2000
G-EXEC	28 October 1999	3/2002
G-BNEN	22 February 2003	11/2005
G-ROLA	8 May 2003	5/2004
G-BEJV	30 March 2004	11/2005
G-BNEN	21 April 2005	4/2006
N43GG	27 September 2005	5/2006

The G-EXEC report contains the results of an examination of CAA occurrence data on nose landing gear collapses affecting the UK light twin aircraft fleet over the preceding 15 years. This revealed that there had been 35 occurrences to Piper PA-34 series aircraft during the period, compared with 13 for the PA-23 (Aztec) series, which had a similar average annual fleet size. In general, the PA-34 events were twice as frequent as the average for the rest of the light twin fleet.

Following the accident to G-BEVG, a similar examination of the CAA occurrence data was conducted, which covered the period January 2000 to January 2008. This revealed a total of eight occurrences, including the subject accident, with six of these appearing in the above table. Incidents in which the NLG collapsed as a result of other events, such as the aircraft overrunning the runway, are not included in this total. Only one occurrence for PA-23 series aircraft was recorded but this was the result of a failure of the landing gear to extend following a loss of hydraulic fluid and so was not directly comparable. The number of PA-34 series aircraft on the register had not changed significantly during the period of the second

survey, although the annual PA-23 fleet had reduced to around half its 1995 size.

The AAIB has made five Safety Recommendations during this series of occurrences; 2000-045, 2000-046, 2004-007, 2005-106 and 2005-107. The manufacturer has made a number of amendments to the Maintenance Manual and, in May 2003, issued Service Bulletin 1123, which introduced a number of maintenance actions and inspections. This was raised to Revision 'A' in November 2004 and Revision 'B' in April 2006. On 8 August 2005, the Federal Aviation Administration (FAA) issued Airworthiness Directive No 2005-13-16, which mandated SB 1123A. Additionally, it required the replacement, at 500 hour intervals, of the bolt that attaches the upper part of the drag link to the nose leg trunnion.

Discussion

Although the wear on the individual bushes and bolts in the nose landing gear of G-BEVG was not deemed excessive by the maintenance organisation tasked with repairing the aircraft, the cumulative effect of such wear, plus the stiffness in the linkage resulting from what appeared to be inadequate and/or old grease, may

have combined to restrict the drag link's movement to the overcentre position, resulting in the NLG collapse. Additionally, it is possible that an exacerbating effect was provided by the undulating nature of the grass runway during the landing roll.

AD No 2005-13-16, in mandating SB 1123A, listed a number of factors identified in NLG collapses, including failure or out-of-tolerances of the retraction links and bolts, lack of cleanliness/lubricant in the components and an out-of-rig condition so nothing new appeared to feature in the subject incident.

The history of PA-34 series aircraft NLG collapses, in comparison with other light twins, might suggest that the landing gear could benefit from some additional development work. Although it would appear that a relatively minor degree of mis-rigging or component wear within the PA-34 NLG mechanism could provoke a collapse, SB 1123A and its associated AD, have identified and addressed several areas of concern. Since the AD was issued relatively recently, and it is possible that its benefits have yet to be reflected in a reduced incidence of NLG collapses, no safety recommendations are made.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-CCVY	
No & Type of Engines:	1 Lycoming O-320-B2C piston engine	
Year of Manufacture:	1991	
Date & Time (UTC):	16 February 2008 at 1545 hrs	
Location:	2 nm north-east of Girvan, near Prestwick	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Severe damage to airframe and main rotor system	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	57 years	
Commander's Flying Experience:	6,728 hours (of which 136 were on type) Last 90 days - 56 hours Last 28 days - 10 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The pilot was carrying out a landing on the top of a steep-sided hill at 1,200 ft amsl. The approach was normal with the carburettor heat selected to OFF in the latter stages of the approach. The surface wind was from the south-west at about 5-10 kt. As the aircraft descended through approximately 20 ft agl, the pilot raised the collective pitch control lever fully but the aircraft continued to descend and struck the ground heavily and rolled over. The pilot escaped uninjured.

The pilot considered that the aircraft had either encountered a downdraft or suffered a loss of power or possibly a combination of both.

History of the flight

The pilot had planned to depart from Prestwick and carry out a flight in the local area. Included in the plan was the possibility of landing on the top of a hill, which he had landed on, without problem, three days earlier. The wind was from the south-west at about 5-10 kt, the visibility was greater than 10 km, there was no significant cloud, the outside air temperature was +5°C, the dew point was -1°C and the local pressure setting was 1042 hPa.

The departure from Prestwick was normal and the helicopter climbed to an altitude of 1,300 ft. The carburettor heat was selected fully ON, where it remained until the approach to the hill, the top of

which was approximately 1,200 ft amsl. The pilot approached the hill from the south-west, which was the downwind leg of a left-hand circuit. The hill was steep-sided but had a large flat area on the top, which was to be his landing point. There was no indication of the wind direction and the pilot reduced the airspeed to about 50 kt and established a gentle rate of descent of 100 to 150 fpm. He selected the carburettor heat to OFF and reduced airspeed to about 20 kt as he passed the landing site.

At about 50 ft agl, and just beyond his landing site, he made a pedal turn to the left through approximately 150°. At a height of approximately 20 ft he raised the collective control lever at the normal rate in order to reduce the rate of descent. The helicopter continued to descend and the pilot raised the collective lever fully to cushion the landing. The left skid impacted the ground with sufficient force to break the skid cross

tube mounts and the aircraft rolled onto its left side. The main rotors struck the ground and the pilot stopped the engine. The pilot was uninjured and hearing fuel escaping he vacated the aircraft through the right door and moved away from the wreckage. He noted that the wind was more southerly than he had anticipated but that his final approach was generally into the wind.

He contacted Prestwick air traffic control on his mobile telephone to inform them of the accident and that he was not injured. He then made his way down the hill to seek assistance.

The pilot could not identify the specific cause of the accident. From the lack of response to his collective control inputs, he considered the helicopter had either encountered a downdraft or suffered a loss of engine power or possibly a combination of both.

ACCIDENT

Aircraft Type and Registration:	Robinson R44 II Raven, G-OSSI	
No & Type of Engines:	1 Lycoming IO-540-AE1A5 piston engine	
Year of Manufacture:	2004	
Date & Time (UTC):	3 August 2007 at 1836 hrs	
Location:	4 miles SSE of Kendal, Cumbria	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 3
Injuries:	Crew - 1 (Fatal)	Passengers - 3 (Fatal)
Nature of Damage:	Aircraft destroyed	
Licence:	Pilot 1: Private Pilot's Licence Pilot 2: Private Pilot's Licence	
Age:	Pilot 1: 39 years Pilot 2: 37 years	
Flying Experience:	Pilot 1: 100 hours (of which 45 were on type) Last 90 days - 8 hours Last 28 days - 2 hours Pilot 2: 91 hours (of which 8 were on type) Last 90 days - 4 hours Last 28 days - 2 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The helicopter, with two PPL(H) qualified pilots seated in the front and with one passenger in the rear, flew from Leeds Bradford Airport to a private site near Arkholme, between Carnforth and Kirkby Lonsdale, where they picked up a second passenger. The aircraft departed from this site but failed to arrive at the intended destination near Lockerbie. Search and Rescue (SAR) activities commenced the next day when people became concerned as to the whereabouts of the aircraft and its occupants. The accident site was located approximately 4 km NNE of Junction 36 of the M6 motorway and witnesses in

the area reported that the local weather, around the time of the accident, was poor. All four occupants received fatal injuries in the accident. No significant pre-accident defects were found during examination of the helicopter wreckage.

History of the flight

The two pilots¹ were friends who regularly flew together. They hired the helicopter from the flying school at Leeds

Footnote

¹ Referred to in this report as Pilot 1 and Pilot 2.

Bradford Airport where they had both trained for their flying licences. They planned to take two passengers on the flight; one would accompany them from the airport at Leeds, the other they planned to pick up from a private site between Kirby Lonsdale and Carnforth. They then planned to fly to Corncockle, a private landing site near Lockerbie, to spend the night and return to Leeds Bradford Airport by 1300 hrs the following day.

They arrived at the flying school at around 1700 hrs and completed their pre-flight procedures, which included checking the helicopter's technical log, the weather and signing the flight authorisation sheet. The flight school's flying order book contains the rules and regulations applicable for the operation of the aircraft, including weather limitations. There is a requirement for all pilots who fly with the school to sign as having read, understood, and agreed to abide by the rules contained within the flying order book. Both pilots had complied with this requirement.

Pilot 2 signed the authorisation sheets for that day's planned flight, but did not mention that they were taking passengers with them, so no details were entered into the school's Passenger Details log.

The flying school provides an internet based self briefing facility for weather, which the pilots used. One of the pilots called ATC to book out the flight and reported that the helicopter, with three persons on board (POB), would be flying from Leeds, via the VRP at Keighley, to a private site at Arkholme, near Kirby Lonsdale. He made no mention to ATC of the planned flight beyond Kirby Lonsdale.

At around 1730 hrs the Chief Flying Instructor (CFI) of the school, who had just landed, spoke to Pilot 2 and checked his intended routing. The CFI then witnessed

the aircraft take off, with Pilot 2 flying from the right seat and Pilot 1 in the left; a passenger was seated in the rear of the helicopter who was unknown to him. The CFI then checked the actual and forecast weather for Blackpool and Leeds, and was satisfied that it was suitable for the planned trip. He tried to get weather for Carlisle but this was not available.

At 1741 hrs, the helicopter took off and, having departed the Leeds Bradford control zone, changed frequency to London Information North. The pilots were given the appropriate transponder code for aircraft receiving a Flight Information Service and, shortly after 1800 hrs, when approaching Kirby Lonsdale, they reported to London that they were letting down to the landing site.

The landing site near Carnforth was a large field approximately 100 ft amsl. The weather conditions at the landing site were described by witnesses as reasonable, with good visibility.

Once on the ground, the helicopter was shut down and the two pilots changed seats. Witnesses recall that Pilot 1 was now in the right seat, Pilot 2 in the left. The additional passenger boarded and with four POB, the helicopter took off again at around 1827 hrs. It flew initially towards the west prior to turning onto a northerly heading to follow the M6 motorway, towards rising ground. A witness reported seeing it in the vicinity of Sill Field Farm, Kendal, just to the east of the M6 motorway, at around 1835 hrs.

The people on the ground at the planned landing site, Corncockle, near Lockerbie, assumed that the aircraft had not arrived because of the bad weather. The families, when unable to contact the personnel on the helicopter, initially assumed that they were in an area of poor telephone reception or that they were socialising.

The next morning, at 0710 hrs, a family member of one of the pilots was able to confirm that the helicopter had not arrived at its intended destination near Lockerbie and that the mobile telephones of several of the aircraft's occupants, would ring, but were not being answered. The family contacted the flight school, who in turn began to make inquiries and contacted ATC at Leeds Bradford Airport. ATC contacted the Distress and Diversion (D&D) cell at the London Air Control Centre (LACC) who, in turn, contacted the Airborne Rescue Co-ordination Centre (ARCC) at RAF Kinloss. In an attempt to locate the helicopter, the ARCC requested that the police ring the mobile phones of the aircraft occupants; the D&D cell checked recordings of the Radar displays. At 0927 hrs, the ARCC scrambled a SAR helicopter to search the area around the M6 motorway, near Kendal.

At 1017 hrs, the police received reports from a farmer that a helicopter crash site had been located just north of Sill Field Farm, close to the M6 motorway and some 4 km to the NNE of Junction 36. The site was at an elevation of 600 ft amsl.

Witness information

At approximately 1835 hrs on the day of the accident, a pilot who owned a R44 helicopter and who lives approximately 1,400 m from the crash site, heard a noise that he recognised as an R44. He had been flying his own R44 earlier that evening in what he described as deteriorating weather conditions, and he was curious as to who might be flying in such conditions. He saw a blue R44 helicopter flying at low level in a northerly direction alongside the M6 motorway and estimated its speed to be around 100 kt. He considered the weather conditions at the time to be a cloudbase of approximately 300 ft agl, with a visibility of about 1,500 m in drizzle and light rain. The helicopter disappeared from his

view and he heard the rotor blades slapping loudly, as though the aircraft was manoeuvring. He considered that the helicopter had probably landed because of the weather, so got in to his car and spent 20 minutes looking for where it had put down, in order to offer assistance. However, he was unable to locate it.

At approximately 1830 hrs, a worker at Sill Field Farm witnessed a helicopter flying low level orbits, in bad weather, around the woods adjacent to some farm buildings. This witness described the weather as very bad with fog and rain. After about three orbits, the helicopter flew out of sight, to the north of the farm, and he assumed it had continued flying to its destination. At around 0920 hrs next morning, when the farm worker was performing his normal check on the livestock, he discovered the wreckage of a helicopter and recognised it as the one he had seen the previous evening.

Weather

At the time of the weather briefing at Leeds Bradford Airport, there were no valid weather reports available for Carlisle airport. The TAF's and METARS for Blackpool and Leeds Bradford Airports at that time showed the weather in those respective locations was suitable for the planned flight.

Blackpool Forecast

EGNH 031504Z 031623 20014KT 9999 BKN025
TEMPO 2123 8000 -RA BKN012=

Blackpool Actual

EGNH 031750Z 19013KT 9999 VCSH FEW015
BKN020 19/15 Q1016=

Leeds Forecast

EGNM 031504Z 031601 22013KT 9999 SCT030
TEMPO 1601 23015G25KT TEMPO 2201 8000
-RA BKN010=

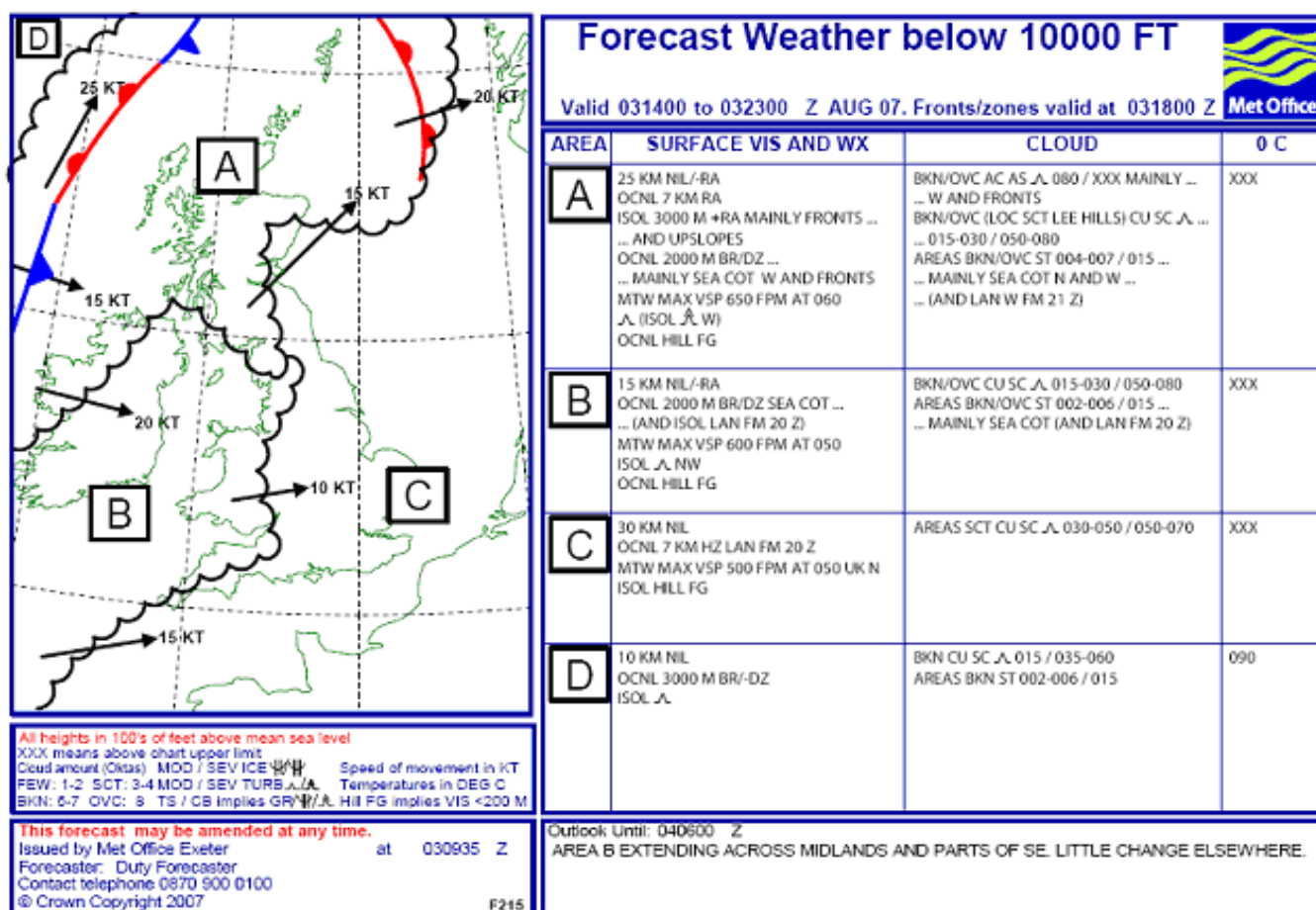
Leeds Actual

EGNM03172022012KT150V2709999BKN030

19/13 Q1017=

The Met Office Form 215, and the Airmet forecast, reproduced below, provided the area forecast for the whole of the UK. This indicated that the weather was

unlikely to be suitable for VFR flying from where the helicopter entered the Lake District up into the Lockerbie area. It is not known whether the pilots involved in this flight were aware of the contents of the F215 or the Airmet, but it was not normal practice at the flying school for pilots to check these forecasts.



Form F215

*AIRMET AREA FORECAST, NORTHERN REGION,
VALID AUG 03/1700Z TO 04/0100Z.*

*MET-SITUATION: A STABLE BUT STRENGTHENING SOUTHWESTERLY FLOW AFFECTS THE AREA.
STRONG WIND WRNG: OCNL GUSTS OF 20-25KT, ISOL 30KT.*

WINDS:

1000FT: 230/25-30KT W. 220/20-25KT E. PS15.

3000FT: 230/35-40KT W. 230/25-30KT E. PS12.

6000FT: 240/35-40KT W 240/20-25KT E. PS09.

FREEZING LEVEL: 12000FT.

WEATHER-CONDITIONS: 3 ZONES AT 18Z:

*ZONE 1: W OF A LINE LYING FROM 54N 07W TO MULL OF KINTYRE TO WINDERMERE TO EDINBURGH,
MOVING NE AT 15KT.*

GEN 15KM IN OCNL RA WITH 6-8/8CUSC 3000FT/6000 AND 6-8/8ACAS 8000FT/18000.

OCNL 7KM IN RA WITH 7/8SC 2000FT/8000 AND 7-8/8ACAS 8000FT/18000.

ISOL MAINLY W, 3000M IN HVY RA, WITH 6/8ST 500FT/1500 AND 8/8SCACAS 2000FT/20000.

CLD ON HILLS. MOD ICE AND MOD TURB IN CLD.

MTW, MAX VSP 650FPM AT 6000FT. MOD TURB BLW 6000FT.

ZONE 2: S OF ZONE 1 AND W OF A LINE 54N 02W TO BIRMINGHAM TO BRISTOL, MOVING E AT 10KT:

Airmet

A Met Office aftercast gave the actual weather conditions in the area at the time of the accident. It concluded that the cloud would have been broken or overcast stratus at 800 ft amsl, but with the possibility that the cloudbase was broken or overcast at 600 ft amsl. The visibility was about 2,000 m in rain below cloud, likely reducing to less than 200 m in cloud. The wind at 500 ft agl was 230°/20 kt, and the surface wind 210°/15 kt.

CCTV footage taken at the farm contained no images of the helicopter, but it did show that at the time of the accident, the weather in the area of the farm was poor with the cloudbase intermittently on the tree tops.

Pilot training

The R44 is a single pilot helicopter fitted with dual controls. Two collective levers may be installed (the left is removable) but the cyclic control is not of a conventional nature. This comprises a central stick terminating in a pivoting T bar, which only allows one of the pilots at any one time to control the cyclic with the handgrip in the 'normal' position. With two pilots on board, the R44 is normally flown from the right seat; it is possible to fly from the left seat and instructors regularly do so. Students and low experience pilots would normally only fly from the right seat, and are discouraged from flying from the left seat when with friends. This is because of the unusual cyclic control configuration and, to some

extent, the different instrument scan and visual references for hovering when flying from the left seat.

Pilot 1 commenced his PPL(H) training in March 2004 which he completed in 59 hours, by May 2005. The PPL(H) syllabus includes a requirement for five hours of instrument flying under simulated IMC. He actually underwent five and a half hours of instrument flying training, with his last flight on instruments taking place in May 2005. The instructor's comments in his training record shows him to have performed well on his PPL(H) course.

Pilot 2 commenced his PPL(H) training in January 2005, which he completed in 60 hours by January 2006. This included the required five hours of instrument flying, with his last flight on instruments occurring in November 2005. His training record shows satisfactory progress throughout the PPL(H) course.

Relevant regulations

The CAA rules require that a helicopter operating under VFR must remain clear of cloud and keep the surface in sight. There is a further requirement that the minimum visibility for VFR flight is 1,500 m. If the weather conditions change such that a pilot cannot meet these requirements, then the flight may continue under IFR but, in this case, neither the pilots nor the helicopter were approved for IFR operations.

The flight school's flying order book contains its own weather limitations, with advice that the stated limits may be more restrictive than the legal minima. The flight centre weather limits applicable to a navigation exercise, for pilots with less than 100 hours experience since achieving a PPL(H), were a minimum cloudbase of 2,000 ft and an in-flight visibility of not less than 5 km. It also states that:

'Occasionally a pilot may encounter worse conditions in which case he is to consider whether to continue with the flight, return to base, or carry out a diversion.'

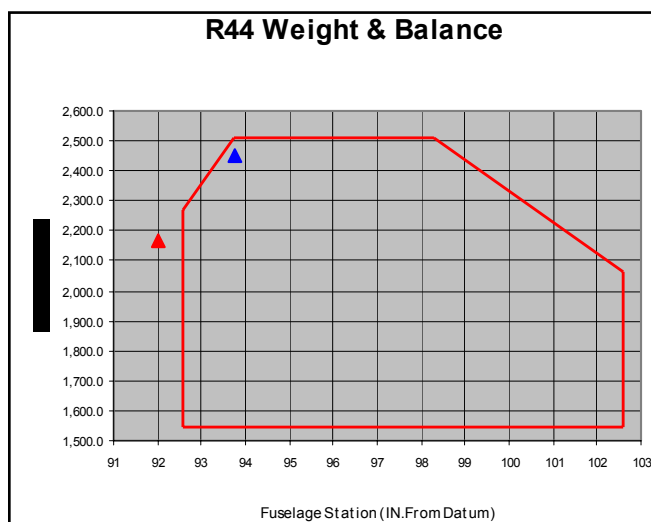
For a VFR flight, the order book also states:

'Pilots should not plan to fly lower than 500 ft above the highest ground within 3 nm of the aircraft.'

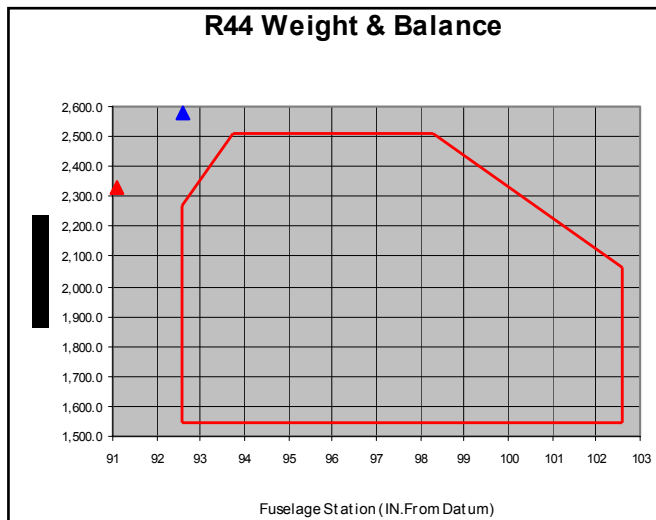
Weight and Balance

Weight and balance calculations were completed by Pilot 2, using estimated weights for the occupants. These calculations underestimated the weight of the pilots, and no allowance was made for the overnight bags which were carried by all of the occupants. The following calculations were made by the AAIB using accurate occupant weights.

Takeoff from Leeds



- ▲ Centre of Gravity at takeoff with takeoff fuel
- ▲ Centre of Gravity with zero fuel

Takeoff from Arkholme

- ▲ Centre of Gravity at takeoff with takeoff fuel
- ▲ Centre of Gravity with zero fuel

CAA Paper 2007/03: 'Helicopter Flight in Degraded Visual Conditions'

In September 2007, the CAA published a paper giving the results of research they had commissioned about helicopter flight in degraded visual conditions. Two test pilots were used to assess the problems associated with flying helicopters in such degraded visual conditions.

The research involved simulations, based on a basic unstabilised helicopter, such as the Robinson R22 or R44, and a stabilised helicopter. The paper commented that:

'Helicopters are difficult to fly at the best of times, ie, even in good visual conditions with plenty of outside world references and with stability augmentation.'

The report found that, as visual conditions degrade, control becomes complicated (workload increases). With the basic aircraft, if speed was lost inadvertently, or a moderate manoeuvre was attempted, the helicopters inherent lack of stability gave rise to very high pilot workload and potential loss of control.

In its summarising discussion, the report stated that:

'it was very likely that a less experienced 'average' pilot would become disorientated and lose control under such conditions [degraded visual cues] with the basic configuration [helicopter].'

Pathology

The post-mortem reports concluded that all four occupants of G-OSSI had received multiple injuries consistent with having been sustained at the time of the accident, and that the forces involved were such that the accident was not survivable. No evidence was found of natural disease in either of the pilots which could have contributed to the crash. Toxicological analysis of the blood from both pilots concluded that there were no traces of alcohol or drugs.

Recorded data

A Skymap IIIC GPS receiver was recovered from the helicopter. This had recorded two flights on the day of the accident with positional information being recorded every 30 seconds. Radar data for the accident flight, identifying the helicopter's position every 3.6 seconds, was also analysed. The following description is based on a combination of both data sets.

The first flight recorded (GPS data) was that which departed from Leeds Bradford Airport, at 1741 hrs, to a field approximately 3 miles south of Carnforth, where it arrived at 1811 hrs. The recording of the accident flight started from the same location at 1828 hrs. After takeoff, the helicopter climbed to approximately 850 ft amsl and tracked northwest until it reached the M6, which it followed northwards at approximately 650 ft amsl. For this period, the height of the terrain beneath the helicopter varied between 60 ft and 250 ft.

The terrain along the M6 increased in elevation as the helicopter progressed northwards and its separation from the ground reduced to less than 200 ft. It then climbed and carried out circling manoeuvres; the radar recording ended just to the south of the accident site and the subsequent final GPS track point, recorded at 1836:46 hrs, was just to the west of the site. Figure 1 shows the last part of the accident flight as recorded by radar.

Accident site

The helicopter wreckage was located on the eastern side of the M6, about 4 km NNE of Junction 36, approximately 400 m east of the motorway, on a small hill.

The wreckage site was surveyed by the Cumbria Constabulary Collision Support Unit and from this it was determined that the majority of the wreckage had

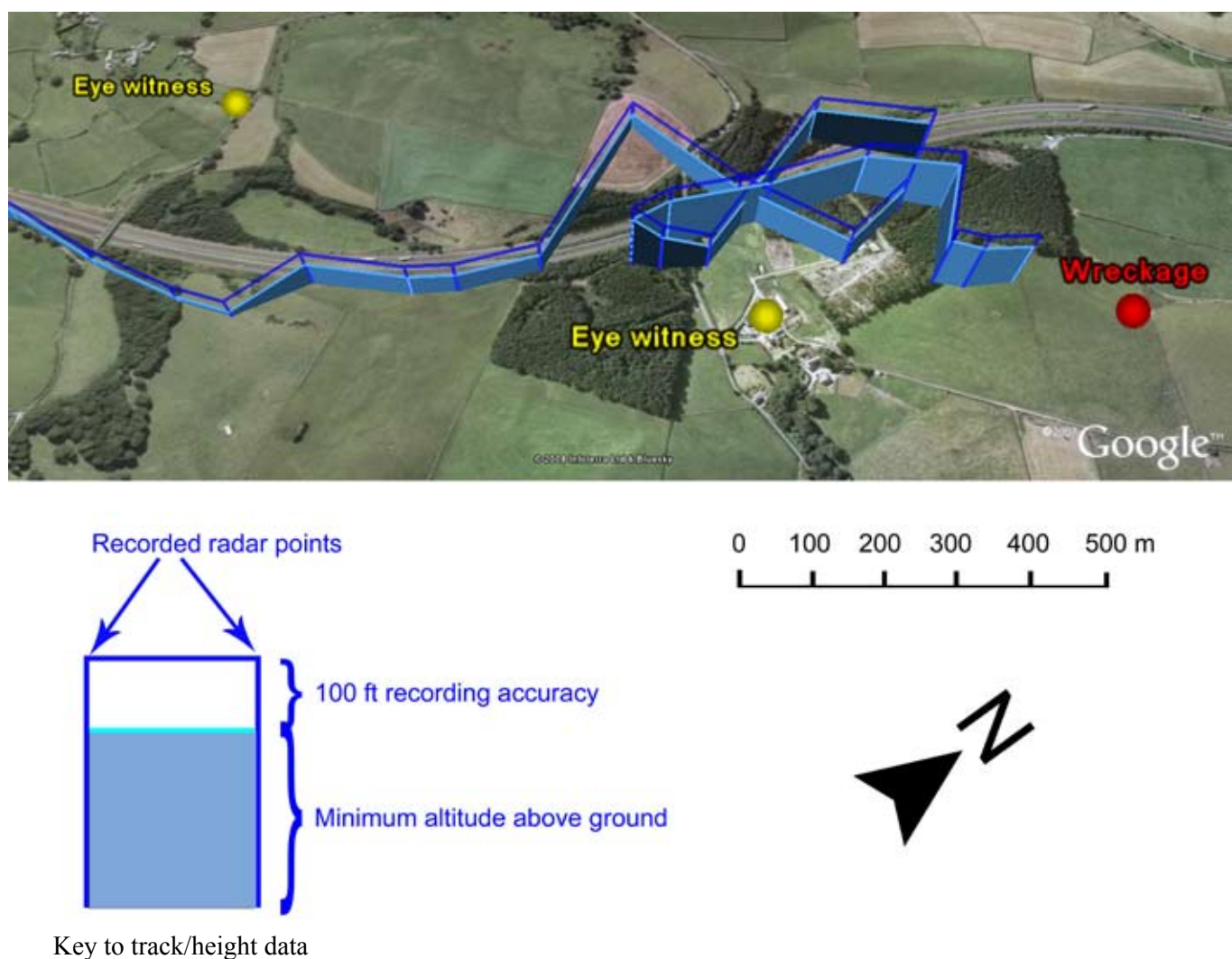


Figure 1

G-OSSI - Track/height plot prior to the accident (Radar Data)

travelled in a direction of approximately 140°M after the initial impact. A ground mark, measuring some 3.1 m x 1.7 m, identified where the fuselage had struck the ground. This was located between a barbed wire fence that separated two grass fields and the brow of the hill. There was a distinctive shallow, curved, ground mark, 7 m before the large ground mark, and this was consistent with a rotating main rotor blade striking the ground.

The forward part of the right skid, together with its forward support leg, had detached and had snagged the barbed wire fence. Whilst this was indicative that the skid struck the fence, such were the ground marks and the nature of the terrain, that the helicopter would very probably still have struck the ground had the fence not been there.

The main wreckage of the helicopter, including most of the fuselage, was 52 m from the initial impact and had been disrupted significantly. The furthest piece of wreckage was the reserve fuel tank, which was 85 m from where the helicopter first struck the ground. The majority of the wreckage had travelled beyond the brow of the hill and came to rest on the downward slope of the hill, contributing to the length of the wreckage trail.

A couple of days after the accident, two areas of stained grass could be seen close to the location of the two fuel tanks. Such staining typically occurs from aviation fuel and the size of the stained areas was consistent with both fuel tanks having contained a significant quantity of fuel at the time of the accident.

It was assessed that just before the helicopter struck the ground:

- it was travelling at a modest ground speed, probably between 50 kt and 80 kt
- it was in a modest dive, probably around 20° to the horizontal
- it had not suffered an in-flight break-up
- it was possibly banked slightly to the right
- the main rotor was turning with significant energy

Aircraft information



Robinson R44 II Raven, G-OSSI

The R44 II Raven is a four-seat helicopter constructed primarily of metal, and powered by a single fuel-injected six-cylinder piston engine. It is normally flown from the right seat, but operation from the left seat is possible if the removable left cyclic control stick is fitted; this was the case for G-OSSI at the time of the accident. The controls are actuated by a conventional system of push-pull rods and bellcranks. Power is transmitted from the engine to the main rotor gearbox by four rubber V belts.

Two fuel tanks, a main tank (120 litres) and an auxiliary tank (70 litres), are located on either side of the fuselage above the engine.

The aircraft was constructed in August 2004 and had flown for a total of 827 hours. It possessed a valid Certificate of Airworthiness and had been maintained in accordance with a CAA approved maintenance programme. The most recent maintenance action was a 50-hour engine inspection on 8 June 2007, at 794 hours.

Engineering investigation

General

Examination of the wreckage revealed that all damage to the airframe had resulted from the impact with the ground, with no evidence to suggest that the helicopter had not been complete and structurally intact prior to the accident. There was good evidence to indicate that all the occupants had been wearing their harnesses correctly.

Flight controls

The continuity and integrity of the collective, cyclic and throttle control linkages were checked. Whilst there was significant disruption to these control runs, all appeared to have been intact prior to impact, and all damage seen was consistent with being sustained during the impact.

Fuel

Both fuel tanks ruptured in the impact and it was not possible to obtain a fuel sample from the wreckage. A fuel sample taken from the aircraft's refuelling source at Leeds Bradford Airport was subsequently analysed; the results showed that the fuel was fit for purpose.

Engine

The engine had sustained only minor damage as a result of the ground impact, most notably to the accessories, particularly so on the helicopter's left side. It was removed from the wreckage and strip examined at a suitable engineering facility. There had been no pre-accident failure of any part and it showed all the signs of being lubricated normally, with no evidence of overheating.

The condition of all the spark plugs was consistent with normal operation.

The gears that drive the cam shaft and magnetos were inspected. There was damage to the left magneto gear and this was consistent with it having made two to three revolutions after the magneto was damaged, but before the crankshaft stopped turning. With a 2:1 gear ratio between crankshaft and magneto drive, this indicates that the engine made approximately four to six revolutions after the magneto was damaged, but before the crankshaft stopped turning, and is consistent with the engine stopping abruptly as a result of the impact.

The right magneto was bench tested at a range of speeds and functioned satisfactorily. It was not possible to test the left magneto due to damage to the contact points. This damage was consistent with occurring during the impact. It was, however, possible to test the coil and the capacitor from the left magneto, and these operated satisfactorily.

Light bulbs

The light bulbs were removed from both the upper and lower instrument consoles and their filaments analysed. All filaments examined were intact and exhibited no evidence of stretching or fragmenting. Either impact loads were insufficient to cause any hot (illuminated) filament to distort or fragment, or none were illuminated at the time of the impact. Given the severe nature of the impact, it is more likely that none were illuminated.

Instruments

The instrument dials were examined under a microscope for evidence of any witness marks made by the indicating needles. Nothing significant was found.

Cockpit heat/windscreen demist

The cockpit heat selector which, when pulled to ON, provides warm air to the cockpit and the windscreen, was found in the OFF position. The valve, which the selector activates, was found in the ON position. However, the disruption to the instrument panel where the selector is located, as well as to the cable and to the valve assembly, precluded the determination with any confidence of whether the heater was ON or OFF at the time of the accident.

Analysis

Engineering

Analysis of the wreckage trail, the ground impact marks and the examination of the wreckage, all indicate that the helicopter was complete, structurally intact and functioning normally prior to the accident. Evidence from the engine examination and the main rotor blade ground mark in particular, indicates that the engine was delivering significant power at the time of the accident and it was only after the impact that it stopped abruptly. It is therefore concluded that no technical issues were causal or contributory factors in the accident.

Operational issues

From the reports of the eyewitness a few miles south of the accident site, the helicopter was travelling at a low height and at a speed which appeared to be inappropriately high in the poor weather conditions. Although the pilots had around 100 hrs flying experience each, they probably had relatively little experience of flying in poor weather conditions and, probably, had not flown into deteriorating weather conditions before. Given that there was evidence of Pilot 1 being in the right seat some eight minutes before the accident, and as it was normal for both pilots to fly the helicopter only from the right seat, it seems most likely that Pilot 1 was manipulating the controls at the time of the accident.

That the aircraft was flying orbits around farm buildings just prior to the accident, suggests that the pilot(s) had realised that the situation was deteriorating. There were suitable areas for a precautionary landing around the farm buildings but they appeared to have chosen not to attempt to land in one. However, it is likely that the pilots would have discussed the situation in which they found themselves and were, possibly, trying to formulate a plan. It is probable that they planned to return to the M6, with a view to heading back to their last landing site near Carnforth.

In the very poor weather conditions, control of the helicopter appears to have been lost. It seems likely that the pilots either inadvertently allowed it to enter cloud, or that the pilot lost his external references. It could not be established whether the cabin heating/windscreen demisting system was selected on at the time. Should the cabin conditions have been conducive to windscreen misting, then this most likely occurred shortly after the second passenger boarded. That passenger's clothing may have been damp, requiring heating/demisting to be selected, once warm air was available from the engine. Nevertheless, this, the possibility could not be fully dismissed that a misted windscreen might have been a factor in the accident.

The helicopter entered a descending turn but flew into the ground in a level attitude. It could not be determined with certainty, but it is considered that the pilot was either attempting to recover to controlled flight using the instruments, or had become visual with the ground at a low height and was attempting to recover from a dive. As can be seen from the load and balance sheets, when the aircraft lifted from Arkholme, it was overweight by approximately 80 lbs, and the centre of gravity was outside the limits. This would have the affect of making the aircraft slightly more difficult to fly, particularly at low speeds.

Conclusions

Control was lost after the helicopter entered an area of poor weather conditions, during which the pilots were probably unable to maintain VMC. This resulted in the helicopter striking the ground in a near level attitude laterally and approximately 20° nose-down, and at a

speed of between 50 kt and 80 kt. Whilst the occupants were all wearing three-point harnesses, the impact was such that the accident was not survivable.

No technical causal factors were identified to explain this accident.

ACCIDENT

Aircraft Type and Registration:	FreeX Arcane, no registration	
No & Type of Engines:	None	
Year of Manufacture:	Not known	
Date & Time (UTC):	2 September 2007 at about 1048 hrs (all other times in this report are local times)	
Location:	Near Woldingham, Surrey	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	BHPA Pilot (Hill and Tow) Rated	
Commander's Age:	47 years	
Commander's Flying Experience:	Approx 140 hours (hours on type not known) Last 90 days - Approx 15 hours Last 28 days - Approx 9 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The paraglider was seen to suffer an asymmetric collapse of its canopy when at a height of about 70 ft. It descended rapidly and the pilot was unable to recover to normal flight or deploy the emergency parachute before impacting the ground. He landed heavily, chest first, which resulted in fatal injuries.

History of the flight

On the morning of the accident, the pilot arrived at the launch site where other qualified paraglider pilots were already flying. A group of student pilots were flying under instruction from the Chief Instructor of a flying school which operated from the site. The wind had been light early in the morning but had increased in speed,

as forecast, so that by about 1030 hrs it was between 16-18 mph. The Chief Instructor assessed that these conditions were unsuitable for the students to continue and had therefore ceased instructing.

The students prepared to leave, and spent about an hour packing up their equipment, whilst the qualified pilots continued to fly from the hill. At one point, one of these pilots suffered a symmetric collapse of his canopy whilst at a height of about 200 ft, but he was able to recover the situation quickly with only minimal height loss. The weather conditions continued to become increasingly difficult for flying and some of the less experienced pilots decided to land. Other pilots, however, remained airborne.

Witnesses describe seeing one of these pilots, at a height of about 70 ft directly above the launch point at the top of the hill, facing into the wind and away from the slope. They estimated he had been airborne for only a minute or two when approximately 60-70% of the left side of his canopy was seen to fold back with the folded back section remaining rigid. The whole canopy turned rapidly to the left, rotating the pilot with it, and began to descend quickly. The pilot, who had now been rotated through about 180° so that he faced the slope, struck the ground just below the top of hill. He was then lifted again a short distance, coming to rest on the hilltop where the canopy collapsed.

First aid was quickly administered to the pilot by those on the site until the arrival of the first paramedic at 1155 hrs. Further treatment was rendered at the scene, before he was transferred to hospital by air ambulance. He later died from his injuries.

Weather

Witnesses at the launch site reported that the weather during the morning had initially been good. The wind was westerly and, early in the morning, had been light to moderate in strength, between 8-12 mph, although from about 1030 hrs, it had started to increase to about 16-18 mph. The airflow was initially smooth but, as the morning progressed, cumulus cloud started to build, indicating a measure of thermal activity, which would have potentially given rise to more turbulent conditions.

Recorded information

A Garmin GPSmap 76C GPS receiver and a Digifly VL100 Flyer Unit variometer were recovered from the accident site.

GPSmap 76C GPS Receiver

The GPS receiver had recorded the GPS position and altitude for two tracks, both on 2 September 2007, the total time span of which was from 1153 hrs to 1157 hrs. These were separated by a seven second period, indicating that they were two parts of the same track and that the unit had either lost GPS signals or that the track had been manually stopped and restarted. The sporadic nature of the GPS positions recorded, within short spaces of time, indicates that the receiver was not generating accurate position or altitude fixes. Accordingly, no reliable analysis could be drawn from this data.

Digifly VL100 Flyer Variometer

The date set on this unit was correct but the time set was 8 minutes behind local time (established on 25 September 2007). The unit recorded two flights on 2 September 2007. The first flight recorded started at 1051 hrs local (corrected time) and lasted approximately 3 minutes, the second started at 1112 hrs (corrected time) and lasted for approximately two minutes.

The times of the flights recorded on both the GPS receiver and variometer could not be correlated with the time of the accident, as recorded on the emergency services log. It has, therefore, not been possible to ascertain whether any of the information recorded relates to the accident flight or to previous flights that were conducted that morning.

Launch site description

The launch site being used that day was called the West Bowl, and was a slope of moderate incline forming, as the name implies, one side of a bowl, the top of which was about 200 ft above the local terrain. The slope used was on the Bowl's northern edge and allowed paragliders to be launched up its entire slope, with the more experienced pilots launching from the ridge on top.

The flying school's site guide describes the best wind directions for operating as south-west and west. Under a section entitled '*Flying History*' the guide states:

'it can be rough, please obey the rules!'

The Chief Instructor at the school stated that this comment related to turbulence and the importance of applying the usual principles in assessing the suitability of the weather for flying. He also stated that the worst wind direction for the site was from the south-southwest, with turbulence likely due to the topography on the opposite side of the bowl.

Another section in the site guide entitled '*Hazards*' warns pilots to keep a good lookout for horses that are sometimes ridden in the area; it does not list any other hazards.

Paraglider description

The pilot was flying a FreeX Arcane. This type of paraglider has been assessed under the German classification system and classed as a DHV2 paraglider. The British Hang Gliding and Paragliding Association (BHPA) Pilot Handbook describes this class of paraglider as:

'Paragliders with demanding characteristics and potentially dynamic reactions to turbulence and pilot errors. For pilots who fly regularly. (Recommended minimum: BHPA Pilot rating)'

Paraglider examination

The paraglider was inspected after the accident and the canopy was found to be undamaged. The rigging lines had all been cut in order to free the pilot after the accident, but they otherwise appeared to be in a satisfactory condition with no signs of fraying or knots

having come undone. The straps forming the harness also appeared in good condition but, because they too had been cut after the accident, it was not possible to ascertain whether they had been correctly adjusted to fit the pilot.

An emergency parachute was fitted to the paraglider but there was no evidence of the pilot having made any attempt to use it.

Pilot's flying experience

The pilot started paragliding in 1997, and qualified as a BHPA Elementary Pilot in May 1998, a Club Pilot in October 1998 and as a Pilot (Hill) in June 2004. He had embarked on training to become an instructor and had also flown in various competitions. He flew regularly and was considered suitably experienced and capable to be flying a DHV2 category paraglider.

BHPA training at all levels includes the assessment of weather conditions, including turbulence, in respect of its suitability for flying, as well as the recovery from such unstable conditions as an asymmetric collapse of the paraglider's canopy.

Other accidents

Prior to this accident, there had been only two other accidents involving the flying school at the site over the twenty years the school had been in operation. Neither of these accidents was particularly serious in nature. However, a serious accident did occur on 5 November 2007 on the same site and under very similar circumstances. On this occasion, the site was affected by a south-southwesterly wind of approximately 18 mph, resulting in some rotary turbulence. This was sufficiently strong to cause a partial collapse of a pilot's canopy and, unable to recover in time, he struck the ground near the top of the slope close to the scene of the

subject accident. On this occasion, the pilot impacted the ground feet first and survived the accident, but having sustained serious leg injuries.

Asymmetric canopy collapse

This phenomenon arises when airflow over part of the canopy is disrupted, causing that part of the wing to stall and collapse. An asymmetric collapse normally results in the canopy turning towards the collapsed side. Higher performance paragliders are more susceptible to collapse due to their less stable design and should, therefore, only be operated by pilots of suitable experience.

It is possible to recover the situation by maintaining directional control and, if necessary, pumping smoothly on the controls on the collapsed side, taking care not to stall the remaining canopy.

The BHPA Pilot Handbook warns that collapses are best avoided by the linked strategy of steering clear of turbulence and flying actively, ie, exercising constant accurate pitch and keeping the canopy directly above the pilot's head. The Pilot Handbook further warns that recovery from the worst situations often requires a great deal of height, with highly experienced test pilots having been known to fall thousands of feet attempting to recover from instability situations. It advises that pilots should monitor their height and, if necessary, deploy their emergency parachute. It has not been possible to determine accurately the minimum height for deploying such an emergency parachute, but it would require, at least, a few seconds for it to be deployed and become effective.

Analysis

The pilot involved in the fatal accident was experienced and had flown at the site regularly. He should, therefore, have been in a good position to assess the

weather conditions and note how they changed during his time there that morning. The evidence presented is of conditions that were marginal for flying, even for such an experienced pilot. That he and other less experienced pilots were still airborne demonstrates that they either incorrectly assessed the conditions or that they chose to accept the additional risks posed by them, in order to continue flying.

The eyewitness descriptions suggest that the paraglider entered an area of turbulence, probably thermal in nature, which caused a large part of the left side of the canopy to collapse. The canopy then turned the pilot towards the collapsed side whilst descending rapidly. He then had insufficient height either to recover the collapsed canopy or to release his emergency parachute before hitting the ground.

The low accident rate experienced by the paragliding school is in large part due to the care exercised by the instructors in determining if weather conditions are suitable for students to be flying, and ceasing flying, as on this day, when they were assessed as unsuitable. Those flying from the site who were not doing so as part of the school, were reliant on their own judgement to assess the suitability of the flying conditions for their own level of experience and type of equipment used.

The site is prone to turbulence depending on wind speed and direction. Thus, whilst the site guide described the most favourable wind direction as south-westerly, a change in direction of only some 20 degrees to the south could result in the airflow becoming turbulent. Whilst this was alluded to in the site guide, the layout and terminology used did not highlight this fact clearly.

Safety action

The school's Chief Instructor will be writing to all those using the site to highlight the risks posed by turbulence and describe those weather conditions most likely to adversely affect the site. He will also review the site

guide in conjunction with the BHPA, to ensure that this information is included in a clear, unambiguous manner and that the guide is prominently displayed to all those flying from the site.

ACCIDENT

Aircraft Type:	Paramotor (comprising a 'Revolution' wing and 'PAP1400AS' paramotor unit), no registration	
No & Type of Engines:	1 'SNAP100' two-stroke piston engine	
Year of Manufacture:	Wing manufactured in 2006	
Date & Time (UTC):	11 June 2007 at 1920 hrs	
Location:	Chavenage Green Airstrip, near Tetbury, Gloucestershire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	Paramotor unit extensively damaged	
Commander's Licence:	N/A - licence not required	
Commander's Age:	24 years	
Commander's Flying Experience:	In excess of 350 hrs hours paramotor Last 90 days - Not known Last 28 days - Not known	
Information Source:	AAIB Field Investigation, with assistance from the BHPA and the BMAA	

Synopsis

The pilot of a paramotor aircraft was attempting a manoeuvre at a low height above the ground when the right-hand side of the wing 'collapsed', causing the aircraft to enter a sudden right-hand spiral dive. There was insufficient height for recovery and the aircraft struck the ground with a high vertical speed, causing fatal injuries to the pilot.

Contributory factors were the pilot's handling of the aircraft, combined with the low height at which the manoeuvre was attempted.

History of the flight

The pilot had been competing in the UK Paramotor National Championships, an annual event held over four days where the competitors perform a number of set tasks on which they are judged. The pilot had completed the final task of the day, on the penultimate day of the event, and was participating in some 'free flying' with approximately five others; this had been approved by the event organisers. These other flyers included the current paramotor world champion and the UK champion.

Having flown for several minutes practising various aerobatic manoeuvres, some of which were flown at very low level, the pilot climbed the paramotor to a

height of approximately 150 ft agl before entering another manoeuvre. Soon after initiating this manoeuvre the right-hand side of the wing collapsed, causing the aircraft to enter a sudden right-hand spiral dive. There was insufficient height for recovery and the aircraft struck the ground with a high vertical speed causing fatal injuries to the pilot.

Weather

The Met Office provided an aftercast for the time of the accident. It stated that the visibility was 7 to 11 km and there was scattered cumulus cloud between 2,500 ft and 2,800 ft agl. The surface wind was variable at 3 kt and the wind at 500 ft agl was variable at 5 kt.

Pilot's experience

The pilot had been flying paramotors since April 2004 and had performed at numerous international events promoting the sport of paramotoring for the wing manufacturer. He was a member of the BMAA and held a BMAA FLM rating, as well as an FAI International Sporting Licence. He was described by those that knew him as a very capable pilot, who enjoyed performing aerobatic manoeuvres. He had had two previous accidents; in one he broke his right heel and in the other his right thigh bone. The causes of these accidents are not known.

The pilot held a Display Authorisation issued by the CAA and was familiar with this model and size of wing, having flown it on a number of occasions, and had reportedly chosen it because of its 'sportier' handling characteristics. He had also flown it previously on the day of the accident and had not reported any problems.

Video evidence

Several spectator videos of the accident were provided to the AAIB, one of which was analysed in detail. The

footage was recorded by a spectator on the ground in front of, and to the right of, the flight path of the aircraft.

Examination of the video recording in slow motion showed that the aircraft was in a wings-level attitude, at a low height above the ground, immediately prior to the accident manoeuvre. The pilot was in a seated position, with his arms extended low down on either side of his torso. The wing was symmetrically inflated and the pilot appeared to be in full control of the aircraft. The sound of the engine was consistent with a high engine power setting.

In commencing the manoeuvre, the pilot reached above his head and grasped either the wing risers or the 'A' lines, causing the paramotor unit to tilt backwards momentarily. In one rapid, continuous motion, whilst apparently holding onto the risers or 'A' lines, he rotated forwards and extended his legs with his feet together. Concurrently, the engine sound decreased in volume. The wing and paramotor unit then began to pitch 'nose-down' and the pilot's body then turned to the right, with his weight biased to the right. The leading edge of right-hand side of the wing then deflected downwards, producing a visible kink in the leading edge at the mid-span location. The right-hand side of the wing rapidly collapsed from the tip inwards, causing the aircraft to enter a tight, descending right-hand spiral. Although the wing quickly re-inflated, there was insufficient height available for recovery and the aircraft struck the ground at high speed, in a steep 'nose-down' attitude. Initiation of the manoeuvre to ground impact took approximately 5 seconds.

A copy of the video footage was provided to the National Imagery Exploitation Centre for analysis. Estimates from this analysis placed the aircraft at a height of between 40 and 50 metres (130 - 165 ft) agl at the start of the manoeuvre.

Other video footage obtained showed the pilot confidently performing various aerobatic manoeuvres in this aircraft shortly before the accident. The aircraft appeared to be performing satisfactorily with no evidence of control difficulties.

Medical examination

A post-mortem was carried out by a Home Office pathologist. It showed that the forces in the impact were such that the accident was not survivable.

Toxicological analysis of the pilot's blood revealed the presence of a small amount of alcohol in his blood. This is believed to have been produced post-mortem. Had it been as a result of alcohol being consumed it is believed that as the concentration was so low it would be unlikely to have had a detrimental effect on the pilot's flying ability. The presence of paracetamol was also found at a concentration consistent with therapeutic use. There was no evidence of natural disease which could have contributed to the crash.

Aircraft description

General

The aircraft was a foot-launched, powered paraglider, comprising a non-rigid fabric 'Paramania Revolution' parafoil, red and white in colour, attached to a 'PAP1400AS' paramotor unit (Figure 1). The paramotor unit is worn in a similar manner to a backpack and consists of a stainless steel metal chassis, to which are attached the engine and the pilot's seat and harness assembly. The pilot must stand to launch and land the aircraft, but may adopt a seated position in flight.

The aircraft did not bear any registration mark (it is not required). However, it was identified with the number '20' in black adhesive tape on the underside of the wing for the purposes of the competition. The aircraft was

not certified to a published standard and there was no requirement for it to be.

The pilot was using a borrowed paramotor unit on the accident flight as the one he had planned to use was unserviceable. This unit was generally similar to his own and he was familiar with its operation.

Wing details

General

The 'Revolution' series of parafoils entered production in 1996 and they are produced in various sizes, ranging from 21 to 30 square metres (m²) in area.

The wing, bearing serial number 0306303, was manufactured in March 2006. It was labelled as a 'Revolution 23', but belonged to a batch of approximately 20 wings that were manufactured undersize and incorrectly labelled. This size of wing proved popular with advanced pilots, due to its higher speed and greater manoeuvrability and it is now marketed as the Revolution 21 model. The wing has a roughly elliptical planform, with a span and maximum chord of approximately 9.75 metres and 2.4 metres, respectively.



Figure 1

Photograph of paramotor aircraft

Wing construction

The wing is constructed primarily from a synthetic fabric and relies on air flowing into it at the leading edge to inflate it and give its aerofoil shape. The upper and lower surfaces are stitched together at the trailing edge and around the wing tips, but the leading edge is open, to allow air to enter the wing. Chordwise vertical ribs are attached to the upper and lower surfaces of the wing, dividing it into cells. Holes in the ribs permit the cross-flow of air, so that air pressure inside the wing is equalised. The air pressure inside the wing is dependent on airspeed and the direction of the relative airflow.

Four sets of cords or 'lines' are attached to the lower surface of the wing at specific chordwise locations. The lines are made of synthetic fibre and are grouped according to their chordwise location. The 'A' lines are attached to the leading edge of the wing, with the 'B' through 'D' lines being attached at progressively more rearward positions on the wing. Each set of lines is colour-coded for identification. The lower ends of the lines on each side of the wing are attached to straps or 'risers', which are connected to the paramotor unit by karabiners and shackles.

A further set of cords, the brake lines, are attached to the trailing edge of the wing and provide the primary means of controlling the aircraft. The brake lines are connected to hand loops located above and on either side of the pilot. Pulling the brake lines on one side of the wing lowers the wing trailing edge, increasing the drag, causing the aircraft to turn in that direction. Pulling on both brake lines simultaneously lowers the trailing edge on both sides of the wing, increasing its angle of attack and hence its lift and drag, which allows the aircraft to be slowed down in flight and flared for landing.

Wingtip steering

An optional wingtip steering kit may be fitted, which allows the pilot to steer the aircraft at higher speeds without using the brake lines. The kit comprises two straps, one on each side, which enable the pilot to pull on the wingtip lines in isolation and turn the aircraft without affecting either the trailing edge or the profile of the wing. The wing in this accident had been modified to add a wingtip steering strap on the right side, but none was fitted on the left side. The reason for this was not clear, but photographs taken earlier that day showed the pilot flying the wing with a tip steering strap fitted on the right side only.

Wing variable reflex

A key design feature of the 'Revolution' wing is that its profile can be varied in flight to provide reflex, so that the profile of the rear of the wing curves upwards. This allows the aircraft to be flown at a higher speed, which is desirable when flying longer distances. The introduction of reflex also moves the lifting forces further forward on the wing profile, so that the front of the wing is more heavily loaded. This has the reported benefit of making the wing more resistant to collapse.

The amount of reflex is controlled by the trimmer system, which comprises adjustable nylon straps looped through the C and D risers. Tightening the straps shortens the C and D risers, pulling the rear of the wing down and reducing the amount of reflex. The trimmed speed of the aircraft reduces as the trimmer straps are shortened and the aircraft becomes increasingly more manoeuvrable. Conversely, the degree of reflex increases as the trimmer straps are lengthened, resulting in a higher trim speed and reduced manoeuvrability.

'Speed bar'

The speed of the aircraft may also be controlled via a foot-operated 'speed bar', which hangs below the pilot's seat. It consists of two cords attached to a metal bar, onto which the pilot places his or her feet. The cords are routed upwards through a pair of pulleys on either side of the seat and are connected to straps looped through the A and B risers. The upper ends of the speed bar lines are terminated in 'quick disconnect' cleats so that they may be detached from the wing when de-rigging the aircraft. Application of the speed bar pulls down on the A and B risers, deflecting the front of the wing downwards, thus reducing its angle of attack and aerodynamic drag, allowing the aircraft to fly more quickly. The pulleys provide mechanical advantage to reduce the forces required to operate the speed bar.

Paramotor unit details

The paramotor unit comprised a stainless-steel frame with a seat assembly at the front and a 'SNAP100' model single-cylinder, two-stroke petrol engine mounted at the rear. The engine drives a two-bladed pusher propeller via a reduction gearbox and centrifugal clutch. Engine speed is controlled via a hand-held throttle.

Two pivot arms are attached to the main frame, extending forwards on either side of the pilot. The arms are pivoted at their attachment to the frame to allow them to be folded down during transportation. Each wing riser karabiner is clipped onto a shackle attached to its pivot arm. The pilot's seat is also attached to the pivot arms. The seat is flexible and can be folded down to allow the pilot to stand during takeoff and landing. The paramotor unit is equipped with a harness incorporating torso and leg restraints.

Aircraft control

The 'A' risers are used primarily to assist in launching a wing. The BHPA commented to the AAIB that, once airborne, the 'A' risers and lines should not be used unless purposely intending to induce a wing collapse, such as during wing testing. If the speed bar is applied, whilst pulling on the 'A' risers, it increases the probability of the wing collapsing.

The wing manufacturer promotes its reflex wings by highlighting its greatly improved stability over that of a non-reflex wing.

Aircraft examination

The wing was found to be in good condition and undamaged, with the exception of the right-hand brake line which appeared to have been cut. The integrity of the wing was verified by raising it and inflating it (Figure 2). Measurements taken by the AAIB showed that the lines were symmetrical on either side of the wing and that their lengths were close to the manufacturer's specified line lengths for this size of wing. Measurements of the wing upper surface area, with the wing laid out flat, gave an estimate of 18.98 m², close to the manufacturer's



Figure 2

Photograph showing test re-inflation of wing

quoted figure of 19.06 m². This wing had, therefore, a relatively high wing loading, in comparison to others in the 'Revolution' series.

A paramotor pilot, who attended the scene immediately after the accident, reportedly found the trimmer settings adjusted towards the slowest (ie least reflex) setting. However, this could not be verified, as the aircraft was disturbed prior to the AAIB's arrival.

The paramotor unit was intact, but the chassis was damaged in the ground impact. The engine turned over freely and appeared to be capable of running. There was fuel remaining in the fuel tank, totalling approximately 1.2 litres in volume. The harness straps were in good condition, but had been cleanly cut in several places. All of the buckles operated correctly.

The speed bar mechanism was still attached to the paramotor unit, but was disconnected from the wing when the aircraft was moved from the accident site. The right-hand speed bar cord appeared to have been cut approximately 38 centimetres from its attachment to the foot bar and the upper section of cord was missing, whereas the left-hand cord was completely intact.

No evidence was found of any pre-accident mechanical failure of either the wing or the paramotor unit.

Analysis

Wreckage examination

All the damage observed to the aircraft was found to be consistent with either ground impact or actions taken in order to free the pilot. Given that no evidence was found of any pre-accident material failures, the wing collapse and loss of control is considered unlikely to have been the result of mechanical failure.

Pilot handling

The pilot was familiar with the wing, having flown it on a number of occasions and had chosen it because of its sportier handling characteristics. He had also flown it previously on the day of the accident and had not reported any problems with it. The fact that video evidence showed him confidently performing aerobatic manoeuvres just before the accident suggests that he was unlikely to have had any control difficulties prior to the accident manoeuvre. Given his considerable experience, it is unlikely that he would have attempted these manoeuvres had there been a problem with the aircraft.

The video evidence showed that, immediately prior to the accident manoeuvre, the pilot had his hands low down on either side of his torso. This is consistent with the symmetrical application of the brake lines. This would suggest that the pilot was slowing down the aircraft prior to entering the manoeuvre. At the same time, the engine was heard to be at a high power setting. The pilot was then seen to let go of the brake lines and raise his arms to grasp the risers or 'A' lines, before standing up in his harness, with his feet held together, as if standing on the speed bar. Releasing the brake lines would have had the effect of reducing the drag of the wing, causing it to accelerate forwards. Standing on the speed bar would then pull down on the front of the wing, reducing its angle of attack, further reducing the drag. With the aircraft at a slow airspeed, the air pressure in the wing would be reduced, making it more susceptible to collapse. The pilot's rapid, full application of the speed bar at this critical point would have increased the probability of it collapsing. Once collapse had been induced, it was seen to progress very rapidly, probably due to the relatively high wing loading of this wing. The right-hand side of the wing collapsed first, possibly as a consequence of the pilot's weight, intentionally or unintentionally, being biased to the right side, or by a slightly asymmetric pull

on the 'A' risers or lines, causing the right side of the wing to be deflected downwards to the point where the relative airflow initiated the collapse. The wing very quickly re-inflated, but, by attempting the manoeuvre at such a low height, the pilot had no margin available and there was insufficient height for him to recover.

It is not known what manoeuvre the pilot was attempting. Some pilots have suggested that he was likely to have been attempting a steep dive, after which he would flare the aircraft so as to fly a few feet above the ground before landing.

Conclusions

In summary, no evidence was found of any pre-accident material failure. The collapse of the wing was probably the direct result of the pilot's actions and the low height at which the manoeuvre was attempted did not provide sufficient height for a safe recovery.

ACCIDENT

Aircraft Type and Registration:	Pegasus XL-Q, G-MWMZ	
No & Type of Engines:	1 Rotax 462 piston engine	
Year of Manufacture:	1990	
Date & Time (UTC):	26 August 2007 at 1830 hrs	
Location:	Clench Common Airfield, Wiltshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Severe damage to wing, minor damage to pod	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	58 years	
Commander's Flying Experience:	63 hours (of which 50 were on type) Last 90 days - 5 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

The aircraft landed heavily and tipped over causing severe damage to the wing structure.

History of the flight

The aircraft had recently had a new sail cloth fitted. On 8 August 2007 the aircraft was checked and a flight test for a Permit to Fly was carried out by an inspector. During the flight test the handling was found to be erratic. Adjustments to the wing were made by the inspector and a subsequent flight test was satisfactory.

On 26 August the pilot flew the aircraft for the first time since the Permit renewal. When he was airborne he found that the aircraft was unstable in roll and difficult

to handle. He was also unable to find a hands-off trim speed. He made two approaches to land on Runway 25, but on both occasions he was not able to stabilise the aircraft and went around. On his third attempt the approach was more controlled but on rounding out the aircraft rolled and landed heavily. The nosewheel dug into the grass runway surface and the aircraft tipped over causing severe damage to the wing. The pilot was not injured in the accident.

The pilot attributed the cause of the accident to the altered handling characteristics of the aircraft with the new sail cloth fitted, combined with his own low level of experience.

ACCIDENT

Aircraft Type and Registration:	PZL-Bielsko SZD-45A Ogar, G-BEBG	
No & Type of Engines:	1 Limbach SL 1700-EC piston engine	
Year of Manufacture:	1976	
Date & Time (UTC):	10 February 2008 at 1430 hrs	
Location:	Hinton-in-the-Hedges, near Brackley, Northants	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	72 years	
Commander's Flying Experience:	902 hours (of which 600 were on type) Last 90 days - 4 hours Last 28 days - 1 hour	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

Whilst taxiing to park at an airfield where parachuting operations were taking place, the left wing tip of the motor glider struck two of a group of parachutists assembled near the left side of the taxiway. At the time, the pilot was concerned about the clearance of the right wing tip from a marker board. There were no injuries.

History of the flight

Following a short flight from Turweston, the aircraft, a motor glider with a wing span of 17.6 m, had landed at Hinton-in-the-Hedges and was taxiing to the fuel pumps. The pilot noted that a group of parachutists had gathered at the left side of the taxiway, close to a fuel bowser being used by the parachute aircraft. They were looking skywards, presumably at their airborne

colleagues. As the pilot both wanted the clear the parachutists with the left wing tip and ensure the right wing tip was going to clear a sign marking the runway holding point, he stopped the aircraft and 'blipped' the throttle to attract the parachutists' attention, following which they started to move away. When he judged they were clear, he moved the aircraft forward at a slow pace. However, he felt a bump and realised that he had struck two of the parachutists with the left wing tip. The pilot was not informed of any injuries and noted that the parachutists had resumed their activities.

He considered that, had the parachutists gathered away from the taxiway and paid attention to aircraft movements, the incident would not have occurred.

However, he also considered, in hindsight, that he should have shut down the aircraft, got out and asked them to move away. In addition, he thought that his ability to judge accurately the distance of the wing tip from the parachutists may have been improved if they had been wearing high visibility tabards.

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2007

4/2007	Airbus A340-642, G-VATL en-route from Hong Kong to London Heathrow on 8 February 2005. Published September 2007.	6/2007	Airbus A320-211, JY-JAR at Leeds Bradford Airport on 18 May 2005. Published December 2007.
5/2007	Airbus A321-231, G-MEDG during an approach to Khartoum Airport, Sudan on 11 March 2005. Published December 2007.	7/2007	Airbus A310-304, F-OJHI on approach to Birmingham International Airport on 23 February 2006. Published December 2007.

2008

1/2008	Bombardier CL600-2B16 Challenger 604, VP-BJM 8 nm west of Midhurst VOR, West Sussex on 11 November 2005 Published January 2008.	4/2008	Airbus A320-214, G-BXKD at Runway 09, Bristol Airport on 15 November 2006. Published February 2008.
2/2008	Airbus A319-131, G-EUOB during the climb after departure from London Heathrow Airport on 22 October 2005 Published January 2008.	5/2008	Boeing 737-300, OO-TND at Nottingham East Midlands Airport on 15 June 2006. Published April 2008.
3/2008	British Aerospace Jetstream 3202, G-BUVC at Wick Aerodrome, Caithness, Scotland on 3 October 2006. Published February 2008.		

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